Disciplinary aesthetics: The role of taste and affect for teaching and learning specific school subjects

Edited by
Per-Olof Wickman, Per Anderhag, Cecilia Caiman
and Steph Ainsworth

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Disciplinary aesthetics: The role of taste and affect for teaching and learning specific school subjects

Topic editors

Per-Olof Wickman — Stockholm University, Sweden
Per Anderhag — Stockholm University, Sweden
Cecilia Caiman — Stockholm University, Sweden
Steph Ainsworth — Manchester Metropolitan University, United Kingdom

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Editorial: Disciplinary aesthetics: the role of taste and affect for teaching and learning specific school subjects

Per Anderhag[1,2]*, Cecilia Caiman[1], Per-Olof Wickman[1] and Steph Ainsworth[3]

[1]Department of Teaching and Learning, Stockholm University, Stockholm, Sweden, [2]Education and Administration, Stockholm, Sweden, [3]School of Teacher Education and Professional Development, Manchester Metropolitan University, Manchester, United Kingdom

Editorial on the Research Topic
Disciplinary aesthetics: the role of taste and affect for teaching and learning specific school subjects

Aesthetics concerns, on the one hand, people's feelings of pleasure and displeasure, and, on the other hand, the objects these feelings are directed to, that is, what people find beautiful or ugly (Wickman, 2006). Traditionally aesthetics and affect have been treated as separate from cognition and only rarely has it been studied how they are intertwined when learning a specific content (Wickman et al., 2021). However, recent situated and socio-culturally oriented research has begun to elucidate how aesthetics plays a key role for selection of content, what route learning takes in the classroom and for students' opportunities to develop an interest or taste for a specific school subject (e.g., Sinclair, 2006; Ainsworth and Bell, 2020; Wickman et al., 2021). This Research Topic compiles contributions from researchers examining these topics further.

Aesthetic judgments are not just reports of inner feelings but also concern outer objects and so constitutes an evaluation of what is the case (Dewey, 1934). What beauty there is in educational settings such as mathematical inquiry (Sinclair, 2009), data modeling (Ferguson et al., 2021), writing a literary text (Gilbert, 2016), learning grammar (Ainsworth and Bell, 2020), cooking (Berg et al., 2019), a ball game (Maivorsdotter and Lundvall, 2009), or when art meets science (Hannigan et al., 2021) is a question of taste and is socially constituted, negotiated, and learnt (Bourdieu, 1984). Distinctions of taste make evident preferences of language and representations, procedures and actions, and ways-to-be as a person. Aesthetics is a question of what and whose content is included and excluded from a school subject (Anderhag et al., 2015). The goal of this Research Topic is to explore these little examined topics extensively and to widen the understanding of what may characterize a school-subject-specific aesthetics and what role it may have when teaching and learning different school subjects, separately or as integrated.

The Research Topic is grounded in the notion of *disciplinary aesthetics* (Wickman et al., 2021), that is, school-subject-specific aesthetics. It focuses on the overarching questions of what may characterize such an aesthetics and what role this may have for teaching and learning in different school subjects. Contributions to the field do not merely examine

specific school subjects, such as mathematics and history, but also studies on intersections between school subjects, as for example art and science (Caiman and Jakobson, 2019).

Ainsworth and Bell suggest that explicit grammar learning may evoke aesthetic experience as existing tacit knowledge of language is transformed into declarative knowledge, generating aesthetic-epistemic feelings of fittingness. Albuquerque and Moore suggest that additional language teaching and learning might be enhanced by framing it as "coartistry," a site for "aesthetic, plurilingual/pluriliterate action, and interaction." Andrée et al. explore learning in programming, demonstrating the importance of aesthetic judgments for orienting student learning toward the movement of the programmed object and the ways to be as a programmer. Berg et al. show how aesthetic values in teaching home and consumer studies play a key role and are constituted as culinary, production, and bodily aesthetics, relating to, for example, presentation of meals, preprocessing of food and bodily consequences of eating, respectively. Ferguson and White draw on a socio-semiotic pragmatist perspective to explore the synergy between science education aesthetics and climate change aesthetics, advocating for a transformative aesthetics of climate change education. Gåfvels explores the aesthetics involved in teaching and learning floristry, providing examples of aesthetic judgements being constructed in interaction, informed by sensory knowing and communicated through embodied actions. Hannigan et al. present a mixed methodology approach to examine the role of aesthetic experiences and art for learning in marine science when children engage in a series of fieldtrips, workshops and lessons on a marine environment. Karavakou et al. present a theoretical model for analyzing students' aesthetically driven mathematical meaning making, using empirical findings to discuss the prospect of an aesthetically oriented curriculum reform. Nemirovsky et al. draw on Rancière's approach to aesthetics and politics and a case study of a conversation between weavers, anthropologists, and mathematics educators on the nature of knots to discuss the implications of aesthetical entanglements for mathematics learning. Prain et al. adopt Peirce's semiotic theory of signs examining disciplinary aesthetics as enjoyment and appreciation learning within and across the two subjects drama and science. They show how students' taste for both subjects is constituted through signs and signs systems.

The contributions within this Research Topic make both empirical and theoretical contributions to the emerging field of disciplinary aesthetics. Together they provide exploratory responses to the hitherto understudied questions:

- What are the objects (language, procedures, and persons) that are aesthetically included or excluded as part of teaching and learning the subject?

- How can such distinctions be seen to be taught and learned as content of the subject?

Substantively, the studies provide an exploration of how the aesthetic dimensions of each of the academic subjects might be characterized, exemplifying the aesthetic experiences that may arise from engaging with particular kinds of subject content in particular ways. Methodologically, the contributions showcase a range of methods that might be used to capture such aesthetic experiences and the particular aspects of knowledge and/or learning that have the potential to evoke them. These articles provide a flexible suite of methodological and theoretical tools, which might be used in future research to broaden the field of disciplinary aesthetics to include further academic disciplines. They also yield a number of important implications for educators, including suggestions for how teachers might harness the aesthetic dimensions of particular subjects to maximize learning and engagement in the classroom. More broadly, the Research Topic argues for the role of aesthetics in education to be taken seriously, and signposts potentially fruitful avenues for future research.

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Interdisciplinary aesthetics when science and drama are linked

Vaughan Prain[1]*, Russell Tytler[1] and Jo Raphael[2]

[1]School of Education, Deakin University, Geelong, VIC, Australia, [2]School of Education, Deakin University, Melbourne, VIC, Australia

There is a strong tradition of viewing these two school subjects as mutually enhancing, but aesthetic aspects of this interplay are less studied. In this paper we define disciplinary aesthetics as appreciation and enjoyment of the what and how of learning within and across both subjects. Drawing on Peirce's semiotic theory of signs, we claim that meaning-making from, with and through signs and sign systems (a) is fundamental to learning in both subjects and (b) constitutes a key feature of valuing and contributing to an aesthetic taste for both subjects. We illustrate these claims through examples drawn from secondary and tertiary learning.

KEYWORDS

science, drama, aesthetics, learning, interdisciplinary

Introduction

Science and drama in school have long been viewed as mutually enhancing for student learning in each subject (Aubusson et al., 1997), but the role of disciplinary aesthetics in this learning is less studied. We define these aesthetics as an appreciation and enjoyment of the goals, meaning-seeking and meaning-making processes, resources, procedures, actions, identities and values entailed in learning within and across both subjects (Wickman et al., 2022). This can be felt as a sense of the beauty and pleasure of what is learnt in the moment and over time in each discipline as well as ongoing enjoyment in and valuing of the process. We consider that these spontaneous and learnt responses to what students are expected to notice, use, do, value and share in each subject shape disciplinary aesthetics and deeply influence learning.

We put a case that this shaping of disciplinary aesthetics depends on learning to use and enjoy the sign systems through which meanings are created, reasoned about, enacted and communicated in each subject. We further claim that each subject's sign system, while distinctive, has flexible overlap to support learning in both subjects. In putting this case, we draw on Peirce's (1913) semiotic theory of meaning-making to elucidate this complementarity. We point to emerging research findings about the value of the aesthetic dimension of using sign systems in learning science (Lehrer and Schauble, 2012) and how an expanded range of sign systems can enrich this learning (Tytler et al., 2020). To further illustrate our general case we draw on examples from secondary and tertiary contexts in which two science topics were enriched by drama approaches, and where disciplinary aesthetics overlapped to enhance student learning.

Meaning-making in science and drama

Both Science and drama entail the invention of models/representations (Heathcote, 1984; Lehrer and Schauble, 2006; Nersessian, 2008) that create new accounts of phenomena

(Gooding, 2004), and both disciplines use old and new sign systems to make and share new meanings and critique alternatives. Following Peirce (1913), we claim that meanings are made in both subjects through creating and reasoning through sign systems. In Peirce's theory of meaning-making, meaning is created when signs are interpreted as standing in for referents or other signs. Thus semiosis, or meaning-making, is a recursive, material-conceptual process involving systems of signs in different modes.

Science and drama exist as cultural practices with elaborate material and symbolic resources (sign systems) for seeking and making meanings through representing possible, speculative and modeled experiences and worlds. Scientists integrate linguistic, mathematical, visual and embodied/actional modes in tandem with material manipulation to make warranted claims. In drama, multimodal resources are used to explore, critique, and represent felt experiences and worlds through integrating linguistic, actional/interactional, gestural, visual, aural, temporal, and spatial signs. The inherent multi-modal nature of sign functions in drama intensifies the scope for memorable meaning-making. Both disciplines overlap in their necessary integration of modes, but drama's aesthetic particularly invites personal felt embodied engagement in the meaning-making, whether as participant, spectator or reviewer of a shared experience. We claim that ongoing student engagement with both disciplinary aesthetics can enhance learning by broadening the range of ways that students can make, interpret, review and consolidate meanings through a richer repertoire of signs.

Feelings, aesthetics, and meaning

In Peirce's (1913) semiotics, initial meaning-making in general, and by implication meaning-making in school science and drama, always entails evaluative feelings towards what is being experienced. These feelings also influence the ongoing process of interest in or detachment from this schooling experience, explaining why students may end up liking or disliking these subjects. Lemke (2015), drawing on Peirce, regarded these feelings as inseparable from meaning-making, entailing aesthetic processes that are "distributed, situated, context-dependent, active and culture-specific" (p. 602). Gallagher (2005) claimed that aesthetics in drama brings together the cognitive and affective, as participants collectively come to know a shared imagined world and their sensuous responses to it. Disciplinary aesthetics entails developing positive feelings towards the specific objects, purposes and outcomes associated with disciplinary practices, whether these are material objects [such as a worm in science (Bloom, 1992) or props in a roleplay or production], experiences (such as fieldwork in environmental inquiry, or taking part in a drama improvisation), conceptual constructs (such as the elegance or power of theories) or practices (such as designated roles in particular drama genres, such as mantle of the expert).

Aesthetics of sign-making in science and drama

Aesthetic values and choices inform the work of scientists and professional theatre-makers. These values and choices also infuse school drama, whether improvised or more formal, and school

science. Wickman (2004) demonstrated the aesthetic commitments of scientists in developing new knowledge, and of students negotiating understanding and developing interest in scientific ways of looking at the world (Anderhag et al., 2015). Jakobson and Wickman (2008) demonstrated that teachers' aesthetic focus enticed students into grappling with conceptual learning. Ferguson et al. (2022) described how the process of learning data modeling processes entailed students shifting from an "art" aesthetic of visual attractiveness to a disciplinary aesthetic of appreciation of a data set that could be explored productively through mathematical concepts such as central tendency and distribution.

In advocating a broader repertoire of representations in school science, we noted gains in student learning above expectations (Tytler et al., 2013). Oher studies indicate how students' aesthetic responses productively influence science learning (Jakobson and Wickman, 2015; de Mesa, 2018; Tytler et al., 2020). Interdisciplinary art-science learning sequences show the distinct but overlapping and mutually reinforcing disciplinary aesthetics (Tytler et al., 2020; Hannigan et al., 2021).

In drama, this aesthetic occurs as participants work together to move in and out of imagined worlds. Heathcote (1984) noted the importance of drama's sign systems, the "sign of the person, in action, using all objects, significant space, pause, silences, and vocal power" (p. 162). Abbs (1989) explained how such non-discursive symbols of art (drama) are powerful in creating and formulating meaning and value, as they bring "sentience, emotion, feeling, aspiration to consciousness by artistically embodying them in such a way that they are understood" (p. 36). McLean (1996) proposed an aesthetic framework for drama where three conditions enable a drama aesthetic to occur: the importance of dialogue; experiential learning and teacher/students working as co-artists; and critical reflection. We illustrate these aesthetic effects in the following two interdisciplinary vignettes, where we argue that intermingling the two subjects enriches the aesthetics of both.

Vignette: trash puppets

This vignette, drawing on Hannigan et al. (2021) and Hannigan and Ferguson (2021) describes research into the aesthetic entailments of science-art activities, and the use of drama to enrich learning about endangered species. The setting was a school-based art-science project, culminating in a performance at the local zoo. Students investigated an assigned endangered animal, then constructed puppets of these animals for a theatre presentation. They worked in groups to build their puppet from recycled materials (e.g., wire, bubble wrap, fabric off-cuts, plastic bags and bottles, twine and plant material). They then produced a script and a backdrop for a portable "theatre in a suitcase" for an audience of pre-school children and their parents at the zoo. This was part of the zoo's endangered species campaign. We draw on quotations from the published research, using Wickman's (2004) practical epistemological analysis to interpret video capture of student and teacher interactions.

One group of students created a Baw Baw frog, endangered through habitat loss and a fungal disease. These frogs are unusual for their high altitude habitat, and are inactive during the snow season. Students were challenged to create a drama aesthetic of persuasive representation that served twin purposes of representing the physical

and behavioural features of the frog pertinent to its endangered status (a science aesthetic of explanatory accuracy) that would enable its appropriate manipulation in the theatre, and also have empathetic appeal (a drama aesthetic related to production values and persuasive representation through character creation).

Hannigan and Ferguson (p. 167) point out that the material nature of doing science and performing art/drama potentially enables student reorientation in relation to the more than human, and the human worlds. Students performing the Baw Baw frog were impressed with its general inaction in the investigation of its status (Hannigan et al., 2021, p. 9):

> S1: Yeah, the Baw Baw frog does not use its legs for anything [laughing]. That's why they are dying out – they are too bloody lazy.

In the drama performance, they conveyed this metaphor of laziness through representing the frog on a couch:

> Student 3: Yeah 'cause that's one of its main traits so we just wanted to emphasise that and play on that–because it's pretty relatable.
>
> Researcher: And were you considering your audience when you…
>
> Student 4: Yeah, we made it more of a relatable frog because if we just said it laid on its back people would not pay as much attention, so we made it a couch potato who likes to play footy and watch it (Hannigan and Ferguson, 2021, p. 171).

The puppets as models thus acted metaphorically, with students connecting with the animals through knowledge of their physiology's nature and function and complicity in their endangered status. Two aesthetics are at work: enjoyment in the science aesthetic of articulating structure and function relations with environmental changes as an explanatory narrative: and the drama aesthetics of preparing the puppets and performing them as a metaphor and empathetic model for the animal's plight (See Figure 1).

This attention to shaping metaphor to the audience is part of the sign system of drama. Students acknowledged the power of what they were doing to engage the younger students with learning the science:

> Student: It's an engaging way to kind of communicate what we have learnt with the students and stuff because obviously seeing a puppet they are interested and want to learn more about it.

Hannigan and Ferguson refer to Mello's (2016, p. 49–50) proposition that the puppeteer-puppet are performing between themselves a trans-embodied dialogue of new meanings. Material embodied engagement is part of a dramatic sign system that opens up possible new insights and feelings for both actors and audience.

There was evidence of the audience relating to this metaphorical device. In the case of the helmeted honey eater (Figure 2):

> Adult audience member 1: Ah that's cool! So, you can actually, move its head around and make its arms flap at different rates….: It's really good. It's got personality too, it's amazing how much personality they all have! (Hannigan and Ferguson, 2021, p. 174).

The aesthetic dimensions of drama work to create a convincing and empathetic subject as intended by the students.

The science related to endangerment (structure and function, ecology, and socio-ecological changes) was made meaningful at a personal and performative level through understanding and appreciating drama's sign systems. The animal could not be presented directly as a convincing subject for understanding and empathy through these science concepts, but is transformed into a metaphor in a narrative setting, eliciting audience attention and appreciation.

Vignette: stem-cell drama

This learning sequence, a two-hour drama workshop for preservice secondary science teachers, was designed to support topic learning as well as how to address controversial issues in science, a part of the senior secondary science curriculum (Raphael and White, 2021; White and Raphael, 2023). Complex issues around the proliferation of stem-cell therapies were explored. Here process drama strategies were applied to learning, with no intended product or performance for an external audience, but rather the participants (students and teacher) were at times both actors and audience. We draw on data previously reported from field notes in the published research above. The workshop began with purposeful theme-connected warm-up activities, including using bodies to create still images to interpret and represent stem-cell news headlines. These strategies facilitate learning sign-systems of co-creating worlds through drama, providing a gradual entry point for less experienced drama participants.

In a final role-play, having identified stakeholders in stem cell therapies (patients, therapists, researchers, medical experts, family members, ethics and government officials, company representatives and investors) small groups were allocated a category (e.g., patients) to research. They held a preparatory discussion to refine and ensure there were diverse viewpoints represented within each category. With students-in-role as the stakeholders, and teacher-in-role as the host of a television current affairs forum a whole-class improvised role-play began. The space was arranged, the scene set and performers were "live on air".

Through dramatic conventions that bring to life key features of stakeholders' (imagined) lived experience, participants have fleshed out the complexity of this scientific issue of stem-cell research and development. For a time, we have lived it. We now comprehend it differently, we appreciate the diverse perspectives, and we can begin to critically reflect on what might be done. We have created a safe space in which to experiment with controversial and even dangerous ideas. Participants have been enticed into an imagined world through linguistic and other signs relevant to creating each of the participant roles. There is tone and rhythm in voice, volume and silences. Physical signs include posture, gestures and the arrangement space as a television studio, with roles positioning emblematic characters in relationship to each other in a state of dramatic tension. The orchestration of these signs rendered the imagined world of the "live" television program authentic, satisfying to the senses, emotions, and intellect. The co-creation of dramatic space created aesthetic engagement, and what Greene (1977) terms a "wide-awakeness". We were our own audience, but if there had been an invited audience,

FIGURE 1
The Baw Baw frog "coming to life" on a couch, in the "theatre in a suitcase".

FIGURE 2
The endangered helmeted honey-eater being manipulated in the theatre in a suitcase.

they too would have engaged and learned something about this complex socio-scientific issue.

Discussion points

The vignettes demonstrate both the role of sign systems in disciplinary aesthetics in learning in each subject, and the different ways these sign systems can interact, enriching what is learnt and what is felt about this learning. In the Baw Baw frog example, students learnt through attending to, and valuing both (a) the interactions between structure and function of the frog and its changing ecological conditions, realised through the material sign systems of the puppet construction and the endangerment narrative and (b) appreciation of the metaphorical sign systems embedded in their dramatization. In the stem-cell drama example, student understanding of the complexity

of the science-society interactions of stem-cell research and development was enriched through immersion in the sign systems of a TV talk show, and through narrative creation representing stakeholders' perspectives. In both cases the science context opened up opportunities to appreciate the particular dramatic conventions/ sign systems that breathe life into these science concepts and their societal settings. Engaging with these sign systems is fundamental to the aesthetics of enjoying, appreciating and valuing the meaning-making in each case. However, as with any pedagogical work, the science and drama links need to be strategically planned to be mutually supportive.

Rather than these cases opening up an interdisciplinary aesthetic that has a meta-character, we argue that the interplay of disciplinary aesthetics that span the science-drama boundary enriches the aesthetic appreciation of each. However, over time this kind of interplay will potentially alter what students experience and enjoy as the aesthetics of each subject. In terms of enabling this interplay, the sign systems in each subject are sufficiently overlapping and flexible to mediate richer meaning-making, valuing and learning in both disciplines. Science has become more human, less abstract, and drama can enable and enact important insights into scientific practices and their effects. The aesthetics dimensions of science opened up by these drama activities are well-represented in scientists' practices within the fields of ecology, and stem-cell R&D processes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Deakin University Human Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional

requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

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Aesthetic values in home and consumer studies – investigating the secret ingredient in food education

Gita Berg[1]*, Eva Lundqvist[2] and Ylva Mattsson Sydner[1]

[1]Department of Food Studies, Nutrition and Dietetics, Uppsala University, Uppsala, Sweden,
[2]Department of Education, Uppsala University, Uppsala, Sweden

Food is a part of everyday life, and formal food education is included in compulsory education in many countries, for example through the subject Home and Consumer Studies (HCS). While food education is often underpinned by public health concerns such as preventing non-communicable diseases and promoting cooking skills, there has been little focus on aesthetic aspects of teaching and learning about food. This study therefore aims to gain understanding of aesthetic values as a part of HCS food educational practices. Aesthetic values are here regarded as socially and culturally shared, and related to notions of pleasure and taste. As this study uses a pragmatist approach, aesthetic values are seen as constituted in encounters, encompassing experiencing individual(s), artifacts, and context. By thematically analyzing empirical data from an exploratory case study, including classroom observations, student focus groups, and teacher interviews, we show how values are constituted as culinary, production, and bodily aesthetics. Culinary aesthetics involved cooking processes, cooking skills, and presentation of food and meals. Production aesthetics involved foods' origin and degree of pre-processing, whereas bodily aesthetics related to bodily consequences of eating. Aesthetic values were vital features of the educational practices studied and played a key role in bringing the practices forward. They also indicated what counted as valid, or desired, outcomes and thereby steered events in certain directions. The study highlights the significance of aesthetic values and argues in favor of acknowledging aesthetics in planning, undertaking, and evaluating HCS food education.

KEYWORDS

food education, aesthetic values, home and consumer studies, aesthetic experience, thematic analysis, culinary aesthetics, production aesthetics, bodily aesthetics

Introduction

In this paper, we investigate how aesthetic values come into play in food education within the school subject Home and Consumer Studies (HCS). The investigation highlights aesthetic aspects of food education that are often invisible and/or taken for granted. By increasing awareness of the aesthetics that guide and shape HCS food education, this study can contribute to future development of food educational practices.

Since food is a part of everyday life, food education takes place in home kitchens and other settings, both informal and formal. Formal food education in schools varies in scope, design, and teaching methods, depending on cultures and traditions (Kauppinen and Palojoki, 2023).

The school subject HCS, internationally known as Home Economics, is one example of formal food education in compulsory school. When the subject was introduced in U.S. and European schools in the late 19th century, the purpose was to prepare women for their domestic roles through lessons in economy, cooking, nutrition, cleaning, and textile care (Mennell et al., 1992). HCS served to spread new scientific knowledge about healthy eating to the public, and another purpose was to educate women in the bourgeois virtues of entertaining and representing through food (Shapiro, 2008). Though the subject's contents have changed over the years – in different directions in different countries – it still has food education at its core (Pendergast, 2008). In Sweden, HCS (Hem-och konsumentkunskap) is permeated by three perspectives: health, finance, and the environment. It concerns not only cooking, but also nutrition, meal planning, budgeting, and environmental labelling (Skolverket, 2011/2019).

Contemporary arguments for including food education in schools are often underpinned by public health concerns such as prevention of non-communicable diseases [e.g., (Lichtenstein and Ludwig, 2010; Lavelle et al., 2016)] and concerns related to environmental sustainability [e.g., (Williams and Brown, 2013)]. Here, the importance of conveying nutritional knowledge and cooking skills is commonly underlined. However, a rigid focus on these instrumental aspects of food and eating leaves little room for reflection upon experience-based perspectives (Rich and Evans, 2015). Food can evoke experiences of pleasure and delight as well as displeasure and disgust, which can be explored through the lens of aesthetics (Brønnum Carlsen, 2004). In recent years, aesthetics has been the subject of increasing academic interest within the field of education. For example, empirical research has investigated the role of aesthetics in teaching and learning within school subjects like elementary school science (Caiman and Jakobson, 2022), data modelling (Ferguson et al., 2022), and grammar (Ainsworth and Bell, 2020). Although these studies were generated from differing educational contexts, they all showed how aesthetic experiences – including intellectual, practical, and emotional aspects – were integral to educational processes.

The concept of aesthetics originates from the Greek word "aisthesis," which means sense perception (Freeland, 2012). With a focus on the senses, aesthetics is broadly interpreted in two ways: as a theory of fine art and as a branch of philosophy which concerns the study of beauty, pleasure, and taste (Shusterman, 1999). Though the senses have been the subject of philosophical inquiry since classical antiquity, food was long excluded from these discussions. The exclusion of food can partly be attributed to the traditional philosophical distinction between higher and lower senses, i.e., the view that (gustatory) taste, smell, and touch are inferior to sight and hearing (Korsmeyer, 1999). A significant shift came with "Art as experience," in which Dewey (1934/2005) made an argument for the aesthetic relevance of food by stressing that aesthetics encompasses every aspect of human experience, including food. He also gave gustatory taste relevance by rejecting the hierarchy of the senses. Korsmeyer's influential work "Making sense of taste" (1999) can be seen as another landmark which paved the way for increased academic interest in food aesthetics (Pryba, 2016).

Taste holds a central standing as a signifier of aesthetic appreciation, but has double meanings with respect to food. It has an everyday use to describe and/or evaluate gustatory qualities, i.e., how food tastes in our mouths. From an aesthetic point of view, however, taste needs to be considered in a broader sense than merely the gustatory – as a socially situated phenomenon used to define and distinguish between groups of people (Bourdieu, 1987). Using the Bourdieusian view of taste as a part of individuals' cultural capital, taste can be described as an "identity marker that facilitates interactions" (DiMaggio, 1987, p. 443). Hence, in relation to food, taste encompasses both personal gustatory qualities and contextually shared norms and values (Korsmeyer, 2017). Moreover, taste is not pre-existing within individuals, but shaped by class, education, and other sociocultural forces (Gronow, 1997).

According to Warde (2016), there has been a growing interest in aesthetic aspects of food in the Western world – an "aestheticization" of eating, which he attributes to the increased interest in eating outside the home (e.g., restaurants). Not only has there been a rise in restaurants offering innovative cuisine in the last decades, but there has also been an increase in entertainment such as television shows and competitions focused on cooking (Sweeney, 2012). Likewise, the rise of digital and social media has made visual food aesthetics even more accessible to the public. The visual representations of food in the media create aesthetic values regarding both legitimate and illegitimate meals and lifestyles (Krogager and Leer, 2021). Thus, food aesthetics is dynamic, constantly changing, and exists in multiple forms simultaneously.

In a study of teachers' food selection in Swedish HCS, Höijer et al. (2014) showed how HCS teachers valued certain foods above others, and that culture and tradition played a role in their food selection. This valuing and selection of certain foods to include in the subject's contents can be regarded as contributing to HCS disciplinary aesthetics (cf. Wickman et al., 2022). More recently, Bohm (2022) explored cultural connections between Swedish HCS and the home. Here, contradictory aesthetic values were reported in observations of HCS classrooms. The classrooms' interior design promoted one type of food (nutritious and environmentally friendly) while storage spaces contained other (nutrient-poor) foods. In another study, Bohm et al. (2023) showed how sweet foods were inconsistently valued in HCS – as fun and desirable, but also as unnecessary and disgusting. These studies did not target aesthetics as a main aim. However, they implicitly highlighted the presence and influence of aesthetics in HCS food educational practices.

Aim and research question

When it comes to HCS food education, aesthetics can be considered a "secret ingredient," as there are few empirical studies which explicitly focus on the roles that aesthetics play within these practices. In a previous paper, we investigated students' cooking in HCS and showed how aesthetic judgments were used to bring the practices forward and directed the students' meaning-making (Berg et al., 2019). However, HCS food education encompasses more than cooking, and the present study sets out to further explore aesthetics within the subject. The aim of this paper is to gain understanding of aesthetic values as a part of HCS food educational practices. The investigation is based on a case study and guided by the research question: What aesthetic values are central when teachers and students engage with food in HCS educational contexts, and how do these aesthetic values come into play?

Theoretical framework

In the present study, we adopt a pragmatist approach, meaning that the focus is on actions taking place within the practices under investigation, as outlined by Biesta and Burbules (2003). This approach draws on Dewey's (1934/2005) concept of "experience," which provides a comprehensive description of the processes in which individuals actively engage with the surrounding world. From the Deweyan perspective, aesthetic experiences involving food are not only affected by appetite and the context of the encounter, but shaped by a broader context which include previous encounters. These previous encounters are re-actualized (Lidar et al., 2010), meaning that they are brought into our current experience and influence how we perceive and engage with food. Likewise, the "current" experience will affect how similar food encounters will be experienced in the future. This continuous quality of experiences is what Dewey (1938/2007) refers to as "the principle of continuity." In addition to being continuous, aesthetic experiences are regarded as context-specific, and inseparable from feelings. Hence, aesthetic experiences encompass emotional aspects which can be described as aesthetic feelings (Prain et al., 2022). Aesthetic feelings contribute to the richness, depth, and transformative power of an experience in the sense that they re-actualize how one feels in relation to the object or event that is being experienced. Thus, aesthetic experiences can change relational conditions as well as courses of events.

As a part of educational practices, aesthetics can play a role in the privileging of educational content, i.e., the process of including certain aspects (questions, artefacts, etc.) and ignoring others (Wertsch, 1991). By influencing what content is included and not, privileging processes govern the learning in certain directions (Van Poeck et al., 2019). As such, aesthetic experiences have normative implications: they distinguish personal likes and dislikes, but also what belongs and does not belong within a shared practice (Wickman, 2006). Consequently, students do not only learn a subject's contents – they learn values tied to the practice and how to relate to these values (Anderhag et al., 2015).

Productive participation in different activities requires making aesthetic distinctions of what is or is not valued as a part of each activity (Wickman, 2006). We assume that the process of making such aesthetic distinctions can be empirically investigated by studying events where aesthetic values come into play. With the pragmatist approach, we understand aesthetic values as "(…) socially and culturally shared, contextualized within shared practices within a community, and they exert themselves by determining what should be considered worthwhile, important, and useful" (Sinclair, 2009, p. 55). Accordingly, the focus of the present study is on aesthetic values as contextual: situated and constituted in transactions. Moreover, aesthetic values are not treated as inherent properties of food, but rather as relations which are created through – and inseparable from – actions. Hence, aesthetic values are not exclusively tied to a subject (the one who values) or object (that which is being valued), but constituted through the transactions that take place in encounters involving subject, object, and context. With this transactional understanding, aesthetic values encompass the experiencing individual(s), the food, and the context in which the valuation takes place (cf. Brønnum Carlsen, 2004).

Method

The findings reported in this paper are part of a more comprehensive study investigating teaching and learning about food, meals, and health in the school subject HCS. In that study, data have been generated through empirical fieldwork following an exploratory, single-case study design (Yin, 2018). It was conducted in a Swedish school at the compulsory level and comprised one school class and two HCS teachers. A range of qualitative data generation methods were used, with data included in the analyses for this paper generated through video-recorded classroom observations, student focus groups, and teacher interviews (Table 1).

Study selection, context, and design

Recruitment was undertaken using a critical case selection rationale (Yin, 2018). In order to obtain favorable conditions for investigating HCS-specific teaching and learning processes, three strategic inclusion criteria were set:

i. Formally qualified teacher(s) with several years of working experience and a pronounced interest of working with food, meals, and health education.
ii. Communicative students who were assumed to have good chances to achieve curricular goals.
iii. Functional classroom(s) with fully equipped kitchen units.

With this selection, the likelihood of disruptive moments occurring in the classroom was less. Purposive sampling resulted in the recruitment of two teachers working at a school located in a socio-economically advantaged area in one of Sweden's largest cities. The two teachers were aged 55–60 years, and both had more than 20 years of working experience as qualified HCS teachers. Informed by the inclusion criteria stated above, the teachers suggested a school class for participation. After being informed about the study and invited to participate, twelve students aged 14–15 years were included, and the first author observed their participation in HCS throughout the school year 2017/2018.

A pilot study was initially conducted, consisting of one classroom observation. The purpose was to get acquainted with the research setting and the technical equipment. The pilot study included one of the recruited teachers and one school class, though not the one recruited to the main study. The pilot study was

TABLE 1 Included data – an overview.

Data generation	Documentation	Amount	Notes
Classroom observations	Video, audio, fieldnotes	36 × 100 min	HCS lessons, scheduled once a week
Focus group sessions	Audio, moderator notes	4 × 46 (42–48) minutes	Four students per group
Teacher interviews	Audio, interviewer notes	8 × 60 (39–64) minutes	Four individual interviews per teacher

documented with fieldnotes, and four students were video-recorded while cooking. Data from the pilot were excluded from the main study but resulted in refinement of the study design and use of the technical equipment.

Subsequently, thirty-six classroom observations of HCS lessons were undertaken. The observations followed guidelines by Angrosino (2012) and were documented with fieldnotes, audio recordings, and video recordings. The video recordings adhered to recommendations made by Luff and Heath (2012) concerning how to conduct video observations of two to three people in semi-public settings. Accordingly, an open camera angle was used with a fixed camera placed on a tripod (i.e., a stable mid-shot). During each observation, two video cameras were placed at two separate kitchen units, and the recordings started when the students went to their assigned kitchen units. Each recording includes two students cooking together, except for one recording with only one student.

Ten of the participating students were included in focus groups, with four sessions held during the school year. The teachers were interviewed on four separate occasions each, which resulted in eight interviews. All interviews were semi-structured, building on guidelines by Magnusson and Marecek (2015), and covered broad topics such as teaching, learning, and evaluation.

The study setting

The two teachers each had their own classroom. Each teacher taught half a school class at a time, as the classes were split in two. The HCS classrooms contained eight kitchen units, a refrigerator, a freezer, a dishwasher, and a small office space. In addition, many details distinguished the HCS classrooms from the school's other classrooms. First, they stood out in a spatial sense as to how they were located: separated from other classrooms, at the top of the school building. Second, they were decorated in a homey way. There were kitchen curtains and flowers in the windows. School desks were placed together to form a big table in the middle of each classroom, resembling a dining table, where the students ate the food that they prepared. The walls were filled with posters of meals, fruits, and vegetables.

The HCS lessons generally followed the same rhythm in both classrooms and over the school year. They started with the students sitting down at the big table and the teacher welcoming them, presenting the subject of the day, and lecturing on different topics such as nutrients, sustainable food consumption, or food's role in prevention of non-communicable diseases. This part typically ended with the teacher presenting the recipe of the dish that was about to be prepared. During the lectures, the students were sometimes talkative, but they usually seemed to pay attention to what the teacher said, taking notes and asking follow-up questions. Next, the students were paired up and went to their assigned kitchen units. Here, the classroom was filled with sounds, smells, and sights of students eagerly working to prepare their food. The energy level in the room was generally high, as students talked with excited voices, laughed, and sometimes argued during the cooking process. The lessons usually ended in a calmer fashion, with the students once again gathered around the big table to eat their food and summarize the lesson together with the teacher.

Data analysis

The analysis started in the data-generating process, where the first author became familiarized with the participants and the studied practices. Once the empirical fieldwork was conducted, the first author transcribed all the data from teacher interviews and student focus groups verbatim. Audio data from the observations were transcribed except in cases of private conversations or strictly practical matters, such as placement and grouping of students. Due to the substantial amount of data, video data from the observations were only partly transcribed. Here, consideration was taken to adhere to the research interest, which for the present study meant transcribing selected events in which aesthetic values could be discerned clearly. Consequently, the transcriptions of video data mainly involved spoken word but sometimes also included visible nonverbal actions such as gestures, facial expressions, body language, and movements through the room.

The transcripts were analyzed through reflexive thematic analysis, using the principles of Braun and Clarke (2021). Accordingly, the analysis process covered six phases (Table 2). The coding and theme generation, phases 2–4, were performed using the software program NVivo11 (QSR International Pty Ltd, 2015). The phases were not strictly linear, with the researcher(s) going back and forth between them, revisiting the raw data and transcripts regularly to check for adequacy and consistency, in line with the reflexive approach described by Braun and Clarke (2021). During the reading of transcripts, specific attention was paid to aesthetic values and how they came into play. Thus, the focus was on situated practices, and the aesthetic values constituted therein. To operationalize aesthetic values, we looked for situated practices where signs of immediate aesthetic feelings could be observed, but also more indirect evaluative statements with aesthetic qualities, such as those dealing with taste/distaste. This way of regarding aesthetic values generated both semantic and latent level coding. To exemplify, a semantic code including an evaluative statement was "I'd rather have a tasty meal

TABLE 2 Summary of the analytical phases [based on Braun and Clarke, 2021].

Phase	Description of the process
1. Familiarizing	Getting a sense of the whole dataset by - Viewing and re-viewing raw data (video, audio) - Reading and re-reading transcripts Note-taking of initial analytical ideas
2. Coding	Importing transcripts into NVivo Coding data from the whole dataset in NVivo Reducing data by selecting coded content based on the research question
3. Initial theme generation	Reviewing and compiling codes based on patterns and shared meanings
4. Developing and reviewing themes	Checking the adequacy and representativity of the initial themes in relation to the whole dataset
5. Naming themes	Deciding on suitable and coherent names for the themes
6. Writing up	

than a nice-looking meal" (student 1, focus group 4). Latent codes included events or series of events in which aesthetic values were perceived more implicitly. One example of a latent code which included signs of immediate aesthetic feelings was when one student during an observation exclaimed to her classmate, with despair in her voice: "I'll get diabetes. Do you know how much sugar I've had? I do not want to get diabetes." (student 2, observation 13b).

Though the first author conducted the analysis, every step of the process was discussed with the third author and revised accordingly. All three authors agreed on the contents and names of final themes.

Ethical considerations

Ethical guidelines for good research practice were followed throughout the research process (Swedish Research Council, 2017). Prior to the data generation, all participants received verbal and written information about the study. Written consent was obtained from all participants and from legal guardians for those under the age of 15 years. The study was approved by the Regional Ethical Review Board in Uppsala (ref. no. 2017/230).

Results

Aesthetic values were constituted through the transactions taking place within the studied practices, where the participants' experiences were re-actualized, negotiated, and transformed. They came into play through direct reactions to experienced objects or sensations, such as the exclamation "yuck" (student 3, observation 1a) when touching a raw fish filet. Another way was through evaluative statements, such as "You'll get really nice MSC-labelled cod from me" (teacher 2, observation 16b).

The analysis shows how aesthetic values could be seen as relating to three themes: culinary, production, and bodily aesthetics (summarized in Table 3). Each theme illustrates a perspective from which aesthetic values related to food came into play in our empirical data.

Culinary aesthetics

In the analysis, aesthetic values involving cooking processes, cooking skills, and presentation of food and meals were regarded as culinary aesthetics. Culinary aesthetics was the most prominent theme throughout the studied practices, highlighted during interviews and focus group sessions as well as in observations.

When the students prepared meals, which they did during almost every observed lesson, their actions indicated a concern about making the food aesthetically appealing with regard to gustatory and visual attributes. During the cooking processes, the students followed the assigned recipes with one exception: they often added extra salt, butter, and/or sugar to their food. This was done secretively, behind the teacher's back, and with the explicit intention of making the food taste better: "You should always have a lot of butter (…) Butter is tasty." (student 4 when adding extra butter to the frying pan, observation 12a). However, aesthetic values regarding gustatory taste encompassed more than personal preferences, as shown when one student during

TABLE 3 Summary of the three themes.

Theme	Contents	Characteristics
Culinary aesthetics	Cooking processes, cooking skills, and presentation of food and meals	Gustatory taste and visual appearance were valued aesthetically. The students focused on the meal as an end product, while the teachers focused on the work processes.
Production aesthetics	Food origin and degree of pre-processing	Organic food and local food production were positively valued, whereas animal production, food imports, and prefabricated food were negatively valued.
Bodily aesthetics	Food in relation to the body, including its biomedical and emotional impact	Food was categorized as "healthy" or "unhealthy," and aesthetically valued accordingly.

an observation asked her classmate for help tasting her mashed potatoes: "Because I do not know how it's supposed to taste, because I do not like mashed potatoes." (student 3, observation 12a). This can be seen as a recognition of a universal aspect of aesthetic values: that there is a "right" gustatory taste which exists irrespective of one's own opinion.

Another way that students' actions could be seen as conforming to the "right" gustatory taste within the subject was through changing evaluative statements. For example, during one lesson, the students were assigned the task of preparing two kinds of soup and comparing them: one prefabricated soup and one with raw ingredients. While the soups simmered on the stove, student 4 told his classmate, student 1, that he thought the prefabricated potato soup would taste better than the homemade equivalent. Student 4 was immediately corrected by student 1, who loudly declared that "I do *not* think that the prefabricated soup is tastiest," followed by a whisper that "[teacher's name] said that it was horrific." Later that same lesson, student 4 raised his hand and stated to the teacher that "I cannot finish [the prefabricated soup], this is *horrific.*" It is impossible to ascertain which soup student 4 preferred and if he really thought that the prefabricated soup was horrific. However, this example shows that student 4 changed his evaluative statement and used the same evaluative term that he had indirectly heard the teacher use.

In the focus group discussions, relations between visual and gustatory attributes were established, where the look of a meal served as an indicator of the gustatory taste. The students in focus group 4 agreed that visual attributes were important when cooking for others in general and in HCS in particular, but not so much when cooking only for themselves, since "then it's just for yourself, you kind of know that it's tasty" (student 4, focus group 4). What was considered visually appealing differed between the students, but there was a collective preference towards meals presented so that different foodstuffs were separated on different sections of the plate. Also, when plating meals, many students preferred combinations of foods with assorted colors. When asked during focus groups about their views on creating visually appealing meals, the students underlined that this was important within HCS, as their teacher "eats with her eyes" (student 5, focus group 4).

While the students related aesthetic values to visual and gustatory attributes of the meal as an end product, e.g., "it should look good" (student 6, focus group 4), the teachers primarily related aesthetic values to cooking processes, such as "one must work neatly" (teacher 1, interview 3). In this context, this meant that the kitchen was kept clean and tidy during the cooking process. One strategy that the teachers stated they used, partly to move the focus away from the end product, was not to taste the students' food. When the students asked about that "(…) then I say that I look at the work process" (teacher 2, interview 8). Thus, the teachers had a process-oriented approach where the cooking processes were the focus, rather than the finished meals:

> "(…) Then it kind of becomes a status symbol that you, that you can make food healthily, beautifully, and that you can use your knowledge and methods." (teacher 1, interview 3)

Though the students' main concern seemed to be the gustatory taste and visual appeal of the meal as an end product, they declared during focus group sessions that they accommodated the HCS teachers' expectations. Examples included wiping the kitchen counter or washing up dishes during the cooking process, which the students said they would not do when cooking at home. This indicates that the students were well aware of which aesthetic values the teacher emphasized with regard to the HCS practice, and that they took action to conform to these values. Thus, the teachers played important roles in constituting aesthetic values. In the transactions taking place in the classroom, the teachers became the ones who dictated the framework for the desired aesthetic values. When it came to cooking skills, they pointed out desired directions of the practices by highlighting positive aesthetic outcomes and by presenting relations between actions and outcomes. In other words, the teachers suggested to the students how best to proceed in their cooking activities:

> "The more you work this dough, the better the gluten threads. So that it's perfect. Then when you see that the dough comes loose from the edges of the bowl, so that it becomes like a ball, then things start to get better. Then you should be able to pick up the dough and kind of roll it a little between your fingers without getting really sticky. Then it's good." (teacher 2, observation 8b)

During another lesson, where the task was making breaded fish, the teacher emphasized that the aim of breading fish was to make it stick together. Subsequently, when one student pair saw parts of their fish falling to pieces in the frying pan, they were quick to label the fish "ugly," and to eat the small pieces "so that she [the teacher] does not see" (student 4, observation 1a). The students' actions could, once again, be seen as accommodating aesthetic values that the teachers had emphasized.

Production aesthetics

Food was valued aesthetically in relation to its origin, i.e., the parts of the food systems that include primary production, processing, and transport. Where, how, and to what degree food had been processed was valued aesthetically. In general, organic foods and local food production were positively valued, whereas animal production and food imports were negatively valued. For example, regarding animal welfare, signs of aesthetic feelings included the exclamation "Ugh" when discussing animal slaughter (student 7, focus group 2). Other examples were evaluative statements such as "the meat industry is horrible" (student 7, focus group 2). Environmental concerns were also communicated in signs of aesthetic feelings, e.g., by a student exclaiming "holy shit" (student 8, observation 4b) when the teacher described the emissions of greenhouse gas from rice production, and in evaluative statements such as "tomatoes are tastiest if they get a lot of sun" (teacher 2, observation 4b).

Production aesthetics also related to the degree of industrial processing that the food had undergone. Towards the end of the Spring semester, there was a course section comprising six lessons called "homemade vs. prefabricated." The lessons within this course section were built around comparisons between prefabricated food and food prepared by the students from raw ingredients. When interviewed, the teachers described the purpose of the lessons as training the students in making conscious choices by comparing homemade and prefabricated food with regard to price, time expenditure, and sensory attributes. These descriptions did not include valuation of the different foods. However, during the lessons, the teachers ascribed positive aesthetic values to the homemade food. The prefabricated food, on the other hand, was problematized and valued negatively: "(…) it is not necessarily really bad, but it might not taste the best" (teacher 1, observation 16a). The message conveyed seemed to be that the industry only worked to maximize profit and therefore produced cheap, artificial substances intended to taste like their "natural" equivalents:

> "There aren't any shrimp in it. It is only in the picture that they have put a shrimp on here. Kind of shameless, maybe, because the shrimp are kind of, they are one of the most expensive ingredients in this." (teacher 1, observation 16a)

During one of the lessons, two students who cooked together were asked by the observer what they believed the purpose of the course section was. The students' answers suggested valuation of homemade food above prefabricated food: "You're supposed to understand that it's better to cook homemade food." (student 5, observation 16a). Akin to culinary aesthetics, the production aesthetic values emphasized by the teachers were reflected in students' statements, as a skepticism towards industrially manufactured food was stressed:

> "When you read the label on some meal and do not understand what it says. Then it's… I think that's weird." (student 5, focus group 4)

The students stated that they would prefer what they called "real food," even if the gustatory taste and nutrient contents of the artificial substance were exactly the same as in the natural one. When this was discussed during a focus group session, the students said that "you would rather have a kind of honest, a real taste of shrimp that are shrimp, instead of a fake powder taste" (student 3, focus group 4).

Bodily aesthetics

In addition to culinary and production aesthetics, aesthetic values which related food to the body were constituted. This included values regarding foods' biomedical and emotional impact on the body.

Biomedical functions of food, and biomedical consequences of eating certain foods, were valued aesthetically by teachers and students alike, using biomedical outcomes as criteria. Overall, dietary fiber, protein, unsaturated fat, and nutrient-dense foods were valued positively, while sugar, saturated fat, and nutrient-poor and energy-dense foods, were valued negatively. For example, when two students discussed dietary fat with their teacher, one student stated that eating certain fats can "create disgusting stuff" (student 2, observation 13b). This is an example of how negative aesthetic values were constituted in relation to fat's biomedical consequences within the body. Biomedical consequences moreover encompassed physical performance and risks for non-communicable diseases. While the teachers mainly valued biomedical aspects of food in relation to bodily functions, the students used foods' effect on the body's visual appearance in their evaluative statements. These statements involved body weight and body shape, e.g.: "If you want to look like me, you need to eat only meat." (student 8, observation 10b).

Some of the HCS lessons had an explicit focus on foods' nutrient contents and the biomedical traits of nutrients. Here, aesthetic values were constituted in relation to biomedical consequences. During one lesson, teacher 2 drew a sketch on the whiteboard, depicting a diagram of a fluctuating blood sugar level and stated:

> "It's really hard for the body to have a blood sugar like this (…) Whoop, a lot of insulin, like you said. And you can die here if insulin is not produced (…) And, if you skip meals or eat a lot of sweet stuff (…) then the blood sugar levels can look like this. *Not* good. You do not want that. So do not skip meals. Eat vegetables. Eat good food." (teacher 2, observation 13b)

In this event, the teacher negatively valued the visual image of the blood sugar level: "It's really hard for the body (…) You do not want that." This is an example of how bodily aesthetic values came to involve the interplay between bodily responses to eating certain foods on the one hand and the agency of making sound food choices on the other hand.

Among the students, aesthetic feelings related to food and eating were similarly valued by linking food and food choices to bodily responses. Through this valuation, relations between biomedical aspects of food and emotional bodily responses were created. When the students discussed foods' capacity to evoke pleasant or unpleasant feelings, they used a dichotomy, labelling food as healthy or unhealthy. While the "unhealthy" food was sometimes related to unpleasant feelings, both the "healthy" and "unhealthy" food was framed as having the power to evoke feelings of pleasure:

> "Then I eat, like, healthily. Then I become, like, super pumped and happy all day. So then, like, I put on my headphones and go out like running. Because I get pumped. I kind of use that feeling to do something. But it is kind of the opposite when I eat something unhealthy. Then I get happy too." (student 4, focus group 3)

The students also discussed "unhealthy" food being used as a reward:

> Student 6: "After you have had like a bowl of pea soup and something, that's, I think it's healthy… Then you feel like this that, that you have done something good. That you can kind of reward

yourself or something." Student 5: "And then you eat unhealthily. [laughs]" Student 6: "Yeah, exactly. [laughs]" (students 5 and 6, focus group 3).

During focus group 4, the students also addressed that it felt better to eat certain food because "you get another feeling" (student 6). However, they could not define this feeling further, only that "it feels better" (student 6). Overall, the students seemed to use food instrumentally, to evoke positive aesthetic feelings:

> "I've started to eat that because, yes, I think that's made me feel better." (student 1, focus group 4)

While bodily aesthetic values enacted among the students were dominated by this embodied, holistic perspective, the teachers had a different way of communicating. During lessons and conversations with students, the teachers treated parts of the body as separate entities, implying that the body and its different organs had feelings of their own: "The brain and the body love carbohydrates, it is the best energy for the body." (teacher 2, observation 9b). "Love" can here be seen as a metaphor used for pedagogical reasons, but also as a way of disembodying the food experience, where different parts of the body are communicated as separate entities, each with its own aesthetic values and feelings.

Discussion

The aim of this study was to gain understanding of aesthetic values as a part of HCS food educational practices. By thematically analyzing empirical data from classroom observations, student focus groups, and teacher interviews, we have shown how aesthetic values in HCS food education can be understood in light of three different themes: culinary, production, and bodily aesthetics. The results highlight the significance of aesthetics in the studied practices, and how aesthetic values were part of bringing the practices forward.

Aesthetic values as part of HCS food education

Food education involves learning to distinguish and value experiences relating to all the senses: sight, smell, sound, taste, and touch (Fine, 2008). Since these processes entail learning what one finds pleasurable and not, they inherently include aesthetics. However, as Ferguson et al. (2022, p. 19) stress, aesthetics in educational activities "(…) is so tightly interwoven with conceptual moves and learning, it tends to be 'invisible' until attention is drawn to it." In a study of handicraft education, Risberg and Andersson (2022) showed how teachers, in a very hands-on way, taught culturally specific ways of valuing products of wood and metal by sensing (touching) them together with students. The present study adds to this body of research by illustrating how aesthetic values were constituted when teachers in HCS food education emphasized preferred courses of actions for the students to take, and the anticipated outcomes of such actions. An example is seen in the culinary aesthetics section of the results, with teacher 2 talking about how to work a dough. In line with the study by

Risberg and Andersson, our results show how HCS food education involves teaching and learning a sensory attentiveness, i.e., which senses and sensory impressions to pay attention to, and how to aesthetically value them.

The results moreover highlight how aesthetic values point towards what counts as valid or desired knowledge within the studied practices and thereby steer events in certain directions. In other words, the results demonstrate how aesthetic values play a role in privileging processes (cf. Wertsch, 1991). Here, the teachers influenced what aesthetic values were constituted, for example by implementing the course section "homemade vs. prefabricated." This is in line with Todd (2020), who likens the role of a teacher to that of an artist, as they stage aesthetic encounters between students and elements in the environment by choosing contents and designing activities. The teacher thereby becomes a "curator" of aesthetic experiences (Ruitenberg, 2015). In a study of early elementary school science, Caiman and Jakobson (2022) showed how emotional aspects of aesthetic experiences were articulated as judgments which often had ethical undertones. This can be seen in our results as well, in relation to production aesthetics involving animal welfare and environmental concerns, and in relation to bodily aesthetics involving bodily consequences of eating certain foods. If HCS teachers are curators of aesthetic experiences, they should be considered as having the power to influence students' aesthetic feelings, not least in relation to ethical matters when valuing different aspects of food.

As seen in the results, aesthetic values came into play when the students conformed to (their perceptions of) what the teachers valued. When one student described his experience of a prefabricated soup, he used the exact same term, "horrific," as the teacher. Another example is the students' stated effort to keep workspaces clean during cooking in HCS. Throughout, the students seemed to make interpretations of what the teacher valued, consider different actions, and choose to act certain ways. It can be discussed whether the students learned to genuinely value certain things through their participation in HCS food education, or if the students' valuing actions reflected their willingness to accommodate the teacher in order to, e.g., obtain good grades. Nevertheless, the students' actions did not always align with what the teachers valued. While the students were seen to emphasize aesthetic values of the meal as an end product, the teachers valued the work process. The process-oriented approach articulated by the teachers is not unexpected, as it reflects the HCS syllabus in force at the time of data generation, where actions such as planning, organizing, and undertaking activities were emphasized over end results such as the finished meal (Skolverket, 2011/2019).

Another example where students' actions did not reflect the teachers' values was when the students secretively added extra butter to their food to make it taste better. In this case, gustatory taste triumphed over the teachers' instructions, i.e., the recipe. The importance of gustatory taste for HCS students' food choices has been highlighted in earlier qualitative studies [e.g., (Bohm et al., 2016; Gelinder et al., 2020)]. Christensen and Wistoft (2016) and Christensen (2019) have shown how taste can be integrated into food education, to promote students' engagement and learning outcomes. These studies all highlight the role of teachers in facilitating taste-based learning experiences. Our results support the prominent standing of taste experiences in food education, but also show how aesthetic values in HCS encompass more than gustatory taste, and how these values relate to aspects other than food choices. The results

thus contribute to existing HCS research by providing empirical examples of how aesthetic values are a part of the transactions taking place in encounters between participants, artifacts, and context within HCS food education. According to the Swedish syllabus, HCS should provide important tools for students to make conscious food choices as consumers with reference to health, finance, and the environment (Skolverket, 2011/2019). We argue that the recognition of aesthetic values as a part of HCS food education can support the processes of fostering consumer awareness within the subject.

Method discussion and future research

Thematic analysis was chosen with the intention to draw attention to aesthetic values by providing an overview of what values were constituted in situated action within the studied practices, and how. In the results, culinary aesthetics is presented more comprehensively than production and bodily aesthetics. This mirrors the differing extents to which aesthetic values were empirically observed: culinary aesthetic values were notably more common than those relating to production and bodily aesthetics and could therefore be investigated more thoroughly. It should be pointed out, however, that the separation of aesthetic values into three themes is not a direct reflection of the studied practices, but rather an analytical approach to discern, highlight, and make sense of the observed values. This way of thematically structuring the data comes with some challenges and limitations. First, data are taken from the context in which they occurred, and thereby run the risk of being fragmented (Maxwell and Miller, 2010). We have addressed this risk by reporting the results in a narrative fashion, where effort has been made to do the raw data justice. Second, one limitation is that the thematic analysis does not address learning *per se*. We have shown how certain contents are privileged, and how the participants are seen to act, but cannot say anything about the actual learning or meaning-making occurring within the studied practices. Forthcoming studies could address, e.g., meaning-making in detail, with specific attention to aesthetic values and privileging. Future research might also further explore how video data can be used to enable analysis of the multimodal nature of aesthetic experiences taking place in the classroom.

A limitation of the study is related to its contextuality. The critical case selection resulted in an undiversified group of study participants: experienced teachers and high-achieving students who came from advantaged socio-demographic conditions. In the words of Bourdieu, the participants' shared tastes may be at least partly explained by their similar social, cultural, and economic capital (cf. Bourdieu, 1987). The results of this study should therefore be considered in light of the context in which the empirical data were generated, and knowledge claims based on the results should not include generalization. However, the purpose of this study was not to make general claims about aesthetic values. The intention was, rather, to describe how aesthetic values came into play in situated action and thereby contribute to informed discussions derived from the particular case. Consequently, the results can offer transferability, i.e., ways to understand other "cases," where similar situations occur. It is nevertheless important to consider the need of studying aesthetics values in other food educational environments. Future studies should explore how aesthetic values come into play in other contexts than that studied here. For example, this could be done within more diverse groups, where experiences and understandings might not be shared to the same extent.

Conclusion

This study unpacks how the "secret ingredient" of aesthetic values comes into play in HCS food educational practices. Based on the results, we underline that the recognition of aesthetic values as a part of food education can contribute to directing the focus towards immediate, experiential aspects of food and eating. These are aspects which are often obscured in the shadow of an instrumental approach, where food is perceived based on its potential consequences rather than as a part of an aesthetic experience. From a teacher's perspective, this can mean acknowledging aesthetic aspects while planning, undertaking, and evaluating food education.

Data availability statement

The raw data supporting the conclusions in this article are not readily available because no permission was given by the participants for anyone to have the raw data except the principal investigators. Requests to access the datasets should be directed to gita.berg@ikv.uu.se.

Ethics statement

The study was approved by the Regional Ethical Review Board in Uppsala (ref. no. 2017/230). It was conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

GB designed the study reported in this paper with support from YMS and EL. GB conducted the fieldwork which generated the data, reviewed literature, phrased the aim, and drafted the first version of the manuscript. GB and YMS conceptualized the results in three themes. YMS and EL reviewed manuscript content. GB edited the first and reviewed drafts of the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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Aesthetical entanglements in mathematics education

Ricardo Nemirovsky[1]*, Vinay Kathotia[2] and
Charlotte Mégrourèche[1]

[1]Education and Social Research Institute, Manchester Metropolitan University, Manchester,
United Kingdom, [2]School of Mathematics and Statistics, The Open University, Milton Keynes,
United Kingdom

In this study, we develop a perspective on the diverse aesthetics historically associated with mathematics, inspired by Rancière's approach to aesthetics and politics. We call "Silencing Aesthetics" a dominant aesthetic that Rota has characterized as a "copout (…) intended to keep our formal description of mathematics as close as possible to the description of a mechanism". The challenge this study attempts to explore is how to question silencing aesthetics to make space for inclusive ones. Our efforts have focused on setting up and studying inclusive and pluralist "Studios", gathering craftworkers, anthropologists, mathematics educators, and mathematics enthusiasts. We include here a case study based on a conversation amongst basket weavers, anthropologists, and mathematics educators focused on the artisanal and mathematical nature of knots. We discuss the implications of aesthetical entanglements, such as those in our case study, for mathematics learning.

KEYWORDS

aesthetics, basketry, knots, mathematics, materiality, craft

Introduction

The literature on mathematical aesthetics is not easy to summarize or recapitulate (Sinclair et al., 2006, p. 1–17, 224–254), but we can succinctly identify certain themes that have been focal for it:

- Discussion about the nature of feelings evoked by mathematical work as well as those accompanying the perception of mathematical diagrams and symbols, which may include, amongst others:

    - Feelings of pleasure elicited by the senses of beauty, elegance, productivity, harmony, perfection, and the like.
    - Feelings of melancholy, detachment, coldness, austerity, and estrangement.

- The psychology of mathematical discovery and the roles of the unconscious.
- Differences and commonalities between mathematics and the arts.
- Criteria for what makes mathematical things beautiful or ugly, and the degree of uniformity of the corresponding aesthetic judgements amongst professional mathematicians.
- Mystical and uncanny dimensions of mathematics.
- Whether the appreciation of mathematical aesthetics is restricted to a small elite endowed with the "math gene" or is accessible to everyone.

Despite variations in conceptions of mathematical aesthetics, there is consensus amongst mathematics educators on questioning the aesthetic appreciation of mathematics developed by students in school settings. A number of mathematics education researchers have proposed approaches to address this issue. For example, Dreyfus and Eisenberg (1988) suggested that educators could foster explicit aesthetic evaluations of problem-solving. Others advocate a more radical approach that involves "pluralizing" mathematics education by expanding the range of perceptual, felt, and bodily aspects involved in mathematics learning (Brown, 1973; Papert, 1980; Nemirovsky et al., 1998; Sinclair, 2009; Sinclair and Pimm, 2010). In this study, we explore how creating entanglements, in the colloquial sense of the word, between mathematical and craft aesthetics might contribute in this direction.

Adding to the pioneering work of de Freitas and Sinclair (2014), this article will develop a perspective on mathematical aesthetics inspired by Rancière's (2000, 2006, 2010) approach to aesthetics and politics. We think that this perspective has the potential to illuminate new mutual implications between mathematical aesthetics and mathematical learning. Rancière (2000, p. 12) proposed that we all live in consensual worlds delineated by certain "distributions of the sensible", which are "systems of self-evident facts of perception based on the set horizons and modalities of what is visible and audible as well as what can be said, thought, made, or done". A distribution of the sensible is a demarcation of that which "truly" exists against a receding background of the unreal and meaningless, together with ways of behaving, perceiving, and valuing that are concordant with the embraced demarcation. These ways of behaving, perceiving, and valuing constitute the aesthetics of those who take part in a prevalent consensus. In times of political turmoil, the consensus validating a certain distribution of the sensible comes under scrutiny and questioning, making possible the opening of new spaces of legitimacy for some of those who had had no part in the prior consensus, which had been relegated to noise and meaninglessness. "Dissensus" (Rancière, 2004, p. 226) is the term used by Rancière for such political questioning. Dissensus is not equivalent to "disagreement" since disagreements are common within a consensual communitarian perspective consistent with a certain distribution of the sensible. Rather, dissensus refers to a struggle toward removing a veil of noise and meaninglessness that had hitherto rendered certain aspects of reality indiscernible.

The main examples chosen by Rancière in his writings on aesthetics were taken from art and literature. We surmise that Rancière's distrust of disciplinary traditions, including the ones permeating the natural, social, and mathematical sciences, prompted him to eschew elaboration on their aesthetical dimensions and moved him to rather focus on their hierarchical demarcations of "who can talk about what". Several artists and craftspeople we have been working with have found formal mathematics inaccessible or alienating, in school and even now. This is despite engaging in a study that is mathematically rich and powerful, where mathematics is conceived in its broadest sense. This silencing of their voice (by the discipline of a discipline) resonates with Rancière's acknowledgment of the political power of disciplinary enculturation in the cutting between "what is visible

and what is not, what can be heard and what cannot, what is noise and what is speech" (Rancière, 2004, p. 225).

The anchor of this study is a case study based on a recorded conversation between basket weavers and mathematics educators. We explore how the work of this kind of pluralist Studio—intermingling mathematics and craftwork—may contribute toward breaking through the silencing power often irradiated by prevalent elitist mathematical aesthetics. The case study, presented in the next section, is based on a conversation in one of the studio sessions hosted by the *Forces in Translation* project. This project[1] focuses on interactions between basket weaving, anthropology, and mathematics. It includes basket makers, anthropologists and mathematics educators, exploring, through in-person and online studio sessions, how different basket-weaving techniques and their cultural traditions interplay with the understanding of mathematical ideas, such as spatial relationships, surfaces, curvature, growth, and forces at play, such as tension, friction, and compression that hold together complex structures.

Methods

Throughout the *Forces in Translation* project, we have developed a methodology for interdisciplinary collaboration that we call Studio Practice. Following Ingold's (2017) differentiation between anthropology and ethnography, Studio Practice involves anthropological work because it is a time during which the role of all the participants, including the researchers, is not to learn *about* but to learn *with* others, materials, and tools. Members of a Studio Practice identify with a variety of personal backgrounds, ages, and life stories, primarily united by their senses of wonder, solidarity, and mutual respect. In addition, all members are presumed to be equally capable of making sense of new questions. Recordings of their activities, in the form of journal entries, videotaped interactions, collections of artifacts, and annotated stories, provide a basis for ensuing retrospective research.

With respect to retrospective research, we adopt microethnographic methods (Erickson, 1996, 2004; Goodwin, 2003; Streeck and Mehus, 2005). Microethnography encompasses a collection of techniques and means of analysis tracing the moment-by-moment bodily and situated activity of subjects engaged in events and interactions. These techniques include the preparation of multimodal transcriptions, bodily re-enactment of interactions recorded in the video, writing commentaries raising questions and issues fully grounded in the recorded events, and, to the extent possible, consulting with the participants in those events. Talk, gesture, facial expression, body posture, drawing of symbols, manipulation of tools, pointing, pace, and gaze are all instances of modalities to be traced. Whilst limited by the recording conditions of an online conversation, we pursued a microethnographic approach in this study.

This research included human participants and was reviewed and approved by the Health and Education Research Ethics and Governance Committee at Manchester Metropolitan University (EthOS Reference Number: 42821). All participants provided

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1 https://forcesintranslation.org/about/

FIGURE 1
Lark's head.

informed consent for participation in the Studio Practice and related research and for their images to be included in this study.

Crafting mathematics—A conversation between basketry and mathematics

The conversation selected for our case study interlaced knot tying as a craft and knot theory as a branch of mathematics. We conjecture that the transitions to and from knot tying and knot theory involve navigating across distinct distributions of the sensible and their aesthetics. For knot tyers, knots are to be made and valued according to their frictional strength, ease of unknotting, and other qualities critical to their use by fishermen, packers, etc. Within the consensual aesthetics of knot tyers, many knots studied in (mathematical) knot theory are not even knots, and vice versa. The two distributions of the sensible share some common entities, such as certain knots, e.g., the *trefoil* or *overhand,* but they are immersed in distinct dialects, patterns of expectations, bodily skills, and ways of making sense of them. The aesthetics of a distribution of the sensible are inseparable from the corresponding histories of communities and practices.

Learning knot tying or knot theory both entail the encounter with an unfamiliar aesthetic, which represents a political engagement in the sense of "bringing to reality" materials and events that had previously been invisible or occluded by irrelevant noise. Experiences with knot making of either kind, however, are not deterministic, in the sense that each of them can become sources for diverse aesthetical orientations, including the possibility of coming to appreciate the same knots and techniques as useless, inspiring, too easy, too difficult, powerful, very strange, being good at them, and so forth.

Results: case study in six scenes

A note on the formatting of the transcript for the following six scenes. Rounded double brackets are used to include references to related actions or materials. Aligned left square brackets on adjacent lines indicate simultaneous speech. The numbered speech segments are referred to as Turns in the commentary, e.g., Turn 5.

Scene 1

1. Geraldine: I suppose a hitch is not a knot, is it?
2. Stephanie: Yes it is ((showing a tied rope with a branch holding it, see Figure 1))
    ((Everybody laughs)).
3. Stephanie: Yeah.
4. Geraldine: It's not quite a knot, it's a hitch.
5. Stephanie: It's a Lark's Head [knot.
6. Geraldine: [Well, If you take it off.
7. Stephanie: Isn't it a Lark's [Head knot?
8. Geraldine: [if you take it ((the branch)) off, it's not a knot. I mean, it's one of those...not knots ((showing a rope forming a circle held by her hands, see Figure 2)).
9. Ricardo: Unknot.
10. Geraldine: If you take it off the string, off the bar, and a knot is meant to be a knot that doesn't come undone ((showing a knot that stays as such when pulled apart, see Figure 3)).

Commentary on scene 1

According to Wikipedia, "a hitch knot is a type of knot used to secure a rope to an object or another rope. It is used in a variety

FIGURE 2
Unknot.

FIGURE 3
Knot that stays knotted.

of situations, including climbing, sailing, and securing loads."[2] In effect, the hitch knot shown by Stephanie in Figure 1, ties a rope to a branch. Stephanie names it "Lark's Head" (Turn 5), which is a type of hitch knot also called "Cow Hitch". Hitch and Lark's Head knots have definite places in the distribution of the sensible inhabited by knotters. However, Geraldine had suggested in Turn 1—the initial question of this scene—that it might not be a knot. Stephanie answered by showing it as an actual knot (Figure 1), which was funny because Stephanie picked up a hitch as if anyone would always have one of those around. However, in Turn 4, Geraldine reaffirms that a hitch "it's not quite a knot"; she makes the case for it by showing that if the branch is removed, it becomes one of those "not knots" (Turn 8). In Figure 2, Geraldine shows what a "not knot," called "unknot" by Ricardo (Turn 9), looks like: the rope tracing the shape of a closed figure with joined ends. Her

holding of the rope in Figure 2 emphasizes that in knot theory, knots—including the unknot—do not have loose ends, which can be achieved by fusing the two ends of a rope. Geraldine understands that if one pulls the ends of the rope without the branch, the hitch undoes itself instead of becoming tighter on its own. However, what does it mean that the hitch undoes itself? Could it mean that the rope can be stretched along a line segment? Perhaps, but she demonstrates the not-knot as a circular figure. A circle-like shape, free of crossings, is the standard way of displaying it in knot theory. Throughout this interaction, we recognize the entwining of two distributions of the sensible and their two corresponding aesthetics. One is the aesthetics of knot tyers, for whom the hitch is a knot and a not-knot is a stretchable rope without crossings; the other is the aesthetics of knot theorists, for whom the hitch is not a knot, as it can be converted into a closed planar figure free of crossings. These differing distributions of the sensible are differences in practices and values, not reducible to different definitions. For example,

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2   https://en.wikipedia.org/wiki/List_of_hitch_knots

filling squares of increasing area with unit squares to generate a number sequence—a classic task in school mathematics—differs from the work of tilers (those who lay tiles) who need to tile walls that may not be covered by square tiles without cutting some of them into smaller pieces; decisions about how to cut them entail criteria about symmetry, attachment strength, sharpness of the edges, continuity of graphic patterns on the titles, and more. All these are aesthetic considerations embedded in a distinct distribution of the sensible that a tiler inhabits. In sum, it is not about how squares are defined, but what kind of practices with squares matter.

Returning to our example of knots, to fit the knot theorist's distribution of the sensible, the branch in the hitch is to be removed or converted into being part of the rope, possibly becoming another knot. We can look at the same object, a hitch around a rod, and see what to do with it, depending on the aesthetics that we adopt. Each aesthetic has an inner coherence, which disallows comparisons between isolated parts. Unless it gets transformed properly, the branch does not exist in the knot theorist's distribution of the sensible, but it is very much part of the knot tyers' one because, crucially, knots secure one object to another one. In knot-tyer aesthetics, all knots can be undone if the ends are pulled properly, which is not the case in the aesthetics of knot theorists because their knots do not have ends. In Figure 3, Geraldine shows an overhand knot as an example of a knot that cannot be undone, which is what makes it a "real" knot; this is the case if the ends are joined, because otherwise, with loose ends, knots could be undone and cease to be knots for knot theorists. Joining the loose ends of an unknotted string leads to a circle/loop, the unknot. Given that its name suggests that it is not a knot, the unknot appears to have an odd role in knot theory. It is not unlike the dubious role that, for centuries, zero had among numbers. Zero doesn't really count anything (so is it a number?), but it serves as the identity or 'do nothing' number when it comes to addition. The unknot plays the same role when it comes to composing/adding knots. It serves as a base or boundary object, which helps complete the mathematical theory but may not be meaningful for knot tying. Scene 1 reflects a lived-in entanglement of distributions of the sensible respectively inhabited by knotters and knot theorists. This entanglement will be further articulated in Scene 2.

Scene 2

1. Ricardo: (...) can you think of the crossings in your hitch knot, even when you are with the branch in the middle?
2. Geraldine: Oh, with the branch, yeah. There's only two, aren't there?
3. Stephanie: Two, yeah. (...)
4. Geraldine: One, two ((counting two rope "contacts" in a knot similar to the one shown in Figure 1)). I think that's because it's not a knot.
5. Stephanie: But it is called a knot by knotters?
6. Geraldine: Yeah, but they don't call things non-knots either, do they?
7. Stephanie: And it is called the Lark's Head as well.
8. Geraldine: Yeah, they are called knots by the knotters, but not by mathematicians, I don't, I think.

Commentary on scene 2

Geraldine and Stephanie counted the times the rope touched itself for the Lark's Head as in Figure 1, which are two (Turns 2 and 3). It is tacitly understood that the rope touching the branch does not count as a crossing. This implicit assumption is a "natural" one from the aesthetics of knot theory, given that the branch is a spurious element in it, at times no more than background noise. In fact, the question of the number of crossings is essential for knot theorists but not for knot tyers, for whom the number of crossings is largely irrelevant. In this sense, Ricardo's question (Turn 1), just by asking about the number of crossings, foregrounded the aesthetics of knot theory, leading to Geraldine's additional argument (Turn 4) for the hitch not to be a knot. This inference, in all likelihood, is derived from a previous conversation situated in knot theory about the minimum number of crossings for a knot other than the unknot being three.

Stephanie shifts the conversation from "being a knot" to "being called a knot" (Turn 5): as opposed to mathematicians, knotters call it a knot. This is a crucial shift because it reframes the question in a manner relative to the communities of interest and their distributions of the sensible. Further elaborating on the differences between knot tyers and mathematicians, Geraldine says in Turn

FIGURE 4
Two linked half–hitches.

6 that knotters do not call things "non knots". This relativism removes hierarchical determinations, such as ascribing to either knotters or mathematicians the possession of a "true" criterion for what knots are: it is now possible, from the aesthetics of knot theory, for a knot to have at least three crossings and to include "not knots", but, at the same time, from the aesthetics of knot tying, knots may have fewer than three crossings and not-knots may be non-existent. What we attend to, what we choose to name, and what we are called to do are very much part of a distribution of the sensible that has been historically developed and presently adjusted by certain communities.

Scene 3

1. Ricardo: (...) Can you count the crossings without the branch in?
2. Geraldine: Well if you pull it off the branch and then it just comes apart.
3. Ricardo: Maybe there is something about the branch that somehow is playing a role of a crossing for some reason, I mean, it's something to wonder about.
4. Geraldine: It's just that lovely half hitch. I really like these half hitches, because this, this one… this one is two linked half hitches ((see Figure 4)). And it's the same as the looping. It's the looping. I mean, that's, but it's two half hitches.
5. Ricardo: But there are more than two crossings there.
6. Geraldine: One, two, three, four.
7. Ricardo: There is something that happens when you have a branch inside that it makes it not so easy to unknot it.

Commentary on scene 3

In Turn 1, Ricardo asks for counting crossings without the branch going through the hitch. In response, Geraldine expects the hitch to come apart (Turn 2). Ricardo wonders how to think of the branch as blocking the unknotting of the hitch (Turns 3, later reiterated in Turn 7). Whilst Ricardo was talking in Turn 3, Geraldine removed the branch from the hitch, and then she moved the rope in some way, which we cannot see because it was off-camera, such that she formed the knot shown in Figure 4: two half-hitches. We can think of a half-hitch as a rope going around and just touching itself. Two half-hitches can come one after another, or they can be made so that the second half-hitch goes through the first one. This is what we see in Figure 4: two half-hitches in which the second one goes through the first one as in a chain. She tells the rest of the group that they are "lovely" and that she "really likes them" (Turn 4). As a basket weaver, Geraldine uses looping techniques to create beautiful baskets of an extraordinary variety, and it turns out that two half-hitches are "the same as the looping." The immense creative value that looping has for Geraldine is also ascribed to two half-hitches; they are prominent in her aesthetic as a master of looping. We chose to highlight in this commentary the emotional investment that Geraldine expresses. This is not meant to imply that emotional values, so central to any aesthetic, are to be seen only in this scene. Anything said or shown in the six scenes is animated by emotional values. We elaborated on them here just because they are particularly salient and explicit. In Turn 5, Ricardo is puzzled by how the hitch became a loop with more than two crossings, four in fact (Turn 6). Looking at Figure 4, you notice that the left and right crossings are very clear, but in the middle, there is an area of contact that is not obviously one or two crossings. One needs to move the rope around there to disambiguate and notice that it is two of them, which is what Geraldine reported in Turn 6.

Scene 4

1. Ricardo: What are you showing, Mary?

FIGURE 5
Overhand knot.

2. Mary: I've just sort of taken the knot that you were showing, the sort of overhand knot ((Figure 5)), and I was thinking if you had one end as a sort of standing still, not moving ((the horizontal end in her left hand in Figure 6)), but if you take the working end ((moving the working end back through the loop, as in Figure 7)), then it makes a complete turnabout. And if you actually sort of suspend it in space, then it only touches at three points, ((correcting herself)) two points ((Figure 8)), but if you pull it up and make it flat, it touches at three points ((Figure 9)). And also that bit ((referring to the horizontal section of the knot in Figure 10)) could be like Geraldine's rod.

3. Geraldine: [Yes.

4. Stephanie: [Yes.

5. Mary: That could be like a rod, that part. And then you've got another part coming around.

Commentary on scene 4

Mary begins by showing a knot that is a "sort of overhand knot". She holds it by pressing two points of contact for the rope, one in each hand (Figure 5). Then, she pulls one end of the rope, straightening the corresponding section of the rope with her left hand (Figure 6). Mary refers to this end of the rope as "standing still" or "not moving." Then, she alludes to the opposite end of the rope (pointing upwards in Figure 6) as "the working end." This distinction between the standing and working ends of a rope is very

FIGURE 6
Still vs. working end.

FIGURE 7
Retracing the working end.

FIGURE 8
Two-crossing view of the overhand knot.

FIGURE 9
Three-crossing view of the overhand knot with related knot diagram in the top left corner.

common amongst knot tyers as they clarify how to make a knot. Moreover, it is often the first thing that they set up, determining which end will be still and using the other one as the working end that will go through space. Mary passes the working end back under the loop to show how it goes from the beginning: "it makes a complete turnabout" (Figure 7). In Figure 8, Mary suspends the rope "in space," indicating how the rope only touches itself at two points. In contrast, "if you make it flat," that is, pulling the ends to press the whole knot closer to a plane, "it touches at three points" (Figure 9). If the two loose ends were joined, this representation would be close to a knot theorist's diagram for the overhand knot, shown in the top left corner of Figure 9. The bit of rope departing

from the still end, Mary adds, "could be like Geraldine's rod" (Figure 10), that is, like the branch that used to go through the hitch (Lark's Head knot in Figure 1), which is agreed upon by Stephanie and Geraldine (Turns 3 and 4). By showing the rod-like part next to the still end, Mary has transformed the branch across the hitch into a continuous part of the rope itself. Mary concludes with an overall description of her overhand knot, which starts with a rod-like part taking off from the still end and the rest of the rope fully "coming around" (Figure 10).

As part of her demonstration, Mary shows that the number of crossings of a knot depends on how one holds it, exhibiting that an overhand knot can feature two or three crossings. This

FIGURE 10
Overhand knot with horizontal "rod" section.

FIGURE 11
One crossing of a trefoil knot.

opens a huge topic: What is a crossing? How come that knot theory stipulates that an overhand knot with joining ends (i.e., a trefoil) has at least three crossings, whilst, at the same time, one can suspend it in space with only two? Or, as it will later transpire in the discussion, with only one or none? How is a crossing different from a "touching"? This isn't purely a semantic issue and brings to the fore how entanglements of different aesthetics can help shed light on and counter the prevalent silencing aesthetic in mathematics. The crossings in a mathematical knot diagram can be seen as arising when one flattens a (three-dimensional) knot onto a two-dimensional plane. In other words, knot diagrams are projections or flattenings. As an example, note the contrast in Figure 9, in which we see the knot held by Mary and the corresponding diagram

for the equivalent knot. However, these issues are often glossed over in the didactical use of diagrams. This sweeping under the carpet of essential features (under the prevailing mathematical aesthetics of brevity or assuming common understanding within the community) is brought to light as the participants try to clarify how touchings and crossings could be the same or different. This topic will be further elaborated on by Charlotte in Scene 5.

Scene 5

1. Charlotte: Yeah, well, I was interested in the idea of crossings and the relation between the three dimensions and
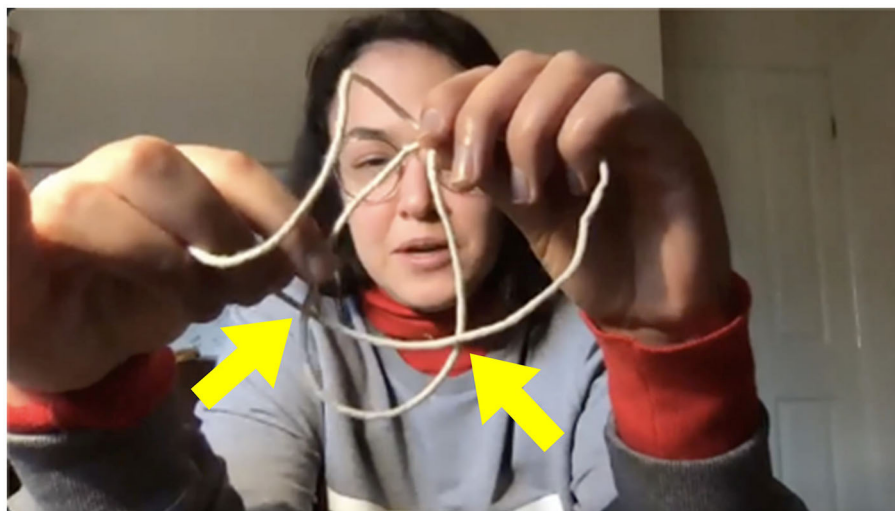
FIGURE 12
One crossing becomes two.

two dimensions, it's related to what Mary just said ((in Scene 4)). I was trying to making sense of the crossings in three dimension and then this one is here. ((see Figure 11, yellow arrow indicating a crossing she was probably referring to)) but then when once you flatten the knot, then it becomes two ((see Figure 12)). And yeah, because the knot is something, well it's three dimensional and then it kind of changes the nature in some way when you flatten it.

Commentary on scene 5

In Figure 11, Charlotte holds a trefoil in such a way that the string appears to touch itself at a point down below. However, as she turns the loop 90 degrees to "flatten" the knot, in Figure 12, that single touch in the lower section becomes two. She is operating all the time with three-dimensional materials, but she envisions a transformation from three dimensions to two, which coincides with what Mary had referred to in Scene 4 as "flattening," which seems to increase the number of crossings. In knot theory, this type of flattening is called projecting, which is more like creating a shadow of the knot on a flat surface. There is also the additional requirement that at most two points in the three-dimensional knot project or flatten onto a point in the diagram (or shadow) and that the strands of the knot that result in such crossing points genuinely cross each other (a transverse crossing) and are not just tangential touchings. In this operation, even a knot that does not touch itself anywhere will generate crossings in its shadow. However, some of the shadowed crossings can be thought of as artifacts that can be eliminated by re-arranging the rope in space. We witness in Scenes 4 and 5 the initial emergence of a new partition in a distribution of the real permeated by knot theory, which allows for the allocation of crossings as distinct from touchings.

The materials in use, such as ropes or diagrams on paper, fully participate in the realization of the corresponding aesthetics and are not just accessories.

Scene 6

1. Hilary: Well, I also agree with Charlotte about the three-dimensional sort of way that it changes because I make knots in willow for my frame baskets. So the frame of it is a knot ((Figure 13)), usually the hoop frame. It doesn't have to be made like that, but that's the way I do it. And so I have a knot in a hoop, in a sort of piece of willow ((Figure 14)). And then I have to find the place at which it balances. (…) So there's a point that I have to choose where everything is going to stay in the right place. That it's going to make a balanced basket. So I'm looking for that when I make the hoop, I'm looking for the point at which that is getting to stay upright, which is about there ((Figure 15)), where I can press down on it, and it's going to be, it sort of balances on itself.

Commentary on scene 6

Charlotte's reflections in Scene 5 prompted Hilary to think of her experiences balancing the hoop of a frame basket. Unlike other types of baskets, which take shape gradually as they are woven, frame baskets are made on the basis of a "skeleton" or "framework" that is shaped from the beginning, orienting and determining the basket's overall shape (Jensen, 1991).

Hilary is a skilled basket weaver, with willow being one of her preferred materials to work with. In Figure 13, Hilary shows the skeleton of a frame basket with two hoops, one vertical and one

FIGURE 13
Knot as part of basket hoop frame.

FIGURE 14
Forming a knot in willow for a hoop frame.

horizontal. The upper side of the vertical hoop, also called the hoop frame, is going to be the handle of the basket. Hilary had made the ring of the hoop frame by tying a piece of willow as an overhand knot. She clarifies that there are other ways of making it, but this is how she does it. In Figure 14, she shows a hoop frame before the horizontal ring is attached to it, just the overhand knot. In making the skeleton of a rib basket, it is important to ensure that it is "balanced" at every step. For example, in Figure 15, Hilary shows that a point can be found at which the skeleton stays upright. This demonstration reveals how critical sensing the materiality of a willow-made knot is, to ascertain conditions enabling the weaving

of a balanced basket. For basket weavers, balanced and unbalanced baskets are part of the distribution of the sensible they inhabit. Knot theorists make use of symmetry (a form of balance) in their knot diagrams, which can aid efficient analysis and classification. In Hilary's case, the balance is integral to the use and materiality of the basket. Could we say that this emphasis on materiality marks a radical difference between the aesthetics of basket weaving and the aesthetics of knot theory? We think it does not. Even the very planar knot diagrams, customary in knot theory, preserve three-dimensional features as they show points of over and underpassing. Such crucial under/over reflects material impenetrability. In fact,

FIGURE 15
Part of the knot serving as a balance point.

knot theory's distribution of the sensible does not involve the melding of two filaments or strings into one, in other words, actual flattening.

Discussion

> *Knots seem to refuse to be seen from one particular point of view or perspective (de Freitas and McCarthy, 2014, p. 45).*

We have set up and studied inclusive and pluralist "Studios", gathering craftworkers, anthropologists, mathematics educators, and mathematics enthusiasts. Many of these Studios were open to the public and family groups as well. The six scenes of our case study, which are part of a much longer conversation, reflect the messy work of a group of participants with diverse backgrounds and ages, as they navigate and comingle various aesthetics, sharing the notion that no single aesthetic has ultimate and dominant value. Scenes 1 and 2 reflect that there are different distributions of the sensible consensually adopted by, in this case, knotters and knot theorists, such that that which exists for them is perspectival, interrelated, and sensible. Scene 3 suggests that materials and techniques allocated in a communitarian distribution of the sensible have multiple and intense powers of emotional attachment. Scenes 4 and 5 evoke how grappling with the idea of "crossing" is a matter of degrees and nuance, dependent on careful attention to materials and diagrams. Scene 6 highlights the multiple lives of knots and their crossings as they basket-weave materials and patterns.

The conversation that we have portrayed entangles different aesthetics, including ones from knot tying, knot theory, and basket weaving. Other aesthetics surrounding knots have been studied by anthropologists:

> *The knot is ascribed more than functional value in the Pacific as it becomes the object of meditative thought and holds together through binding not two things but two concepts: that of the visible, and that of the invisible whose momentary entanglement facilitates temporal concepts of genealogy and remembrance (Küchler, 2003, p. 207).*

In this discussion, we want to elaborate on the significance of aesthetical entanglements in mathematics learning because they may help question a prevalent and widespread aesthetic of mathematics that works by silencing those who fail to appreciate it, a community that includes the majority of students. This aesthetic is not an honest one either. The actual practice of mathematicians is much more similar to that of craftspeople or students, though that is occluded in much of how the subject is presented and taught. The mathematician Rota (1997) has described two interrelated aspects of what we call "Silencing Aesthetics": (1) sudden light in the darkness and (2) attributions of mathematical beauty to cover up the messiness of mathematical enlightenment. They are two sides of the same impetus. Regarding the former, he writes:

> *All the effort that went in understanding the proof of a beautiful theorem, all the background material that is needed if the statement is to make any sense, all the difficulties we met in following an intricate sequence of logical inferences, all these features disappear once we become aware of the beauty of a mathematical theorem (…) [all that will remain] is the image of a flash of light of insight, of a sudden light in the darkness (ibid, p. 179).*

Rota views veiling the messiness inherent in enlightenment, which is regularly hidden when mathematicians formally present their work, as motivated by powerful aesthetical and political forces:

> *The term "mathematical beauty", together with the light-bulb mistake, are tricks that mathematicians have devised to avoid facing up to the messy phenomenon of enlightenment. The comfortable one-shot but misleading idea of mathematical beauty saves us from having to deal with the messy situation of a concept having degrees. All talk of mathematical beauty is a copout from confronting the logic of enlightenment, a copout that is intended to keep our formal description of mathematics as close as possible to the description of a mechanism. This copout is a step in a cherished activity of mathematicians, that of building a perfect world immune from the messiness of the ordinary world, a world where what we think should be true turns out to be forever true, a world that is to be kept free from the disappointments, the ambiguities, the failures of that other world in which we are forced to live (ibid, p. 182).*

Numerous efforts have been made to *unveil* the messiness of mathematical enlightenment. There is a considerable literature in mathematics education research dedicated to this, most notably from philosophy, *Proofs and Refutations* (Lakatos, 1976), and from cognitive linguistics, *Where Mathematics Comes From* (Lakoff and Núñez, 2000). However, these untidy accounts of mathematical work are often marginalized as belonging either to historical epochs prior to the development of contemporary mathematics or to students who are still far from mastering the subject. The underlying message for many students, who seldom experience flashes of light of mathematical insight whilst often sensing unapproved messiness in their understandings, is that they lack the abilities necessary to enjoy mathematics and appreciate its alleged aesthetics.

This study attempts to explore how we could question silencing aesthetics to make space for inclusive ones. Given the dominant cultural images of mathematics, it is a complex issue. Aesthetical entanglements such as the one reflected in our case study, in which knot theory and knot tying aesthetics are compared on an equal footing, each equally legitimate despite their radical differences, may help in grasping an aesthetic of knot theory that is neither mechanistic nor flawless. The episode was not, for the most part, a matter of dissensus; none of the participants were prone to argue that knots used by fishermen should be considered knots by knot theorists or that the latter should discriminate knots according to their frictional strength. These would be dissensual claims to the extent that they attempted to subvert the distribution of the sensible consensually adopted by each of the communities. We can recognize many points of contact between knot theory and knot tying, such as the trefoil being an overhand knot with its ends joined. These points of contact constitute rich counterpoints to be explored. There is nothing absolute about defining knots, say, as not having loose ends. The issue can be highlighted by noticing that without friction, knots with loose ends can always be unscrambled onto a linear rope, which would make knot theory pointless.

Regarding classroom implications, as we touched on earlier, there is a small strand of literature on mathematics classroom dynamics favoring or countering what we have called "silencing aesthetics," as well as exploring ways of nurturing inclusive aesthetics (Brown, 1973; Dreyfus and Eisenberg, 1988; Sinclair, 2008, 2009; Sinclair and Pimm, 2010). The thematic lines introduced in this study, on taking a Rancièrian perspective on aesthetics and intermingling mathematics and craftwork, could be of significance on this front by facilitating the entanglement of diverse aesthetics in the classroom and questioning silencing aesthetics. This is a complex agenda because attending to more inclusive aesthetics is likely to demand slower and less predictable courses of action, which are inherent in striving to ground learners' conceptions in their own tangible experiences. This creates tensions with respect to constraints of time, "covering" extensive curricula, and standardized assessments. These tensions make the work in informal learning, such as the Studio Practices reported in this study or our past study with 10-year-old children in an afterschool programme (Nemirovsky, 2018), not easily transferable to goal- and assessment-driven classroom mathematics. The entanglements we propose could result in slower and more deliberative mathematics, with opportunities for reflecting on different aesthetic values. There are examples of curricular materials that could support such practice. For example, the *Math in a Cultural Context* materials for elementary school, developed in southwestern Alaska, bring together classroom mathematics and indigenous Yup'ik cultural knowledge of Yup'ik cosmology and everyday practices, such as garment-making (Lipka et al., 2013, 2015).

With an emphasis on the entanglement of diverse aesthetics, this study contributes to a vision that interlaces mathematics learning and craftwork, which has become a small but growing movement in recent years (Belcastro and Yackel, 2011; Gresalfi and Chapman, 2017; Nemirovsky, 2018; Taimina, 2018; O'Brien, 2022; Peppler et al., 2022). More broadly, the overall idea is to liberate space and time for the artisan, the practitioner, the child, and the lay citizen to partake in the sharing of the sensible and to become "a deliberative citizen" (Rancière, 2000, p. 12) in mathematics and beyond.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Health and Education Research Ethics and Governance Committee at Manchester Metropolitan University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RN: Writing – original draft. VK: Writing – original draft. CM: Writing – original draft.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Bridging disciplinary aesthetics: when mathematics meets art through educational technology

Myrto Karavakou[1], Chronis Kynigos[1] and Nathalie Sinclair[2]*

[1]Educational Technology Lab, School of Philosophy, Department of Educational Studies, National and Kapodistrian University of Athens, Athens, Greece, [2]Faculty of Education, Simon Fraser University, Burnaby, BC, Canada

In this article, we discuss the way students' aesthetic experiences can shape the learning of mathematics at higher school levels. We designed a learning environment based on three main design principles: (1) Mathematics as Artistic, where mathematics is used for open artistic creation; (2) Aesthetically rich mathematical experiences, that enable students to appreciate mathematical beauty and aesthetic experiences of wondering, imagining, conjecturing, testing, discovering, making connections, problem posing and solving; (3) Constructionism, where mathematical sense making is interwoven with constructing a personally meaningful digital artefact. Two students of the 11th grade participated in a case study, where they used expressive digital resources for representing, manipulating and exploring periodic functions in order to create an animated artefact based on a piece of music. The collected data fed the formation of a theoretical model for analysing students' aesthetically driven mathematical meaning making, in an attempt to structure existing theoretical concepts around mathematical aesthetics in education. A part of the analysis of students' aesthetic experiences based on this model is presented and further reflectively discussed with respect to the prospect of an aesthetically oriented curriculum reform.

KEYWORDS

mathematical aesthetic experience, mathematics learning, educational technology, programming, art, periodicity

1 Introduction

In this paper we join our three voices to point to the profound role of aesthetics in the development and appreciation of mathematical knowledge and our concern in the lack of cultivation in school settings, where this role has been paradoxically marginalised (Papert, 1980; Dreyfus and Eisenberg, 1986; Sinclair, 2018b). Recently, researchers have highlighted the importance of (re)considering the aesthetic aspects of school mathematics, based on the affordances of digital technologies and future societal needs (De Freitas and Sinclair, 2014; Bu and Hohenwarter, 2015; Nemirovsky, 2018; Sinclair, 2018a). They argued that the expressive, experimental and multisensory nature of new technologies has allowed students to experience mathematical aesthetics in a novel and accessible way, by integrating the factors of subjectivity and personal sensibility within the traditional elitist perception of mathematics as a discipline (De Freitas and Sinclair, 2014). In parallel, a growing number of studies recommend the integration of arts within school mathematics as a fruitful means for cultivating aesthetic, sensory, bodily and human-scale experiences that are closer to students' personal interests (Gerofsky, 2013; Gadanidis et al., 2016; Moerman, 2016; Portaankorva-Koivisto and Havinga,

2019; da Silva, 2020; Jasien and Horn, 2022). Nonetheless, there is a dearth of research on the aesthetic considerations related to *mathematics learning* with or without technology, particularly in relation to teaching practises (Sinclair, 2018a).

After presenting the theoretical ideas behind its design, we propose a model for analysis, named CrEAM, i.e., acting on (A), evaluating (E) and mathematizing (M) the artistic creation (animated artefact) in the context of re-defining aesthetic criteria (Cr). Our CrEAM model was founded on a synthesis of existing theoretical constructs and structured under an abductive analysis of the results of the current study. Students were invited to create figural models by means of programming and their animation by means of dynamically manipulating variable procedure values (Kynigos, 2007; Kynigos and Karavakou, 2022). We draw on the CrEAM model to analyse the role of aesthetic experiences in the meaning-making process of two participating students of the 11th grade. Finally, we reflect on the way aesthetic considerations could shape educational reform in relation to the selection of mathematical content and the learning processes. This study is part of a broader design-based research project that investigates how aesthetic experiences can shape students' mathematical meaning making; what kind of mathematical content can be selected as aesthetically fruitful; and how technological resources can be exploited to nurture this kind of aesthetic engagement. In this article, we address the research question 'How do students' aesthetic experiences shape their meaning making around the notion of periodic functions within a constructionist, aesthetically rich learning environment of open artistic creation?'

2 Theoretical framing

In this section, we outline our theoretical framework which was shaped as a bricolage (Cobb, 2007) of distinct theoretical constructs around aesthetics and mathematics learning. These involve aesthetic experience and practise in mathematics and mathematics education, integration of mathematics and arts, aesthetically rich environments, and constructionism as a theory of design and a theory of learning. The theoretical framing of the study is situated within epistemological perspectives and the literature.

2.1 Aesthetic experiences in mathematics

The issue of aesthetics has triggered a long-standing epistemological discussion around the nature of mathematical practises, akin to discussions on aesthetics from different disciplines (Dreyfus and Eisenberg, 1986; Sinclair, 2001; Parrish, 2009). Many mathematicians and researchers argue that mathematical activity centrally involves affect, feeling, pleasure and the sense of beauty (Poincaré, 1956; Papert, 1978; Brown et al., 1989; Goldenberg, 1989). These considerations place the attention to the way aesthetic experiences shape mathematical practises of problem posing, developing conjecture for solutions/proofs and evaluating results. The generation of mathematical knowledge is guided by the mathematician's own aesthetic criteria, which exceeds the objectiveness of pure logical deduction, making it a human, profoundly personalised matter. However, not all

theorists that recognise the significance of aesthetic in mathematical practises share the same views. For example, Poincaré (1956), Dreyfus and Eisenberg (1986), Krutetskii (1976) and Silver and Metzger (1989) claimed that only a small minority of people would be able to appreciate mathematical beauty, feel mathematical pleasure and, thus, have access to mathematical aesthetic experiences. They theorised aesthetics as an innate ability to identify formal qualities, such as economy, simplicity, originality, elegance, profundity or clarity in mathematical objects (e.g., in concepts, theorems, proofs) and to appreciate inner mathematical elements, such as symmetry, infinity, harmony and regularity. According to this traditional perspective, aesthetic criteria are objective in nature and possess a status of intellectual autonomy outside the human world.

On the contrary, more recently, researchers have sought to enlarge the meaning of aesthetic, to involve not only acts of judgement (of beauty, interest, etc.) but also—returning to its etymological roots—the idea of knowing through the senses (Sinclair, 2004; Gadanidis et al., 2016; Sinclair, 2018a; Beckmann, 2022). In other words, the aesthetic is both axiological (concerning values) and epistemological. This epistemological aspect of the aesthetic relies on assumptions of embodied cognition in which the senses—seeing, touching, hearing, moving, etc.—are central components of knowing. That these sensory mathematical experiences are then open to value judgements—does the diagram look symmetrical?; does the periodic function sound sad?—shows that the epistemological and the axiological are intertwined. Following de Freitas and Sinclair (2014), who in turn draw on Rancière (2004), we posit that the aesthetic functions in mathematics—much like in the arts—through a paradoxical mix of autonomy and dependence. For example, the painter creates an artwork depending on their own sensory engagement, but, once hung on the wall, the artwork becomes autonomous, its meanings are no longer dependent on the painter's brushstrokes or intentions. A similar phenomenon occurs in mathematics; mathematicians notice patterns, make calculations, see new objects—all of these are dependent on their sensory engagement—but once the pattern is generalized or the theorem is published, it gains autonomy, no longer dependent on their involvement. The mathematician lives with this paradox of 'it depends on me' and 'it is independent of me'. As Tan and Sinclair (2023) argue, in the case of engaging preservice teachers in mathematical proofs, this mixing of autonomy and dependence can be challenging, with most students veering in one direction or the other.

2.2 Toward aesthetically rich educational reform

One of the main challenges faced by researchers who envision the aesthetic turn of mathematics education is the level of dissenting from dominant school practises within a behaviourist-rooted curricular system (Maaß and Artigue, 2013; Hoyles, 2016). Gadanidis et al. (2016) introduced such a model of educational reform in view of integrating mathematical aesthetic experiences in school mathematics through design principles. They suggest that aesthetic elements, such as surprise, insight and vicarious emotional engagement, can be added on educational practise. They included the design principle of

'covering the curriculum' to make it applicable to today's mathematics classroom, which is resistant to any radical change. Even though this model is insightful for bringing aesthetic elements closer to practise, it has limitations in cultivating mathematical aesthetic experiences as an integral part of mathematics education.

Instead of trying to 'aestheticise' the existing curricular structure, by looking into which and how mathematical concepts from the curriculum can be infused into aesthetically rich learning activities, the focus can be reversed. The selection of mathematical content can be reconsidered under the lens of its aesthetic potential. This leads to the following question: what kinds of mathematics are more fertile for aesthetic experiences? And, what type of learning processes would support an aesthetically rich environment? Fruitful answers to this question can only emerge from combining theories and design-based research empirical data for shedding light on students' aesthetic experiences.

Starting from Sinclair (2001, 2004)'s definition of an aesthetically rich learning environment, design principles involve providing opportunities for wondering, exploring, imagining, noticing, feeling, making decisions and experiencing mathematical beauty. Sinclair distinguished two main aspects equally important for the formation of such environments: the aspects of perception and of action. On the one hand, students are provided with opportunities to express their own sensibilities (which may be different from normative mathematical ones) and subjective opinions, based on their sensory perception. On the other hand, effort should be made to provoke students' interest, in terms of communicating, discovering, making things and expressing themselves artistically.

Sinclair (2004) also theorised the role of aesthetic experiences in shaping mathematical inquiry within an aesthetically rich learning environment, in three distinct ways; through (1) a generative, (2) a motivational and (3) an evaluative role. The generative role involves the guiding process of gaining insight connected to both problem posing and problem solving. It is physically driven by feelings of wonder and curiosity that give rise to ideas on the formation of a particular problem or on the way to proceed with its solution. The motivational role refers to the development of personal interests that attract learners to engage in mathematics in particular ways. Having the freedom to select mathematical concepts, problems and strategies based on inner motivational mechanisms can lead students to develop a personal taste and agenda on mathematical inquiry. It is connected to emotions of interest and desire. The evaluative role concerns the learners' engagement in the process of deciding whether a specific result of mathematical inquiry is good or beautiful enough, following a socially shared or a personal set of criteria. It is connected to emotions of surprise, amusement, anger, confusion and disappointment. An aesthetically rich educational design should cultivate all three roles of aesthetic experience in the learning and doing of mathematics in the classroom.

Finally, regarding Rancière (2004)'s description of how the aesthetic functions, an aesthetically rich educational design should strive to allow for both autonomy and dependence (De Freitas and Sinclair, 2014). This means that students should be free to experience mathematics in sensorially diverse ways, while also having the opportunity to interact and connect with the symbolic, automated and generalisable mathematics.

2.3 Artistic as mathematics vs. mathematics as artistic

Some researchers considered different forms of arts, such as painting, architecture, music, visual arts, theatre, poetry, literature and dance, as possible bridges for infusing the aesthetic in school mathematics (Gerofsky, 2013; Moerman, 2016; Portaankorva-Koivisto and Havinga, 2019; Jasien and Horn, 2022). This integration might provide a transdisciplinary space for students to see and establish links of their mathematical meanings to specific contexts of application, to their personal taste and sensibilities and engage in creative problem-solving (Liao, 2016). This combination of arts and mathematics in education can be carried out in many ways, following different epistemologies. We use Betts and McNaughton (2005)'s distinction between *Artistic as Mathematics* and *Mathematics as Artistic*. In the former perspective, educational design places the aesthetic connected to the arts (artistic aesthetic) in the forefront, following the typical alliance between art and aesthetics. It is mainly based on artworks generated by artists who, intentionally or not, incorporated mathematical concepts in them, as well as artistic elements encountered in the nature. Examples include exploring the golden ratio in architecture (Beckmann, 2022), visual arts (Jarvis, 2007) and nature (Manuel et al., 2011); learning about the symmetries and perspective properties of paintings (Jensen and Gymnasium, 2008; Beckmann, 2022); recognising pattern and proportion within musical scales (Johnson and Edelson, 2003; Geist et al., 2012; An et al., 2013); investigation of symmetry in dance (Helsa and Hartono, 2011; An et al., 2019); and more. *Artistic as Mathematics* plays an important role in contextualizing and representing abstract mathematical ideas. However, there are many limitations to this approach, regarding the stimulation of mathematical aesthetic experiences. For example, Sinclair (2004) is concerned that by locating the aesthetic within the art, its role within mathematics becomes obscured. Accordingly, counting on students' interest to the arts as the basis for engaging them in mathematics might imply that mathematics itself is 'aesthetically sterile' (Sinclair, 2004, p. 94).

On the other hand, *Mathematics as Artistic* implies that mathematics itself can be experienced for artistic creation and appreciation. Instead of the artistic aesthetic being treated as a motivational extension of the mathematical engagement, this view frames a joint, intertwining exploitation of aesthetic aspects of both disciplines. To support this type of art-mathematics combination in educational practise, the focus is less on their similarities and more on their complementarity. Aesthetic experiences that emerge from this context combine: (a) the subjective, affective, emotional, intuitive aspect of the arts, which is closely connected to the powerful sensory effect of perceiving or creating an artwork, along with (b) the aspect of shaping taste in mathematics, appreciating both intellectual and sensory (e.g., visual) mathematical beauty, making sense of concepts, experiencing surprise and insight of discovery. Some researchers have considered this approach in designing educational resources and exploring students' mathematical engagement, especially in primary level, by using physical manipulatives. For example, Lehrer et al. (1999) explored students of second grade meaning making on symmetry while they were engaged in creating and investigating quilt patterns; Eberle (2014) studied the role of mathematical aesthetics in promoting mathematical learning of students of age 8–10 through the creation

and evaluation of tessellations with different geometric shapes; Vogelstein et al. (2019) explored 8th grade students' meanings on symmetry and geometric transformations while they were reenacting and creating their own dance performances using a geometrical shaped sheet; Jasien and Horn (2022) looked into children's mathematical aesthetic practises and meaning making while participating in interactive exhibitions providing manipulatives, such as cubes, geometrically shaped puzzle pieces and coloured eggs for open creation of artworks, e.g., aesthetically pleasing patterns or tiling. All the prementioned studies reported positive effects of aesthetic experiences on students' meaning making. However, research on *Mathematics as Artistic* in secondary and especially upper secondary levels remains understudied.

2.4 Constructionist ideas in educational design and learning

One primary epistemological step for making an aesthetically rich educational reform is based on readdressing educational time and space. Quoting Ricardo Nemirovsky's phrase taken from discussions in CERME 13, we need to "slow mathematics down" (CERME13, WG29, in July 2023). Students should be provided with an adequate amount of time to experience aesthetic aspects in their own pace and should be free to learn how to manage time for themselves (Papert, 1999). They should also be free to shape their own taste in mathematics (Kynigos and Diamantidis, 2021) and form their personal mathematical identity. At the same time, adding a variety of different representations and contexts of the same mathematical concept, can expand the space of mathematical engagement and would deepen their aesthetic experience and their meaning making (Turkle and Papert, 1990; Papert, 1993; Latsi and Kynigos, 2021). A substantial reform should also take into account current societal needs and new representational infrastructures that prioritise the aesthetic experience over the acquisition of specific mathematical content. Given the limitations of physical manipulatives and the human body itself in exploring, expanding and expressing abstract mathematical concepts, we turn to the affordances of digital resources. Exploiting the highly visual, dynamic and experimental nature of computer-based environments could provide a broader space for experiencing mathematical aesthetics. Constructionism provides both a design principle and a learning process that would support students' involvement in an aesthetically rich learning environment (Harel and Papert, 1991; Kynigos, 2015). Within a constructionist approach, the design of computational spaces aims at providing opportunities for exploration and personally meaningful construction activity, within which mathematical meaning is shaped and shared (Papert, 1980; Kynigos, 2007, 2015). Students working in such environments "learn to transfer habits of exploration from their personal lives to the formal domain of scientific construction" (Papert, 1980, p. 177). This kind of bridging of personal identity and mathematical engagement is one possible way to infuse the subjective-dependent dimension of mathematical aesthetic experience along with meaningful creation of artefacts and artistic engagement.

3 Methods and materials

Taking all the above statements as design values, we created an aesthetically rich, constructionist, *Mathematics as Artistic* learning environment for analysing students' aesthetically driven mathematical meaning making. In this section, we discuss the methods and materials of the study in terms of mathematical content, digital resources, task design and data collection and analysis. We explain how we used the CrEAM model to address and understand students' thinking processes taking a perspective where aesthetics and mathematics are fused in their constructionist activities. We formed the model not only by means of synthesising theoretical aspects from the previous section but also as a result of applying a first coding analysis of the current data.

3.1 The case of periodicity

Periodicity was at the centre of the mathematical content embedded in the designed task. Rather than looking to fit content to existing curricular structures we searched for a conceptual field which we believed to be fruitful for constructionist activity of the kind we were hoping to observe (Vergnaud, 2009; Wilensky and Papert, 2010). In most curricula, periodicity veers toward the outreach of the respective borders, as in most countries it does not receive much attention. However, we particularly valued it as a broad, complex, interdisciplinary concept, linking mathematics to different scientific disciplines and contexts of application, as well as to artistic domains, such as music (Flannick et al., 2005; Quinn et al., 2019), visual art (Puc and Škrekovski, 2011; Farris, 2013), poetry (Grosholz and Glaz, 2019) and more. We also appreciated that it is connected to the concepts of pattern, symmetry, fit and rhythm, each of which, as supported by the literature, entail rich aesthetic potential. At the same time, it is linked to more advanced mathematical concepts and a wide variety of representations and applications (Gerofsky et al., 2009). For these reasons, we assumed periodicity to be aesthetically and mathematically fruitful. We selected digital expressive media which afforded construction of periodic functional relations and the inclusion of the parameter of time thus providing a dynamic context of implementation, which can be associated with music and dance. In this context, our design involved digital tools for the artistic creation of periodically animated 'dancing figures' tuned to the rhythm and matched with the style of a specific song.

3.2 Task design and digital resources

The task designed for this study was an open activity for creating an animated figural artefact based on a piece of music (also known as music visuals). Students were given a list of specific songs of different styles, which, according to the first author, were rich in rhythmical diversity and complexity and had a strong affective aspect. Two digital resources were used, affording different type of mathematical
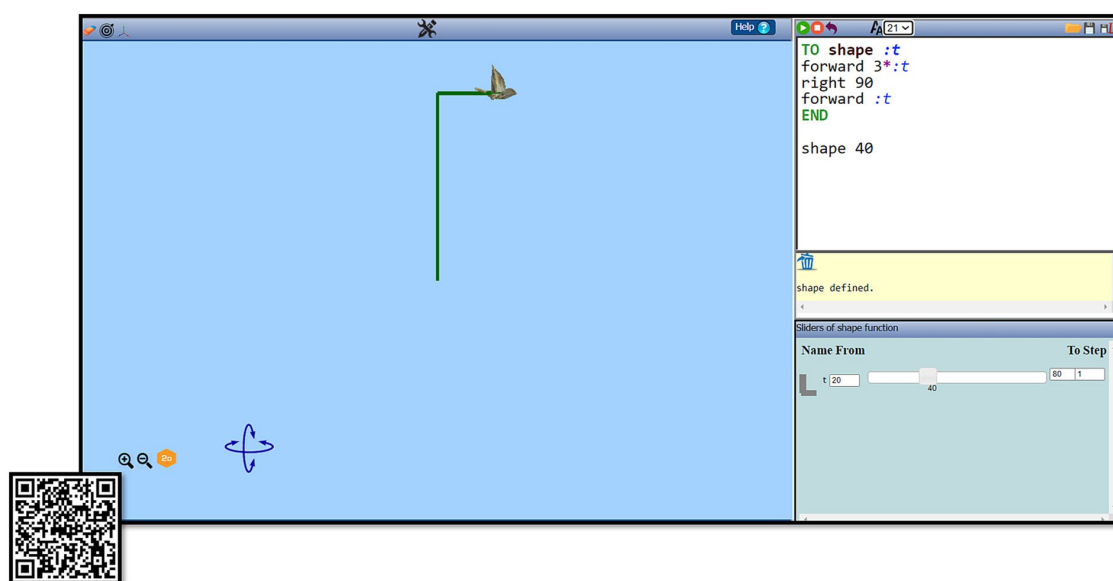
FIGURE 1

The digital environment of MaLT2; In this screenshot, an example of the procedure 'shape' is given. It is written and defined in the Editor (upper right window). It has one input variable (:t) and consists of three logo commands (forward 3*:t; right 90; forward: t). The procedure is executed with the input value of 40. The avatar has created two successive perpendicular segments of length 120 and 40, respectively (main window). The slider of the variable: t has been activated. The video shows how moving of the slider animates the constructed figure https://drive.google.com/file/d/1EkGmTqZE6S1uDngFB0DNVE-J9dPEUrqV/view?usp=sharing.

engagement and providing different types of mathematical representations MaLT2[1] and GeoGebra.[2]

According to Sinclair (2001)'s reflection on Papert (1980)'s Mindstorms, Turtle Geometry was 'an example of an environment that resonates with a child's existing sense of aesthetics, one that allows her to use her body-and ego-knowledge to draw, explore and make mathematics' (p. 25). MaLT2 was used as a medium for expressing and exploring mathematical and artistic ideas (Kynigos, 1995). It integrates a UCB-inspired Logo procedural language with Turtle Geometry in 3D and dynamic manipulation of variable values through sliders (Grizioti and Kynigos, 2021; Kynigos and Karavakou, 2022). Thus, it provides the affordance of animating figural models created by means of mathematical formalism embedded in a programming language. This important feature supports the framing of periodic functions and the integration of the notion of time, which can support connections to dance. For these reasons, MaLT2 was used for the creation of the animated artefact and for hosting a *Mathematics as Artistic*, aesthetically rich, constructionist learning environment. MaLT2 users can construct figural models through programming for the movement of an avatar that leaves a coloured trace behind. These figural models can be animated by (a) defining a procedure (e.g., '*TO shape:t*') whose variable (:*t*) is included as input in a logo command (e.g., '*left:t*' or '*right 2*:t*' or '*forward 30*sin(:t)*') or in a sub-procedure (e.g., *square:t*), which once defined works as being a command; and then (b) by dragging a slider that controls the values of the corresponding variable

and the figural transformations of the avatar's trace shown in the 3D scene (Figure 1).[3] By constantly pressing the keyboard's right arrow for moving its slider, a parameter can conventionally represent time, embedding the concept of motion in time.

Two GeoGebra files were additionally designed and used as graphing calculators for plotting (i) trigonometric functions of the form $a \cdot sin(b \cdot t)$ and $a \cdot cos(b \cdot t)$ (Figure 2A) and (ii) approximations of Fourier series of the form $a_1 \cdot sin(t) + b_1 \cdot cos(t) + a_2 \cdot sin(2 \cdot t) + b_2 \cdot cos(2 \cdot t) + a_3 \cdot sin(3 \cdot t) + b_3 \cdot cos(3 \cdot t) + a_4 \cdot sin(4 \cdot t) + b_4 \cdot cos(4 \cdot t)$ where parameter values a_i, b_i could be manipulated through sliders (Figure 2B).

3.3 Data collection

In this paper, a case study is presented, which is part of a wider design-based research project, comprising iterative cycles of designing, testing and analysing for the creation of empirically based theories and frameworks for action (Cobb et al., 2003). The empirical data consisted of: (a) screen and voice recordings from one laptop, shared by the two participants (capturing both input and output sound); (b) their written notes; and (c) their body gestures and expressions noted down by the attending researcher (first author). Abductive thematic analysis

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1 Link to MaLT2 website: http://etl.ppp.uoa.gr/malt2/.

2 Link to GeoGebra website: https://www.geogebra.org/calculator.

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3 Figures that include a QR code, like this one, are connected to a short video that better captures the described (in text) situation represented in the Figure. The reader can either click on the link provided in the caption, or scan the QR code using a QR code scanner application.

FIGURE 2
Two GeoGebra files for plotting periodic functions **(A)** The function $a \cdot \sin(b \cdot t)$ or $a \cdot \cos(b \cdot t)$ is plotted, with values of a and b controlled by two sliders. **(B)** The function $a_1 \cdot \sin(t) + b_1 \cdot \cos(t) + a_2 \cdot \sin(2 \cdot t) + b_2 \cdot \cos(2 \cdot t) + a_3 \cdot \sin(3 \cdot t) + b_3 \cdot \cos(3 \cdot t) + a_4 \cdot \sin(4 \cdot t) + b_4 \cdot \cos(4 \cdot t)$ is plotted with values of a_i and b_i controlled by eight sliders.
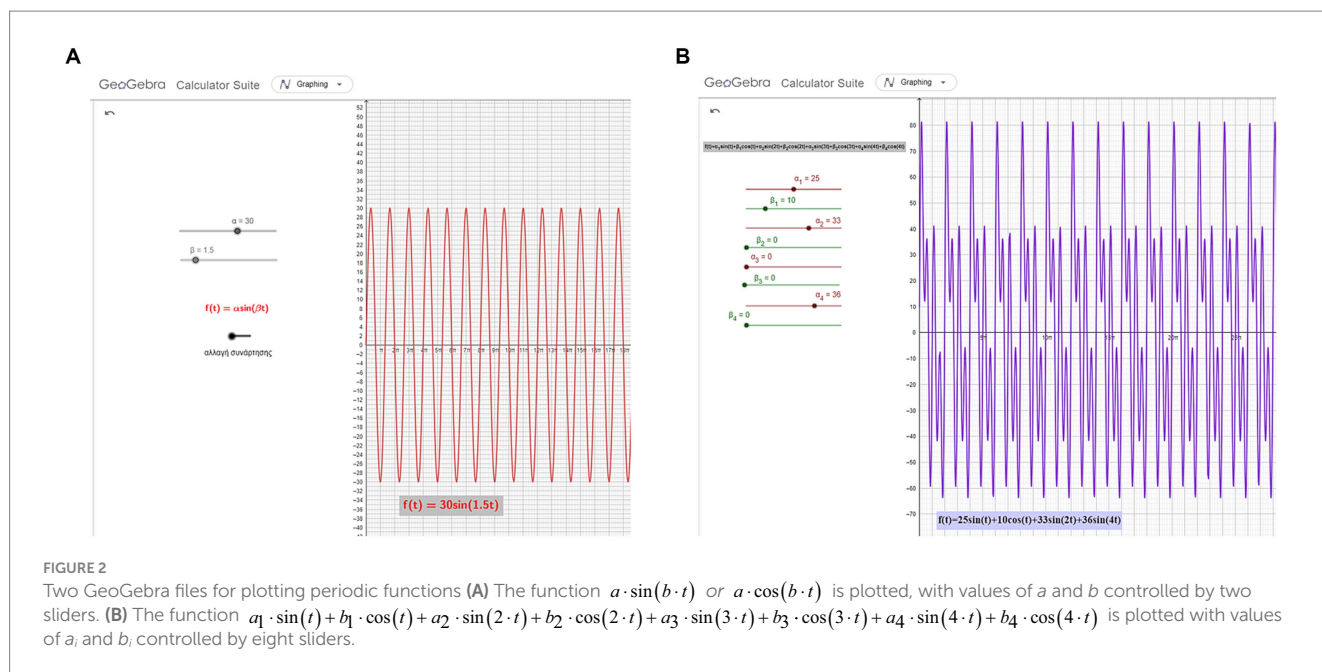
(Thompson, 2022) was implemented in two distinct levels, that informed the formation of the theoretical model CrEAM, as described in the following section.

3.4 CrEAM: a model for analysing aesthetically driven mathematical meaning making

Integrating different theoretical concepts and design principles entails the need for a broad, compound lens of analysis that could capture the respective complexity of the results. For that reason, we developed a model for analysing students' mathematical meaning making through aesthetic experiences, or 'aesthetically driven mathematical meaning making', situated in an aesthetically rich, constructionist, *Mathematics as Artistic* environment. In this model, which was named after its components as 'CrEAM', students' meaning making is interwoven with their aesthetic experiences while using the digital tools. The creation of CrEAM resulted from synthesising and structuring theoretical concepts mentioned in the 'Theoretical Framing', along with an abductive thematic analysis of results from the current study. In an attempt to describe students' aesthetic experience as a relation between sensory ways of knowing and meaning making, this model provides a phasing trajectory as a 'conceptual map' that connects the 'sensing' facet of aesthetics (upper half of the model in Figure 1) to the 'making sense' one (lower half of the model in Figure 1).

The model is mainly based on Sinclair (2004)'s definition of three roles of aesthetics in mathematical inquiry (1. the motivational, 2. the evaluative and 3. the generative) and on the interplay between dependency (which we refer to as *sensing*) and autonomy (where sensing plugs into some aspect of mathematical autonomy, and which we call *making sense*). We are therefore using the notion of making sense in an axio-epistemological sense, and not just as a cognitive or psychological process. It is also inspired by the way more recent

studies use these roles in analysing students' aesthetic experiences and practises (Eberle, 2014; Jasien and Horn, 2022). The roles were embedded within the model and further conceptualised as guiding students to transition among (a) phases of using their senses to imagine, construct, manipulate and evaluate digital artefact representing mathematical ideas and (b) phases of making sense of these ideas in order to control and improve their choices (description of arrows in Figure 3). The diagram of the model (Figure 3) illustrates the transition among four distinct phases of aesthetic experience in students' mathematical activity: (1) (re)defining aesthetic Criteria (Cr); (2) Acting on an artefact (A); (3) Evaluating the results (E); and (4) Mathematizing of the findings (M). The aim of CrEAM was to capture the dynamic nature of the continuous, multidimensional aesthetic experience that a student can go through when engaging in an aesthetically rich, constructionist learning environment. Contrary to the model of Gadanidis et al. (2016), aesthetic and mathematical elements in CrEAM are interwoven, rather than dissociated.

The model can be briefly described as follows:

1. Defining aesthetic criteria (Cr): Constantly revisiting and reconsidering aesthetic criteria is a natural human process, that, in this context, depends on the development of personal taste and agenda in arts and mathematics, as well as on cultural influences and emotional states. In contrast to the traditional perspective on mathematical aesthetic, which is connected to the objectivity of mathematical beauty defined by predetermined qualities, mathematical aesthetic criteria in this learning context are mainly subjective, as they are connected to making or appreciating arts. They involve personal filters for the appreciation and evaluation of mathematical beauty either applied within an artistically based, sensory context, or connected to sense making of mathematical ideas. When someone creates an artefact using mathematical notions as tools, these filters are defined either subconsciously or intentionally. Students' aesthetic criteria can be traced through

FIGURE 3
The diagram of the CrEAM model on aesthetically driven mathematical meaning making.
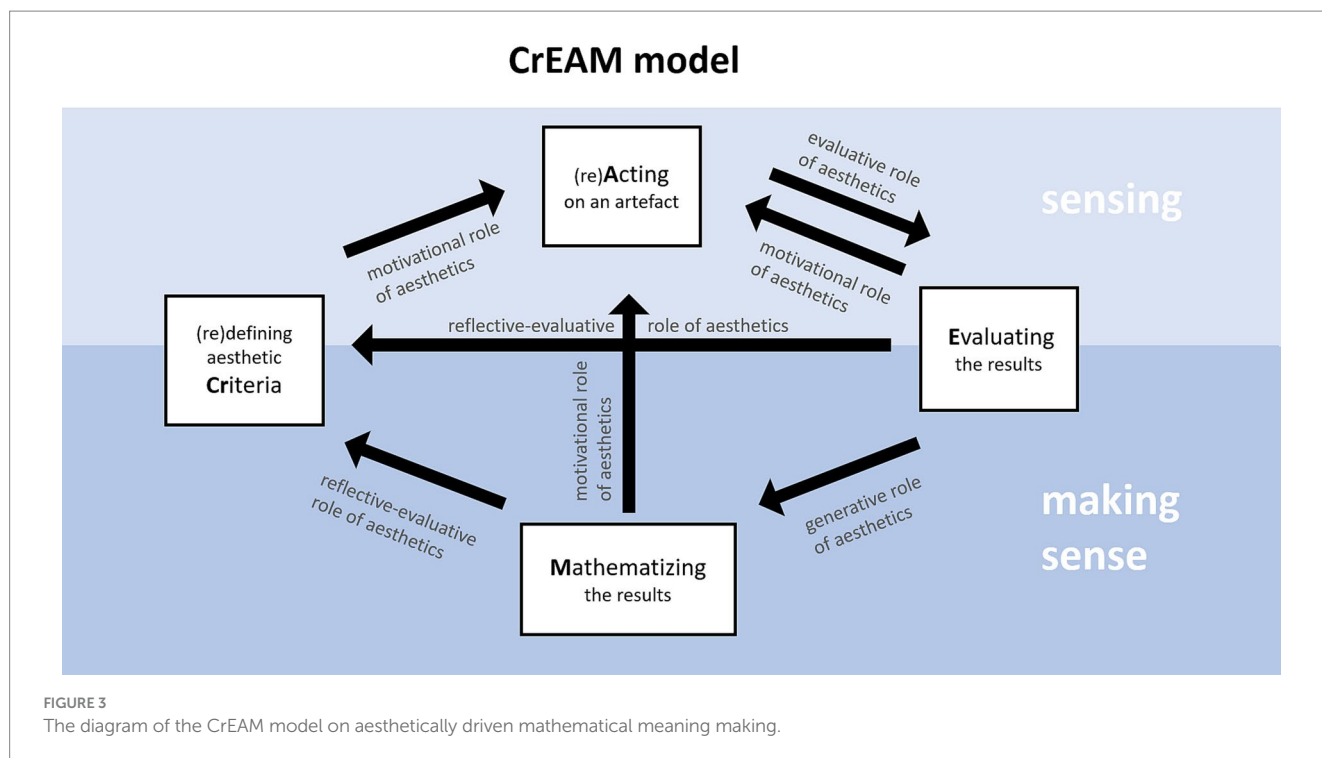
the aesthetic goals that they set and communicate, connected to problem posing or strategy selection, during their mathematical-artistic engagement. Setting up goals, or reconsidering and extending the previous ones, is the starting point of each round of mathematical exploration and can be repeated many times throughout the creative process, depending on its compliance with students' interests. This phase is connected to emotions of interest and desire. Both *sensing* and *making sense* can delineate aesthetic criteria. The aesthetic experience of defining or redefining (in case that circular transition among cases has led to reconsidering or enriching) them motivates students to act (A) in a particular way, either intuitively or reflectively.

2. Acting on an artefact (A): Within a constructionist environment, where the computer works as a 'window to mathematical meaning making' (Noss and Hoyles, 1996), aesthetic choices can be easily detected through students' actions within a digital resource. This type of action connects a mathematical notion to the senses, since students manipulate its representation(s) using their hands, body, eyes, ears, feelings, depending on the representational registers and features of the digital resource. For this reason, (A) lies in the *sensing* facet of the model. During this acting phase, students can experience the aesthetics connected to artistic engagement, by entering a state of intense attention and high vigilance, with a strong focus on the creation of the desired object. When acting is not supported by *sense making*, which means that no phase of mathematising on the mathematical concept in use has been preceded, this phase is defined as 're-acting'. (A) automatically leads to (E) through playing an evaluative role, which is completely connected to the *sensing* facet.

3. Evaluating the results (E): After acting on the digital resource, instant feedback is usually provided automatically. The results

of the computer-generated response on their actions are connected to immediate sensory perception, e.g., visual or acoustic, and consequently lead to aesthetic judgement. This phase of the aesthetic experience involves students using their own so-far-defined aesthetic criteria in order to decide whether the generated result is beautiful, helpful or successful enough. The artistic context guarantees the degradation of objectivity, in the sense that mathematical beauty is situated within this context of application and reflected by student's own sensibilities, e.g., their sense of fit or rhythm. It has an intense affective dimension, positive or negative, depending on elements like the unexpectedness and the desire. It is connected to emotions of amusement, surprise, anger, confusion and disappointment. Based on the progress and depth of their engagement, this phase can lead to any one of the other three: (a) it can instantly motivate the student to re-act (A) within the digital resource, remaining in the *sensing* context; or (b) guide them to reflectively evaluate and reconsider their aesthetic criteria (Cr); or (c) play a generative role and lead to the Mathematising (M) phase for gaining insight on the results. This phase can also lead to events of contradiction, once the sensory feedback is different to the expected outcome.

4. Mathematising the results (M): Even though the cycle of the CrEAM diagram can 'close' without the inclusion of the fourth phase (and thus be seen as CrEA), remaining in the *sensing* context, mathematization is essential for satisfying students' natural aesthetic urge for explaining and *making sense* of the results. This phase is physically driven by feelings of wonder and curiosity [though, crucially, students might bask in wonder for some time, before wanting explanation, which relates back to Nemirovsky's injunction—and see Sinclair and Watson (2001)]. Given that the perceived results originate from abstract mathematical notions expressed within a sensory context, there

is a mediating level that needs to be bridged in order for students to control the core of the artistic outcome according to their criteria. This process can be traced through students giving mathematical names and communicating meaning to the interpretation of the results. Consequently, the mathematization (M) can give rise to ideas toward two different directions: (a) by playing a motivational role for acting (A) with the digital tools by persisting in finding a solution to the initially set goal or (b) by playing a reflective-evaluative role (this time involving the mathematical meanings rather than the perceived outcome) for redefining the aesthetic criteria (Cr) and taste in mathematics and extend or change the initial goal.

3.5 Participants and implementation elements

Two students of the 11th grade from Greece, who will be referred to as S1 (gender: male) and S2 (gender: female) participated in the study. The overall activity lasted for 9 h, divided into 2 days in an out-of-school atypical setting. Even though the activity was designed for 6 hours, it was the students' own choice to spend more time to complete the creation of their artefact. They both had some recent experience in periodic functions at school mathematics, as they had just completed the chapter of trigonometric functions. However, this was not an intentional research choice. They participated voluntarily and characterised themselves as 'being good at mathematics' and 'wanting to try something new'. They had also some previous experience with MaLT2 and GeoGebra from participating in a different study 3 years before the current implementation. For this study, the digital resources and the artistic context along with the group of two students composed a culturally rich community of practise that determined the politics of this learning environment.

4 Matching movement to sound

In this section, we present a part of the results based on the CrEAM model. They are divided into three thematic categories, named after students' own words, while stating their aesthetic criteria emerging from listening to a part of the song. Each category corresponds to different mathematical ideas connected to *sensing* or *making sense* in order to reach the aesthetic goals. Students had already participated in a two-hour introductory activity, where they explored how to use programming and tools in MaLT2 in order to (i) create parametric procedures of different figures (e.g., square, triangle, hexagon); (ii) use the slider of each parameter in a steady way to animate the figure (by constantly pressing the keyboard's right arrow); (iii) use different kind of functions as input values of different logo commands; e.g. '*forward sin(:t)*' or '*square sin(:t) + cos(2*:t)*', which raised a discussion on kinds of movements. The results of this introductory phase will not be presented here. At the beginning of the main activity, students chose a song to make the animation for, after listening to a given list of songs[4].

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4   They ended up choosing the song 'victim' from the album named 'OCCULT' by Macroblank (https://macroblank.bandcamp.com/album/occult).

4.1 Matching the motion to the rhythm

The students started by defining the aesthetic criteria (Cr) for the creation of the first part of dancing animation. The first goal explicitly set up was to create a dancing move that matches the rhythm of the song. After listening to the first part of the song (*00:00–00:23*) three times, they begun to make fluctuating movements with their hands in order to express the motion they had in mind.

S1:	I think it is more like that. (S1 moved his hands periodically approaching and distancing in a slightly different rhythm.) A bit slower so that we match the motion to the rhythm.
Researcher:	Your moving hands looked very much alike. Can you imagine a way to make the animation moving like that?
S2:	We need to use one of the functions that did that.
S1:	Yes, sine! Sine and cosine did this motion, when we put them in a command.

Students expressed their ideas for the desired rhythm and recalled that the trigonometric functions of sine and cosine in MaLT2 can produce a similar motion, thereby making an initial coordination of dependency (hearing a rhythm) and automation (the mathematical description of rhythm). This idea motivated them to act (A) on the coding part of MaLT2. They used the function '*sin(:t)*' as input value of the command '*square*' in the '*dance*' procedure (Figure 4A). They tested the graphic outcome of their code, but disappointingly realised that it was not close to their expectation.

S1:	Oh no, disaster. (Both laughing.) Why does not it move? We put sine, it was supposed to go like this, up and down.
S2:	I think it does that, see? It is not that bad!
S1:	Oh, yes. There is a slightly noticeable motion. Maybe we should change the limits? Change them to 0 and the upper to 500.

The evaluative role of the aesthetics led them experience a contradiction between the expected and the sensory outcome. They were negatively surprised and evaluated the visual result (E). This motivated them to try re-acting to the artefact (A) by expanding the range of values of the slider corresponding to the input variable *t*; from *25–100* to *0–500*. Then in an additional (E) – (A) transition, S2 changed the upper value again from *500* to *1,000*. The result, however, was evaluated with further disappointment and a bit of anger (E). The latter aesthetic experience played a generative role and led them to mathematize the results (M).

S1:	Ok it does not have to do with the input values. It has to do with the function.
S2:	Yes. Sin(t) keeps repeating the same pattern. It does not matter how big it gets; the same tiny animation will be created.
S1:	What should we do? (…) Oh! It makes sense! Sine does not get output values bigger than 1. So this only goes forward 1 and-1 at most.
S2	You are right. (…) We need this number in the front to multiply. Let us make it 100?

FIGURE 4
Acting on matching the motion to the rhythm in MaLT2. **(A)** Part 1: Trying the command *"square sin(:t)"* with *t* values from *0* to *673*. The video shows the constructed animation https://drive.google.com/file/d/1JXgYBM2dezL0HgzSLySuQDMoq33A_4gl/view. **(B)** Part 2: Trying the command *"square 100*sin(:t)"* with *t* values from *0* to *945*. The video shows the constructed animation with this part of the song playing along https://drive.google.com/file/d/18UckJ_OVapy_pJIED7ouHCjFjlTO7XWW/view?usp=sharing.

Students *made sense* of the constructed square being so small, and the animation barely noticeable, by mathematizing the results (M)—the fact that the sine function repeats the same pattern, no matter how the input value changes, speaks to its autonomy, which the students respect, but which does not prevent them from thinking that it can be modified to suit their target rhythm. Here, the initial contradiction was overcome, through interacting with each other and the computer. They recalled the property of limit output values of sine and applied them in this context. They further thought of a different mathematical solution that motivated them to act (A) on the code of the artefact. They changed the function from '*sin(:t)*' to '*100sin(:t)*' and moved the slider of the variable *t* from *0* to *1,000*, while listening to the song (Figure 4B). Then S2 used her aesthetic criteria to evaluate the results (E), while connecting the visual to the acoustic and expressed some displeasure.

S2:	It gets too large! The square must be smaller to match the music, because at first it sounds very calm. We need to make it smaller.
S1:	Hmm. Ok, I see. Should we make the number in front smaller? 50?

Students mathematized the situation in order to better match the motion of the square to the song. S2 redefined the aesthetic criteria (Cr) for its completion by connecting her feeling of calmness to the length of the square. Then they turned to MaLT2 in order to test their new conjecture (A). S2 changed the command '*square 100*sin(:t)*', to '*square 50*sin(:t)*', moved the slider from *0* to *250*, while listening to the song (Figure 5A). S2 silently made an expression of discomfort (E) and immediately reacted on the code by changing the command from '*square 50*sin(:t)*' to '*square 30*sin(:t)*' and retested it by moving the sliders from *0* to *499*. This led them to further mathematise (M) the output values of sine.

S2:	I wanted the square to be even smaller. It's much better now. Do not you think?
S1:	Yes, 30 works fine. The highest value it can be is 30 times 1, so 30. The length is ok, but I still feel it is out of rhythm.
S2:	How do you mean?

S1:	It is too slow. It is completely out of the main rhythm. It goes tan-tan-tan-tantan.
S2:	To me it looks fine. Every time it does this druuun and repeats itself, the square gets the smallest and then it restarts and gets bigger again. I think it is synchronised.
S1:	Ok, I see that but I had something else in mind. To me it's too slow. Do you want to try to make it quicker? Just to see?
S2:	Yes, fine.

S1 convinced S2 to redefine the aesthetic goal (Cr) of the animation, according to his different idea on musical rhythm. He then turned to the GeoGebra file where the parametric function '$f(t) = \alpha \cdot sin(\beta \cdot t)$' was plotted for the values $\alpha = 20$ and $\beta = 1$. He changed the parameter α from *20* to *30* by dragging its corresponding slider and then moved the slider of the parameter β slowly from *1* to *10* and back again, from *10* to *1* (Figure 5B).

S1:	So this number inside may work. It makes the graph thicker, when it gets bigger.
S2:	So we can change the number inside! To affect the density.
S1:	Yes, this may work.
S2:	Let us try *30sin(2t)*?

After S1 acted (A) on the GeoGebra tools to explore the different graphs of parametric function of sine, by manipulating the values of the parameters, they noticed that the parameter β affects its density and intuitively evaluated (E) the usefulness of this result. S1 turned to MaLT2 to re-act (A) on the code of the artefact and changed the command from '*square 30*sin(:t)*' to '*square 30*sin(2*:t)*'. Then they observed the animated result, while moving the slider of the variable *t* from *0* to *708* (Figure 6A). After *sensing* the visual result, S1 evaluated (E) and seemed excited:

S1:	Yes, it is much quicker! This is the way to fix it! But we are not there yet.
S2:	What do you mean?

FIGURE 5
Acting on matching the motion to the rhythm in MaLT2 and GeoGebra. **(A)** Part 3: In MaLT2, trying the command "square 50*sin(:t)" with *t* values from *0* to *250* and then consequently the command "*square 30*sin(:t)*" with *t* values from *0* to *499*. The video shows the constructed animation with this part of the song playing along for each try https://drive.google.com/file/d/16ZhY2KdeeJIRGbVcKtzDfgIWFKBxMWAS/view?usp=sharing. **(B)** Part 4: In GeoGebra, moving the slider of the parameter *β* from *1* to *10* and backwards, from *10* to *1*, when *α* = *30*. In the video, the variations of the plotted graph of the function *a·sin(b·t)*, while the value of the parameter *β* was changing are shown https://drive.google.com/file/d/1eSTRxtQjAu_QGWGucNS5dJCKkPQ-Vvcl/view?usp=sharing.
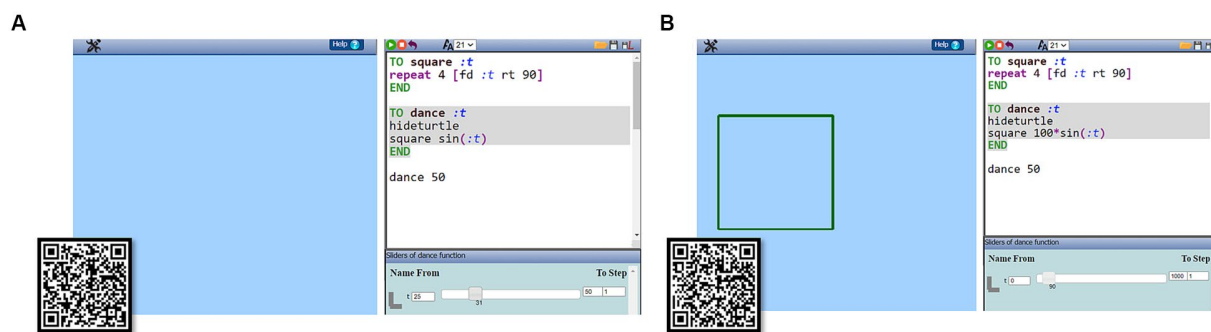

FIGURE 6
Acting on matching the motion to the rhythm in MaLT2. **(A)** Part 5: Trying the command "*square 30*sin(2*:t)*" with *t* values from *0* to *708*. The video shows the constructed animation with this part of the song playing along https://drive.google.com/file/d/1j30bjF9zE7J14_mz-Eea3U7HbzxhNU7z/view?usp=sharing. **(B)** Part 6: Trying the command "*square 30*sin(3*:t)*" with *t* values from *0* to *765*. The video shows the constructed animation with this part of the song playing along https://drive.google.com/file/d/179g8QbviiO_hP-IG8yTuf6XIx0zjDNOx/view?usp=sharing.

S1:	I mean it is not completely matching the rhythm. I think it needs to be a bit quicker. We can increase this number in order to make it quicker, (…) to reduce its period.

S1 mathematised (M) the role of the parameter *β* in the function $α·sin(β·t)$ and consequently used it to find the perfect matching, by going through cycles of acting on the artefact (A) and evaluating the animated result (E) while listening to the song. He changed the command from '*square 30*sin(2*:t)*' to '*square 30*sin(4*:t)*'; then to '*square 30*sin(3*:t)*'; then to '*square 30*sin(5*:t)*'; and finally back to '*square 30*sin(3*:t)*' (Figure 6B).

S1:	I think I found it. This is the perfect match, as I imagined. What do you think?
S2:	Well, it is not completely synchronized as before, in my eyes. But, I think I like it more than sin(x). The more I listen to the song, the more it gives me a weird feeling of mystery and anxiety. I do not know how to say it. And this is why I think it is very suitable for them not to be completely synchronized. Does it make sense?

S2 was inspired to redefine her aesthetic criteria (Cr) after observing and evaluating the animated result along with listening to the song. Her thoughts fueled the beginning of a different CrEAM transitioning, by playing a motivational role for continuing with the construction of their animation.

4.2 Gradually raising the tension

After matching the motion of the animation to the rhythm of the first part of the song, the students continued by setting up the next goal of their creation. The following part of their discussion reveals the definition of their aesthetic criteria on the imagined animation (Cr).

S1:	I agree, it gives a sense of intensity. We could add more shapes to capture it.
S2:	Maybe with different colours, appearing around the centre of the screen.

S1:	Yes, nice. But not at the same time. This is like what we call tension in music, you know? It is a kind of repetition of the same tone that slowly builds up and gives the feeling of anticipation. It keeps you waiting and it gradually raises the tension.
S2:	Yes, I get it. The more it repeats, the more intense it is.
S1:	Exactly, yes. So, we could add them in steps.
S2:	Oh, yes. You hear when it starts repeating. We need to find those points.

The students used their imagination, personal interests, knowledge and sensitivities to set another specific goal for their animated artefact. S1 brought into the discussion the term 'tension' from his music background, visualised and expressed one way to capture it. S2 acknowledged S1's thought and extended it, by specifying one thing that they had to focus on: "to find those points." This was clarified further through her acting in MaLT2 (A). She moved the slider of the variable *t* and set its value to *0*, played the song along and slowly moved the slider to the right, while moving her other hand rhythmically. She stopped moving the slider by raising her finger from the keyboard right after the end of the first rhythmical unit of the song, when the value of *t* was *184* (Figure 7A).

S2:	This is the point I mean. From *0* to *184* is the space that matches this first rhythm: toun, toun, toun, toun-toun; that repeats itself four times. When this part of the song restarts, this is when the other square must appear. Note down 184. Do not miss it!

S2 gave the meaning of moment in time to the previously mentioned concept of 'point' and corresponded it to a specific value of the variable *t* (=*184*) from the slider. Thus, based on the song and the motion of the slider, she evaluated (E) that this was an important value for better matching the appearance of the second square. She further *made sense* of it mathematically (M) as being an important unit of values, approaching the concept of period. S1, however, had a slightly different opinion during his evaluation (E), as he noticed a time difference between the end of the song unit and the moment S2 stopped moving the slider. Then he re-acted (A) in MaLT2 by moving the slider of *t* slightly to the left, from *184* to *180*.

S1:	I think it was a bit earlier. Maybe 180 instead? (…) Yes, this is great how it stops! Look! At *t* = 180, the square disappears, since sin(180) = 0? Right?
S2:	Yes, sin(180) is zero, this is why it disappears. Its sides are equal to 0.
S1:	Ok, so, think about it. When it starts growing again after this point, another square will simultaneously appear and grow at the same rhythm. Isn't it cool?
S2:	Yes, I like it.
S1:	And for the next square; it can also appear when the others start re-appearing. So we need a value of *t* that zeros the sine. And we have got a lot of them!

S1 evaluated (E) the slider's value of *180* as visually being more suitable for adding the second square. Then he mathematised (M) the result in order to *make sense* of that specific number as input value of the sine function corresponding to zero output value. This generative role of aesthetics led them to further mathematise the multiple

possible values of *t* that would zero the sine function, based on its periodic nature. As they slightly redefined the aesthetic criteria (Cr) of their desired creation based on the 'important' value for the appearance of the second square, S1 turned to MaLT2 and acted (A) on the code. After three acting (A), evaluating (E) and re-acting (A) cycles, accompanied by some technical support given by the researcher, they ended up to the final code. They used the command '*if: t > 180*' before adding the second animated square '*square 30*sin(3*,t)*' at the point (10, 10, 0) of the 3D cartesian space '*penup setpos [10 10 0] pendown*' (Figure 7B) and tested the animated result through moving the slider.

S1:	Wow! It's great!
S2:	Yes, indeed, well done! 180 was a great idea!
S1:	And I think the third one can appear at 360, right? That was the correct point.
S2:	Try it again, come on.

S1 was motivated by S2 to re-act (A) on the animation by repeating moving the slider from *0* to *381* and back to *360*, while listening to the song.

S1:	Yes, I think 360 is when the third repetition of the song begins. It is perfect because it is also a value that zeros sine.
S2:	Yes, 180 and 360. It makes sense. And every other 180. Try 360 plus 180 just to see.

S1 moved the slider to *540* (A) and evaluated (E) S2's conjecture as being correct. They mathematised (M) the periodicity of sine and used it in the code (A) in order to select the right values for the third and the fourth square of the animation. While making the code for the third square to appear, by adding the commands '*if: t > 360 [penup setpos[10–10 0] pendown blue square 30*sin(3*:t)]*', S2 further mathematised (M) the period of sine for adding the fourth square without having to test it empirically:

S2:	Before testing it, why do not we add the fourth, too? Since there are four clear repetitions of this part of the song. And they are the same, you know? So the same interval, which means plus 180. The fourth square should appear at *t* = 540.
S1:	Yes, we want all the multiples of 180. Something happens at every multiple.

This generative role of the aesthetics guided them to *make sense* of the relationship between sine input and output values. This motivated them to further act (A) on the code for also including the animation of the fourth square appearing at the right moment-value of *t*. S1 wrote: '*if: t > 540 [penup setpos[−10 10 0] pendown green square 30*sin(3*:t)]*' and then tried the animated result (Figure 7C).

S2:	This is the perfect timing!
S1:	Yes, I agree. It's so good! It gives this sense of tension that we were talking before.

FIGURE 7
Acting on gradually raising the tension in MaLT2. **(A)** Part 1: Connecting the period of the song to the period of the animation by moving the slider. The video shows the animation along with the corresponding part of the song during their first period, until the point ($t = 180$) when they decided for the second figure to appear https://drive.google.com/file/d/1XuJrSqYp0mwtR5AyFhUbDS9UGdDgWLZ9/view?usp=sharing. **(B)** Part 2: Looking for the right value of t that corresponds to the beginning of the third period. The video shows the animation generated by the new code, along with the corresponding part of the song during their two first periods, until the point ($t = 360$) when they decided to make the third figure appear https://drive.google.com/file/d/1knTCKe-lMRu9wCsrc8-6LqMC6zeqcpNX/view?usp=sharing. **(C)** Part 3: After setting 180 as the value of the period of the animation, testing the code including 'if: t > …' commands for all three squares to appear at the end of each period. The video shows the animation along with the corresponding part of the song during the first four periods ($t = 720$) https://drive.google.com/file/d/13fMnYO3AgOArjmu-fwtkYd0U6KX62EzE/view?usp=sharing.

S2:	Yes, it slowly adds some tensity! We made it!

The students were excited from the evaluation (E) of the animated outcome of their code and the reflection that they achieved their initial aesthetic goal. They used their mathematised meanings on the period of sine throughout their whole engagement in acting (A) on the artefact, for easily controlling the time of adding something new, since, according to S1 'Something happens at every multiple'. At some point, they revisited their meanings on periodicity, when they changed the starting point of the animation to be at $t = 60$, rather than $t = 0$. This issue guided them to another set of CrEAM transitioning cycles,[5] where they mathematised that the period of the function $30 \cdot sin(3 \cdot t)$ is 60, since every 60 t-values the square animation 'repeats itself'.

4.3 Capturing the anxiety

Another example of multiple CrEAM transitioning cycles was initiated by the students' aesthetic response on a subsequent part of the song ($00{:}48–01{:}31$). They listened to this part for four times and discussed the emerging emotions and ideas:

S2:	At this point ($00{:}48$) it becomes calm again. And then slowly grows some tension.
S1:	Yes, but the sound is much richer than before.
R:	How does this make you feel?
S1:	I think, in some way, it gives me the feeling of stress. It has a growing tension, even more than before.
R:	What about you?
S2:	Yes, I agree. The more the time passes, the more anxiety I feel. (…) The rhythm is not so clear. Maybe this is why we get this sense. I'm just thinking out loud.
R:	How do you imagine the animation?
S1:	The motion can also be like this, a bit unstructured. I imagine something like this. (S1 made a messy movement with his hands.)
S2:	(Laughing) Ok we could do that by using the fuzzy functions. From GeoGebra.

This discussion marked the definition of aesthetic criteria (Cr) for making an animation that would express their feeling of anxiety. They connected this feeling with a messy movement and with the 'fuzzy

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5 These cycles of CrEAM on expanding meanings on periodicity will not be described in this paper, because of length limitations.

functions', as S2 referred to the sum of trigonometric functions – approximations of Fourier series, which were plotted in GeoGebra. These elements composed the initial aesthetic goal, which was later expanded by connecting four sub-parts of this song to 'different levels of anxiety'. These aesthetic criteria motivated them to start a cycle of acting (A) within the digital resources (MaLT2 and GeoGebra), evaluating (E) the visual and dynamic outcomes and mathematising (M) them to *make sense* of the unexpected connections between representations and finally achieve their goal. Because of the long timespan of this CrEAM transitioning process, only a small part is presented in this section.

Once the goal was set, the students initially acted (A) in MaLT2 through trying different combinations of sums of trigonometric functions as input to the 'square' procedure, to create the 'first level of anxiety'. For example, they successively tried the commands '*square 10*sin(:t) + 20*sin(2*:t) + 30*sin(3*:t)*', '*square 10*cos(:t) + 20*cos (2*:t) + 30*cos(3*:t)*' and '*square 30*sin(:t) + 20*cos(2*:t) + 40*sin(4*:t) + 20*cos(4*,t)*'. This acting (A) – evaluating (E) – reacting (A) cycle was not followed by any clear expression of mathematisation (M). However, S1 made a general evaluation of the perceived situation, that was the turning point of the rest of their engagement:

S1:	I'm confused. I do not get how these functions work. I like the complex movement but it's not what I had in mind. It was nice by accident.
S2:	Would it help if we could first see their graph?

S1 turned to GeoGebra and changed the parameters a_i and bi ($i = 1,2,3,4$) of the function $a_1 sin(t) + b_1 cos(t) + a_2 sin(2t) + b_2 cos(2t) + a_3 sin(3t) + b_3 cos(3t) + a_4 sin(4t) + b_4 cos(4t)$ (A). While the first combinations seemed to be chosen randomly, at some point S1 zeroed all the b_i parameters and plotted the following four functions: $23 sin(t) + 12 sin(2t) + 15 sin(3t) + 17 sin(4t)$,
$23 sin(t) + 13 sin(2t) + 15 sin(3t)$, $30 sin(t) + 21 sin(2t) + 25 sin(3t)$ and finally $30 sin(t) + 21 sin(2t) + 25 sin(3t) + 29 sin(4t)$. He evaluated the visual result of the graphs and mathematised (M) some graphical properties of the sine of sum.

S1:	I like this graph a lot. It is very symmetrical and complex at the same time. As much as it goes up, the same goes down. And did you get it? As many parameters as it has, it is the same amount of ups and downs. Here we have all four a-s, it has four peaks within each period. And each peak is lower than the previous one.
S2:	Yes, looks nice. I wonder how it will look on the animation.

The students evaluated (E) the look of the graph in terms of symmetry and complexity. S1 mathematised (M) the relation between different combinations of trigonometric sums and symmetry of the graph. He noticed that the sums of sines (functions of the form $a_1 sin(t) + a_2 sin(2t) + a_3 sin(3t) + a_4 sin(4t)$) are symmetric with respect to the *x*-axis. S2 was motivated to try this function on the animation in MaLT2 (A) and expressed interest in animating it. Thus, S2 changed the already written command to '*square 30*sin(:t) + 21*sin(2*:t) + 25*sin(3*:t) + 29*sin(4*:t)*' and tested the animated outcome (Figure 8A).

S2:	Wow, it is almost perfect.
S1:	I just think that it could be a bit smoother.

After his evaluation of the animation, S1 went to GeoGebra and changed (A) the parameter α_4 from *29* to *0* and then to *15*. He silently evaluated (E) the form of the graph with an expression of satisfaction and immediately tested the function in MaLT2, by changing the same parameter. He also changed the figure from a square to a hexagon, because, as he later mentioned, 'the hexagon matches better because it is more complicated and mysterious than the square'. His evaluation on the final animation (E) inspired them to redefine their aesthetic criteria and goals (Cr):

S1:	Ok, here's an idea. When the sum only consists of sines, it is a bit more symmetrical. Right? Compared to the sum of all kinds of sines and cosines. So, I'm thinking, how about starting with this black hexagon that matches the calmer tone? Just that because the motion is really beautiful. And then, as the anxiety raises, make a more asymmetrical and quicker one?
S2:	It sounds nice. So we must find a timing where the tone gets more intense.
S1:	And find a different, asymmetrical combination. Great, I think it will be awesome.

S2 went through two cycles of acting on the artefact (A) while listening to the song, evaluating (E) and re-acting (A) in order to find the right timing for the second animated figure to appear. She wrote down the value *2,220*.
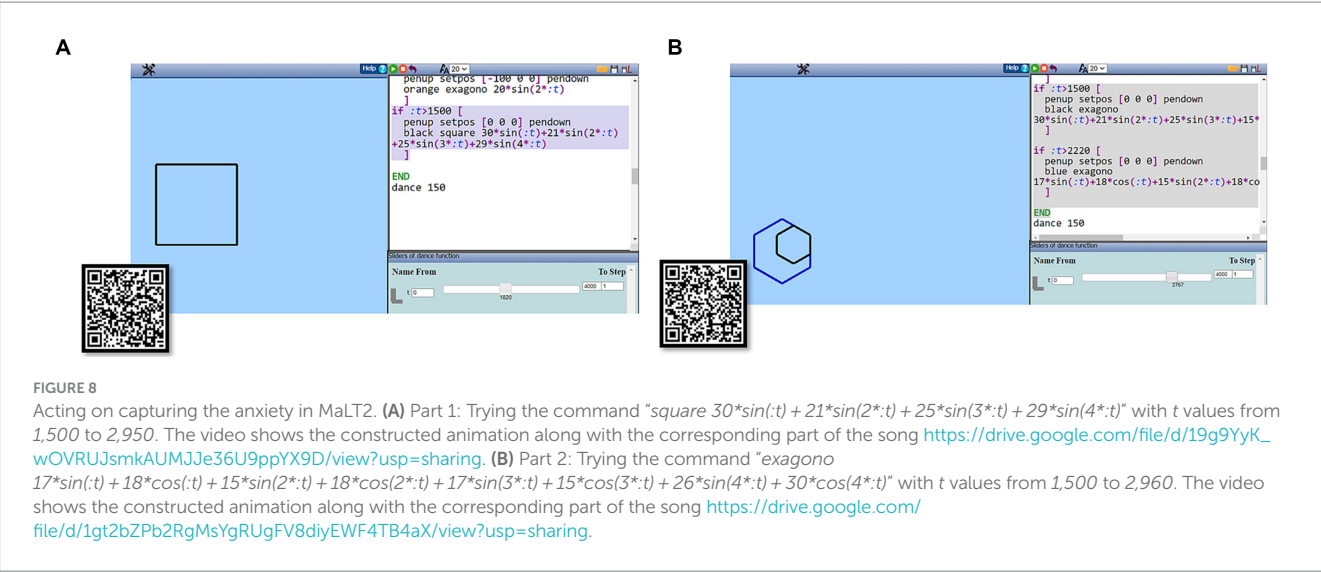
S2:	This is the exact moment when the higher tone enters I think. At $t = 2,220$. See the position that the black hexagon freezes at 2220. Wouldn't it be cool if another hexagon would appear at exactly the same spot, but facing the other way?

S1 relistened to the song and made some sketches of a graph using paper and pencil. After three sketches that he immediately tore up, he elaborately made the sketch shown in Figure 9A. He then set the goal to find a formula that would resemble his sketched graph.

S1:	This is how I imagine it. It starts really high and goes down abruptly, many times. But not the same distance up and down as before. This kind of asymmetry I meant.
S2:	Can make a graph like this here?
S1:	Yes, I think. But we need to add all the parameters, not just a-s or b-s.

S1 used the mathematised meaning from his previous sense making (M) and proposed a specific way for acting in GeoGebra. S2 started acting (A) on the new goal, according to S1's guidelines. After a sequence of evaluating (E) and re-acting (A), they ended up with the graph in Figure 9B, which they evaluated (E) by agreeing that 'it seems crazy'.

They turned to MaLT2 and added the part of the code: '*if: t > 2,220 [penup setpos [0 0 0] pendown blue exagono 17*sin(:t) + 18*cos(:t) + 15*sin(2*:t) + 18*cos(2*:t) + 17*sin(3*:t) + 15*cos(3*:t) + 26*sin(4*:t) + 30*cos(4*:t)]*'. They tested the result by moving the slider of the variable *t* from *1,500* to *3,000* (Figure 8B). They were thrilled by the animated

FIGURE 8
Acting on capturing the anxiety in MaLT2. **(A)** Part 1: Trying the command *"square 30*sin(:t) + 21*sin(2*:t) + 25*sin(3*:t) + 29*sin(4*:t)"* with *t* values from *1,500* to *2,950*. The video shows the constructed animation along with the corresponding part of the song https://drive.google.com/file/d/19g9YyK_wOVRUJsmkAUMJJe36U9ppYX9D/view?usp=sharing. **(B)** Part 2: Trying the command *"exagono 17*sin(:t) + 18*cos(:t) + 15*sin(2*:t) + 18*cos(2*:t) + 17*sin(3*:t) + 15*cos(3*:t) + 26*sin(4*:t) + 30*cos(4*:t)"* with *t* values from *1,500* to *2,960*. The video shows the constructed animation along with the corresponding part of the song https://drive.google.com/file/d/1gt2bZPb2RgMsYgRUgFV8diyEWF4TB4aX/view?usp=sharing.

FIGURE 9
Acting on capturing the anxiety in paper-and-pencil and GeoGebra. **(A)** S1's sketch of a periodic function while listening to the corresponding part of the song. **(B)** The final graph in GeoGebra that satisfied them as resembling to the sketched graph.

result; aesthetics played both an evaluated and a generative role for making sense of the outcome.

S1:	This is better than I expected. The moment the blue hexagon pops up, it becomes more chaotic and captures this sense of anxiety. Like the one is chasing the other!
S2:	This is so good, I want to replay it! (…) You know what I do not get though? How great it is that at *t* = 2,220, they are facing at opposite sides. How did this happen? Since in GeoGebra, it would start from being at the highest point.
S1:	(Opened the tab in GeoGebra.) Yes, you are right. Oh, but the input value is 2,220, not 0. (…) So, we need to find where 2,220 is here (shows x-axis). It is not normal numbers, it is in pi-s. We need to convert it.
S2:	Oh, right! So it will be below zero at that point.

To *make sense* of this graphical-dynamic incompatibility, the students mathematised the result (starting point of the second hexagon when *t* = 2,220) by making sense of the graph and its *x*-axis

units. These cycles of CrEAM transitioning on 'capturing the anxiety' for this part of the song were completed after some further redefinition of aesthetic criteria and goals, that led to their final creation. During these last cycles, the aesthetic played strong motivational, evaluative and generative roles, connected to deeper mathematisation.

5 Discussion

This study, even though limited in scale, allowed us to look deeply into the way aesthetic experiences guided both the content and the process of these two students' mathematical meaning making around periodic functions. The CrEAM model provided a comprehensive way to describe the students' aesthetically driven mathematical meaning making within this example of *Mathematics as Artistic*, aesthetically rich, constructionist learning environment. Their learning was captured through their continuous transitions between (a) *sensing* mathematical concepts, for example through viewing the dynamic motion generated by a specific periodic function and making its

connection to the audio-rhythmical and affective part of the song; and (b) *making sense* of these mathematical concepts in order to explain an unexpected outcome, or control and improve the creation of the animated artefact, according to their aesthetic criteria. We note that in this process, the juxtaposing of dependence and autonomy did not pose problems for the students.

Based on our analysis, the students tended to follow cyclic paths, (1) starting from clarifying their aesthetic criteria (Cr), through which specific aesthetic goals were set up, that motivated them to (2) then acting on the digital resources (A) to achieve those goals; (3) evaluate (E) the aesthetic result by using their senses; and (4) mathematise (M) that is making sense of the mathematical content in use. The latter phase was vital for satisfying their need to explain the unexpected, as well as to reach their goals. In the beginning of each thematic set of CrEAM transitions, presented as separate subsections in the previous section, the students tended to transition among phases of the *sensing* context. They acted based on aesthetic criteria that were mainly governed by aesthetic values closer to their senses and artistic sensibilities, such as the synchronisation to the musical rhythm, the tension raising and the feeling of anxiety, then they evaluated the results based on the sensory feedback gained from the digital resources and finally re-acted without mathematising, making a smaller cyclic path of CrEA. However, while continuing to engage in the activity, they went through more and more phases of mathematising. Each phase of mathematising played a reflective-evaluative role in reconsidering their aesthetic criteria from a mathematical perspective. Thus, their aesthetic values started having a clearer formal mathematical flavour, for example by preferring specific type of functions over others, based on their properties around period and symmetry. In this context, aesthetic judgement and appreciation of mathematical beauty was a subjective matter, depending on the way the students *sensed* different situations (i.e., parts of the song) and their own views and sensibilities.

Another interesting point emerging from the results was the intervention-less way that students engaged in the activity and continuously went through all phases of the CrEAM model. The role of the researcher was limited to helping the students with technical issues emerging in MaLT2. Of course, these students might not be typical one, since both were very talkative, were friends outside the classroom and 'really good in mathematics', as they stated themselves. However, it is safe to say that this learning environment, combining the specific design aspects, can cultivate long-lasting, agential, collaborative and highly communicative mathematical engagement. We do wonder whether the fact of being outside the classroom enabled the students to coordinate so smoothly dependence and autonomy—after all, the mathematics classroom is often a space in which sensory experiences are less welcome or even disconnected from mathematical concepts. This speaks to the particular distribution of the sensible, to use Rancière's term, that dominates mathematical classrooms and that makes it difficult to students to engage the mathematical aesthetic.

Regarding the mathematical content that students focused on for their meaning making; even though some main mathematical concepts were embedded through the given digital representations and task design, students were free to use them in any possible way. These two students mathematised properties around the notions of variable and function and periodicity and symmetry of periodic functions of sine and approximations of Fourier series. These latter notions are marginalised in the current mathematics curriculum structure, with many properties that students used and *made sense* of being completely absent from the curriculum (in Greece). However, they composed a mathematical field fertile for aesthetically driven mathematical learning. Providing multiple representations of the same concept, such as the symbolic, the graphical (both in two dimensions on the Cartesian graph of GeoGebra and in one dimension in MaLT2) and their dynamic manipulation, was also definitive for fostering connections and sense making. This was evident, since students' transitions between different representations, especially while trying to 'Capture the anxiety', were connected to deeper mathematisation.

Another aspect of this learning environment that comes in conflict with the current curriculum status is the level of *a priori* control of students' learning outcomes. In this study, the politics of the learning environment were free to be determined by the small community of practise. The two students' mathematisation was driven by their joint, interpersonal aesthetic criteria and sensibilities and the way they interacted with the computer. If the same task were to be given to two different students, it is most likely that they would not go through the same path of transitions among CrEAM phases. They would probably end up mathematising different properties and facets of the concepts in use. This could be either considered as a limitation of this approach, or as an opportunity to open the conceptual borders of the curriculum and shift focus from content to the learning process.

All three design aspects of the learning environment played an important role in boosting students' movement through different CrEAM phases. On the one hand, *Mathematics as Artistic* provided a context that was close to students' senses, personal interests and general aesthetic sensibilities in art and life, integrating the elements of subjectivity and freedom of expression into mathematical engagement. On the other hand, the combination of aesthetically rich and constructionist learning environment, provided opportunities for (a) sensing and connecting different representations of mathematical concepts; (b) experiencing all types of mathematical pleasure; and (c) strengthening the need for deep mathematisation of concepts for the construction of the artefact. It supported a continuous mathematical involvement based on trial and error within the digital resources, that even though sometimes was quite time consuming, it was valuable for giving students the feeling of ownership and pride for their mathematical meaning making. In our view, this learning approach was an example where 'slowing mathematics down' is pedagogically meaningful. Our next step is to adjust the next cycle of the design to be applicable to a whole mathematics classroom. The CrEAM model will be revisited and potentially expanded with the new set of data originating from the classroom implementation.

We consider this small-scale design-based research as a starting point for opening a wider research discussion on aesthetically rich educational reform for higher school levels, where mathematics formalism is more dominant and mathematics teachers more resilient to change. Educational design in this context would be radical, in terms of curriculum content, structure and teaching practises. Such educational transformation needs to be founded on pedagogical, theoretical and epistemological perspectives, as well as considerations on the affordances and limitations of aesthetically rich learning environments. All these elements need to be studied in depth, before considering their implementation in school classroom. However, we recognise that providing the kinds of

learning opportunities we describe in this chapter will involve changing the current aesthetic of school mathematics, one that downplays the senses, that privileges certain forms of sense-making, and that separates concepts from contexts of use. It is in this manner that the aesthetic functions political in school mathematics by determining what is valued—and as a result, who benefits from inclusion into the system of values. We thus see our work not only as aiming to make mathematics more palatable or enjoyable, but to disrupt some 'common sense' beliefs about what counts as mathematics and why we are teaching it.

Data availability statement

The datasets presented in this article are not readily available because the restriction is imposed by the ethics board. Requests to access the datasets should be directed to karavak@eds.uoa.gr.

Ethics statement

The studies involving humans were approved by Research ethics board of the National and Kapodistrian University of Athens. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

MK: Conceptualization, Investigation, Software, Writing – original draft. CK: Conceptualization, Investigation, Software, Supervision, Writing – original draft, Writing – review & editing. NS: Conceptualization, Writing – review & editing.

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Science education in the Anthropocene: the aesthetics of climate change education in an epoch of uncertainty

Joseph Paul Ferguson* and Peta J. White

School of Education, Deakin University, Melbourne, VIC, Australia

We have a responsibility as science educators to work with young people to enact education that enables collective rebalancing of relationships between humans and more-than-humans that are disturbed by human-induced climate change. However, to date, climate change education has not been prioritized in school science at a policy, curricula, classroom and community level, due to an aesthetic which does not sufficiently value climate science or recognize the social impacts of science as part of the discipline. We argue in this conceptual research paper from a pragmatist perspective that an aesthetic shift is required to include science as part of climate change education as a transdisciplinary endeavor that focuses on addressing socio-ecological challenges through student agency and community action. We explore the synergy between science education aesthetics and climate change aesthetics as we advocate for a transformative *aesthetics of climate change education*. We do so through a process of reflection on and conceptualization of our stories of climate change education in Australia. We propose that such an aesthetic (how we ought to value) should not be considered in isolation but rather that it forms the basis for the ethics (how we ought to conduct ourselves) and logic (how we ought to think) of young people being with us in a *community of inquiry in the Anthropocene*. We argue that we (teachers and students) ought to conduct ourselves in loving ways toward human and more-than-human kin that necessitates that we think as a community of inquiry to address the challenges of the Anthropocene. In doing so we suggest that we can realize a radical pragmatist meliorism for climate change education that is underpinned by the three normative sciences, the most foundational of which is aesthetics.

KEYWORDS

climate change education, science education, anthropocene, aesthetics, school strike for climate

Educational hope in an epoch of uncertainty – reimagining science education

We are all currently living in the Anthropocene (Lewis and Maslin, 2015), a geological epoch characterized by catastrophic human-induced climate change. Humans as well as more-than-human kin are on a path toward annihilation (IPCC, 2021). Human-induced climate change impacts marginalized communities with the least power and who have done the least to contribute to the current crises, such as young people with whom we enact education in both formal and informal contexts. Greta Thunberg famously exclaimed on January 25, 2019 at the

World Economic Forum in Davos, Switzerland, "Our house is on fire. I am here to say, our house is on fire." While the situation is seemingly little different almost five years later, there is an increasingly bright glimmer of educational hope that has grown from this activism of Thunberg and the Youth for Sustainability/School Strike 4 Climate allies. As Ross (2020, p. 474) points out, the climate crisis is "firstly and above all a matter of the future of education," with Toscano and Quay (2022, p. 1) making clear that at present "an ecological crisis coincides with an educational crisis." The discipline of science, and by extension science education, is Janus-faced in this regard as it has instigated and exacerbated climate breakdown but may also play important roles in technological solutions, mitigations and adaptations, therefore providing more hopeful futures.

In a recent special issue of the *Australian Journal of Environmental Education* on the School Strike 4 Climate movement (Volume 38, Issue 1), we co-wrote a paper (White et al., 2022) with two school-aged members of *School Strike 4 Climate Australia*: Niamh O'Connor Smith and Harriet O'Shea Carre. We argue that humanity needs to "dare to think differently about education" (White et al., 2022, p. 27), as necessitated by young people's initiation and continual enactment of striking from school as political climate action. We suggest this education/activism is an iterative and emergent process of "empowering young people through education to develop the skills and knowledge necessary for them to take action on matters of importance as we negotiate uncertain futures" (White et al., 2022, p. 37). In this regard, science education has a particular role to play as discipline-specific knowledges and practices that "enables them [young people] to take necessary action to generate change" (White et al., 2022, p. 36). Many young people value knowing and enacting climate science as part of their climate activism; science education ought to be about providing young people with the support and opportunities to realize what matters to them and to act accordingly so that science changes their lives and the lives of their communities in meaningful ways. All of which is a matter of aesthetics, and all of which is thus not possible without a carefully framed understanding and enactment of the aesthetics of science education (Wickman, 2006).

However, as we suggest in White and Ferguson (2021), realizing this education with young people requires us to critique and reimagine fundamental aspects of what education ought to be, which is difficult and risky work. We take up this challenge with this conceptual research paper forming part of our radical reimagining for the future of science education. We reflect on and conceptualize in new ways our stories of climate change education in Australia to realize a transformative aesthetics of climate change education.

Esthetics of science education

The intertwining of science education and young people's climate activism is a matter of aesthetics, both *aesthetics of science education* and *aesthetics of climate change*. The history of philosophy and education is rich with a diverse range of accounts of what is meant by aesthetics. In this paper, we limit ourselves to one such account, albeit a highly respected and much-used account in science education (Wickman, 2006), which is Dewey's pragmatist perspective (Dewey, 1934/1987). However, we also innovatively draw on Peirce's pragmatist semiotic account of aesthetics (Peirce, 1894/1998, 1907/1998), in its relations with ethics and logic (Peirce, 1903/1998), to enrich Dewey's

ideas as we strive to realize a new *aesthetics of climate change education*. In doing so, we continue to follow Sinclair (2006, 2007) in our endeavor to explore the productive synergies between Dewey's and Peirce's accounts of aesthetics (Ferguson et al., 2022; Prain et al., 2022), and what this might mean for teaching and learning science through/as inquiry (Wickman et al., 2022). We also, when needed, make use of Bourdieu's (1984) notion of taste to make clearer the social nature of aesthetics in education, in particular for the discipline of science (Lima Junior et al., 2022).

A socio-semiotic pragmatist account of aesthetics

Dewey's (1934/1987) account of aesthetics focuses on the way by which we make meaning of the world is determined by what we value as reflected in our judgments of objects and our associated feelings. We judge objects – that is the constituents of reality – as valuable (or not) in terms of whether (or the degree to which) they serve the immediate purpose as part of consummating experience. These judgments manifest not only cognitively but also emotionally as we experience either positive or negative feelings, which is dependent on whether (or not) the object is judged as moving meaning making closer to (positive, e.g., joy) or further away (negative, e.g., disgust) from the consummation of experience. As such, for Dewey, all feelings, and not just positive feelings, are potentially aesthetic in nature as paired with associated cognitions. Dewey also highlights the way in which meaning making through/as aesthetic judgments and associated feelings is always continuous in the sense that what is experienced in one sphere (e.g., school science) is intimately linked with the experiences in other spheres (e.g., home environment) as different objects are brought into alignment as we strive to know the world. This pragmatist account of aesthetics, not just Dewey but also Peirce whom we'll hear more about later, also dictates that we develop particular sets of judgments and feelings that we are predisposed to enact in particular situations, such that we can talk of aesthetic habits (i.e., habits of aesthetics). Such habits are not routines that we execute in a robotic manner, but rather are beliefs as actions that we are aware of and which we can alter to change our meaning making practices. Bourdieu (1984) framed these habits of judging and feeling as taste, and argued that they are significantly shaped by our social and cultural milieus. As such, we certainly do not have complete control over our aesthetic habits because context – in the past, present, and future - always plays a key role, and often we are powerless as individuals to remove ourselves from certain contexts and/or immerse ourselves in other contexts. However, this is not to say that we cannot develop different or particular tastes, but to do so requires awareness, discipline and control in regard to what we think and feel. Aesthetic judgments and feelings are always dependent on context.

If we accept Dewey's aesthetic perspective then there are certain objects, in relation to any particular purpose, that we ought to positively value as contributing to the consummation of experience and which should be included in the meaning making process. In contrast, there must also be certain objects that we ought to negatively value and so should exclude from the meaning making process as they do not contribute to the consummation of experience. As such, to advance meaning making in any particular sphere then we need to value specific objects in particular ways, and so we should feel and

think in certain ways. Therefore, aesthetics is normative in nature, as we will explore later through a Peircean lens, such that we ought to develop particular aesthetic habits/tastes to successfully undertake meaning making in different contexts, as we strive to consummate experience across different spheres.

Peirce (1894/1998, 1903/1998, 1907/1998) introduces a semiotic element to framing aesthetics that highlights the epistemic nature of cognitions and feelings. We call this "an emotionally-infused semiotic" or "a semiotically-infused aesthetic" (Ferguson et al., 2022, p. 771). In doing so, we follow the lead of Lemke (2015, p. 602) in considering that "feeling and meaning are coeval, coevolved, functionally complementary, co-determined, and co-determinative" in their development of/as systems of signs. Peirce proposes that meaning plays out through the triadic relationship between *object*, *representamen* and *interpretant* (all three combine to form the sign), with not only cognitions but also feelings manifesting in sign form. Such a Peircean account of semiotics is epistemologically and ontologically different in significant ways from representationism/representationalism (Lycan, 2023) according to which signs merely represent things in the world.

In coming to understand an object as part of consummating experience in our endeavors to realize a particular purpose to resolve a current situation, we engage with/generate cognitions and feelings as signs. These representamens stand for these objects as we experience the effect of the object-representamen connection as interpretants that themselves function as representamens/objects/interpretants in the ongoing linking of meaning-making triads known as semiosis. Therefore, developing particular aesthetic habits as specific tastes is a matter of sign making and transducing across/between different sign forms (e.g., cognitive and affective). It's critical to emphasize here that to consider feelings as signs is not to reduce feelings to cognitions, and to also highlight that feelings are at least partly manifested in corporeal and materials forms (so we could talk of embodied-material-semiotics). We thus reiterate that "conceptualizing feelings as interpretable meaning-filled signs" (Prain et al., 2022, p. 739) is of methodological as well metaphysical significance as it empowers us to explore aesthetics as a semiotic, as well as pragmatist and social, process.

Science disciplinary aesthetics

So, what does this socio-semiotic pragmatist approach to aesthetics mean in the realm of education? Östman and Wickman (2014, p. 378) argue that teaching and learning is "not about the transformation of an individual's cognitive structure" but rather "the transformation of observable habits in action." And, as we have just explored, these habits necessarily include particular judgments and feelings as key to meaning making, so that education is about the development of aesthetic habits; or as Lima Junior et al. (2022) propose, teaching and learning is a matter of developing particular tastes. The role of teachers is to foster the development of such habits/tastes in students, while they themselves need to develop particular habits/tastes to make this happen for their students.

Wickman (2006) argues that students' and teachers' experiences of science are aesthetic in nature and in ways that are specific to the discipline, such that we can talk of "a science of disciplinary aesthetics" (Wickman et al., 2022, p. 727). Wickman (2006) expands on this

position to propose that this aesthetic manifests in two distinct, but related, forms; disciplinary and experiential. Disciplinary aesthetics can be understood as "appreciating the beauty of the objects of scientific study, as well as the elegance of scientific methods and accounts of these objects" (Hannigan et al., 2022, p. 798). As such, science is defined by "a taste for particular topics, inquiry approaches, and ways of thinking in this discipline" (Hannigan et al., 2022, p. 798). Experiential aesthetics involves "participants' feelings in engaging with the purposes, objects, instruments and inquiry strategies of a subject" (Hannigan et al., 2022, p. 798). The latter is considered to enable the former; "what students feel in doing science leads to their general taste (or not) for this subject" (Hannigan et al., 2022, p. 798). Disciplinary aesthetics for the learner and teacher thus consists of both personal feelings and meanings as well as disciplinary feelings and meanings.

Students' induction into the practices of science therefore involves an alignment between the aesthetics of science as a discipline and the aesthetics of students' encounters with the world, which includes science (Anderhag et al., 2015a,b). The role of the teacher is to provide opportunities for students to develop a set of habitual judgments that value the various objects of science to enable understanding of natural phenomena as manifested in the objects of reality (Anderhag et al., 2015c, 2016). As we argued earlier, these value judgments are cognitive and emotional in nature as students start to, for example, "like" and "dislike" certain science objects in terms of their facilitating the consummation of scientific experience as they are, for example, "happy" or "disgusted". This development of a taste for science is a semiotic process as students' cognitions and emotions, as well as the objects of focus, are present as signs of various forms that must be recognized as such both in their use and creation.

We do not have scope in this paper to systematically detail all the objects that are included (and by extension those that are excluded) from science, but we can generalize and say that the objects valued in science are those which progress cause-effect understandings of the structure and function of natural phenomena. It is such objects that we want students to value and thus to think and feel positively about as they do science as a semiotic undertaking (i.e., meaning making as/through signs). But this is only possible if the students' personal aesthetic experiences are aligned with those of the discipline of science, in other words indoctrinating students with a disciplinary aesthetic of science is antithetical to the aesthetic endeavor. The development of taste, including when it comes to science, is a lifelong endeavor that is always socially constituted across and between multiple life words of the individual (Tytler and Ferguson, 2023).

While disciplinary boundaries evidently serve an important role in maintaining the aesthetic integrity of particular disciplines, including science, this does not preclude the integration of different disciplines as part of rich learning experiences for students (Prain et al., 2022; Wickman et al., 2022). An important part of preparing students for their future lives as agentic citizens who are able to productively negotiate the challenges of the Anthropocene, is authentically integrating science with other disciplines as part of project-based learning and other similar approaches. Teachers' and education researchers' success in fusing science with the arts (e.g., Caiman and Jakobson, 2022; Hannigan et al., 2022; Mun, 2022), to provide potentially transformative learning experiences for students, is a result of clearly determining and demarcating the distinctive tastes of science and the arts.

Esthetics of climate change (education)

Our concern in this paper is to develop a new aesthetic of climate change education, so we now turn from the aesthetics of science education (an aesthetic with a disciplinary and personal dimension) to the aesthetics of climate change (an aesthetic with multiple disciplinary dimensions and with a strong personal dimension). To be clear, what we advocate as an aesthetic of climate change education is not simply the combination of the science and climate change elements; it is something more and something different, as necessitated by the extreme nature of the educational and environmental challenges that we must negotiate in the Anthropocene. It's what Mikkonen (2022, p. 57) calls a "future aesthetics," concerning as it does "new models for appreciation that are able to account for environmental and conceptual changes." In making clear what is new and useful about our socio-semiotic pragmatist account, we will also map out (in a selective as opposed to exhaustive way) existing aesthetic accounts of climate change education, as we value the important work of our environmentally-oriented educator colleagues.

Environmental aesthetics in the Anthropocene

Mikkonen and Lehtinen (2022) argue that the extreme nature of the Anthropocene calls for an equally radical environmental aesthetic to account for our fundamentally altered experiences of the world. This is a world consisting of "mashed-up Anthropocene environments" (Di Paola and Ciccarelli, 2022, p. 85) consisting of "the dynamic entanglements and agglutinations of the human and non-human, local and planetary, fossil-fuelled, capital-driven, techno-powered, ecologically systemic forces and processes" (Di Paola and Ciccarelli, 2022, p. 88) that define the current epoch. As Auer (2019) points out in his overview of environmental aesthetics in the age of human-induced climate change:

> Philosophical inquiries on aesthetic experience in the age of climate change are relatively few, though interest in the subject is likely to grow as climate change affects more people's associations with nature and with places and spaces people inhabit. (Auer, 2019, p. 2)

We consider our paper and our work more generally to form part of this philosophical enlightening of the changing aesthetic nature of our experiences in the Anthropocene, which of course includes education in all its forms (both existing and potential). This is a world, according to Auer (2019), with:

> (1) Fewer opportunities for positive environmental experiences and an overall increase in ugly environmental conditions; (2) increasing instances of climate change "winners" and "losers" and zero sum outcomes; and (3) the increasing obscurity of the moderate autonomist orientation, particularly as the consequences of climate change—and the ugliness it generates—intensifies. (Auer, 2019, p. 7)

Environmental aesthetics, as outlined by Auer (2019), is concerned with engaging with these issues; the ways in which we (humans) care about the natural environment in all its forms, which includes both cognitive and noncognitive (i.e., emotional) processes of initiation and response. Such caring is necessarily grounded in how we value this environment, with ongoing debate as to whether such aesthetics is necessarily linked to our moral concerns (i.e., how we conduct ourselves) (Brady, 2022). It is important to note here that there is a prominent thread running through the environmental aesthetics literature (referred to as the moderate autonomist perspective) which argues that such aesthetics need not entail issues of morality, something with which we strongly disagree as we will explore later. In this way, we support Auer (2019, p. 7) in foregrounding "the moral quandary of whether we should alter our climate-forcing behavior today, knowing that business as usual" is what got us into this mess in the first place. In a "climate change-ravaged world, aesthetic values are more difficult to isolate from moral consideration" (Auer, 2019, p. 9). We join Brady (2022, p. 41) in emphasizing the need for us to be attuned to "aesthetic-ethical harmonies and conflicts" when it comes to the current climate crisis and the role of science education.

As the world changes in radical ways due to human-induced climate change, will our positive and negative experiences of the biotic and abiotic environment also change in radical ways that make our lives less satisfying? Those invested in environmental aesthetics are deeply concerned with this question, and almost unanimously answer in the affirmative (Mikkonen and Lehtinen, 2022). While many of the challenges we currently face are global in nature – that's part of their "wickedness" – it is at the local scale that these value judgments about nature play out most meaningfully for us; the impacts of human-induced climate change are felt most intensely in our daily lives. It is in our daily routines (i.e., habits) that we intimately encounter but also find refuge from the impending doom of global forces; it is the alignment of daily aesthetics of caring for nature with the aesthetics of nature in its pan-ecological forms that makes us feel happiness or sadness (Auer, 2019). To be clear, this is not to reduce aesthetics to a bourgeois contemplative relationship with nature, rather aesthetics is a concern for all people (regardless of race, gender, class) in their valuing of what matters most to them which includes all the various political, social, and cultural entailments. Such is the inequity of human-induced climate change that those most likely to need to change their daily routines are those who have least contributed to the current climate crisis and who have the least power to change their current circumstances. However, the momentum of these climate change forces is so strong that no one is immune; all will have to adapt their daily practices in some way (Brady, 2022). It is not just that we will have potentially fewer positive aesthetic experiences of the biotic and abiotic environment, but all of our aesthetic experiences will take on a different form, as not only will routines "need to adjust, but more radically, people may need to prepare for a perpetual state of complex problem-solving" (Auer, 2019, p. 7).

The role of climate science is critical here for the "object of science-based aesthetics is ecological processes and ecosystems" (Mikkonen, 2022, p. 51). Climate science "helps contextualize conjectures about life in a climate-changed world, sharpening our understanding of who will be (and is already) affected by climate change, with implications for our understanding of aesthetic experience" (Auer, 2019, p. 7). In this way, environmental aesthetics is infused with science, such that our value judgments about nature in the throes of human-induced climate change are at least partially framed by the aesthetics of science

(Mikkonen, 2022). But we must be ever vigilant to the instrumentalist and Cartesian nature of this inherently Western science; as environmental aesthetics develops as a response to help us cope with our dramatically changed/changing world, those advocating for its merits (including us) seek to productively disrupt entrenched dichotomies in particular the divide between 'human' and 'non-human' (Diaconu, 2022). We need to realize that we (humans) are not separate from the natural world, but rather are part of it (and vice versa). In so doing we can realize that all within and beyond the human needs to be cared for through our value judgments, what Diaconu (2022, p. 71) refers to as "a transaaesthetic." This position is strongly aligned with what we argue later in this paper in regard to the merits of our pragmatist semiotic account of aesthetics for climate change education in the Anthropocene.

Esthetics + climate change + education

Auer (2019, p. 9) reasonably suggests that "one might imagine experts in climate change aesthetics helping people to adjust to the harsh realities of their transformed and disfigured environments." The recent emergence of climate change education aesthetics, we argue, is part of this future-oriented initiative to take seriously our aesthetic experiences that necessarily involves the role of education as a way for young people to work with adults (and vice versa) in intergenerational learning to relate to this radically changed/changing world in satisfying ways. We share Van Poeck's and Säfström's (2022: 399) interest in the "the relation between education and societal transformation" in particular "the public role of education in the face of sustainability challenges through interdisciplinary research collaboration." Teachers and students, which we must remember are mutually-constitutive roles with which both adults and young people identify, are "experts" in this sense presented by Auer (2019). They (which includes us) are constantly engaged in aesthetic work as education to realize new relationships of knowing and being (Todd, 2020). To date, much of this work to understand and make explicit the aesthetic dimension has focused on climate change education in its "informal" form (Hansson and Öhman, 2022), most notably the public pedagogies of young people striking for the planet (Verlie and Flynn, 2022). While recognizing the essential role of such informal educational experiences for young people, we propose in this paper the need to consider also the aesthetic dimension of climate change education in formal settings, most notably schools (this includes the various curricula and policies that structure the school experience for teachers and students), and in particular the role climate science can play in empowering young people to enact climate change education for caring futures for all.

The ongoing global actions of the Youth for Sustainability/School Strike 4 Climate movements have been the catalyst for this realization of the need to take seriously the aesthetics of climate change education. In August of 2018, Greta Thunberg protested outside the Swedish Riksdag in Stockholm and in doing so, along with fellow protestors around the world, she initiated a global youth movement which demands that we radically change our ways in order to realize a more just future for human and more-than-human. Young people are leaving formal educational settings (i.e., schools) and entering the streets (as informal educational settings) to realize this change. In the process, they are educating both themselves and others; these youth movements are educational as well as environmental movements. As Wildemeersch et al. (2022) argue:

> Youth activism is a site where taken-for-granted ways of relating to each other and to the world are being questioned and where young people learn from their peers and from informed adults about what is currently at stake and, through their practices, learn how to deal with these challenges. (Wildemeersch et al., 2022, p. 421)

Wildemeersch et al. (2022) make clear that in order to understand, appreciate and contribute to this revolutionary movement that it is essential to recognize the aesthetic nature of what is taking place; the environmental, educational and aesthetic elements are intimately intertwined. They draw on Latour's and Stark's (1999) work and Latour's later musings Latour (2018) to consider "new attachments to the Earth" (Wildemeersch et al., 2022, p. 421) as they seek to frame the aesthetic nature of these youth movements in relation to the environment and education. In doing so, they continue the Latourian work of Todd (2020, p. 1112) who argues for the need for education in the Anthropocene to focus on "encounters of the world" as opposed to "relations to world" in shifting toward ecocentrism. According to this approach, humans are attached to non-humans and vice versa, such that the traditional dichotomy between humans and non-humans is blurred as they are "interlinked and interdependent" in forming "specific alliances or bonds" (Wildemeersch et al., 2022, p. 422). In making clear the aesthetic repercussions of such a framing, Wildemeersch et al. (2022, p. 422) point out that "the choice is not between attachment and detachment, but between good and bad attachments, those attachments that contribute to sustainability in contrast with attachments that tend to decrease our capacity to live in a sustainable way." The process of determining what is a "good" or "bad" attachment is all about value judgments and thus is a matter of aesthetics. Wildemeersch et al. (2022) highlight that aesthetics is not simply a cognitive process but also emotional, bodily and transactional (i.e., ongoing interchange between objects and subjects) in nature as grounded in our everyday experiences. As Todd (2020, p. 1110) points out, education ought to be "a way of creating encounters of the world that educate about the climate emergency while also giving time for climate sorrow" on the path to "a living relationship to the more-than-human world" (Todd, 2020, p. 1112).

Wildemeersch et al. (2022) propose that the aim of the Youth for Sustainability/School Strike 4 Climate movements is to realize "good" new attachments of humans to non-humans (and, presumably, humans to humans). As such, these revolutionary actions of young people are intended by them to educate themselves and others in the value judgments that will save the planet. While such endeavours and their entailed framings of education are issue-focused as opposed to focused on the particular and distinctive disciplines of knowing at play, Wildemeersch et al. (2022) point out that science and its links with aesthetics seems to be central to the educational potency of these movements. In this way, there is a recognized need to make explicit the aesthetic nature of the science component of climate change education and what this might mean for an aesthetics of climate change education, which is the aim of our paper.

The conspicuous absence of climate change education

Globally to date, climate change education has generally been *excluded* from school science, at a policy, curricula, as well as the

classroom level. There are some notable exceptions that we explicate below, yet these remain the exception not the norm in a global context.

The status quo

Climate science is noticeably absent from students' and teachers' experiences of science in the classroom. In our recent paper (White et al., 2022) with *School Strike 4 Climate Australia* members Niamh O'Connor Smith and Harriet O'Shea Carre, Harriet reflects on her formal school experiences of climate change education:

> I was at a Steiner school, and I do not think we ever explicitly learned about anthropogenic climate change. However, a relationship with nature and conscious consumerism were strongly fostered. At school we were taught about ways to live more sustainably, we learned a lot about organic and biodynamic agriculture. We learned about climate change more so from a humanitarian perspective than a scientific one, but we were always encouraged to listen to the climate scientists. (White et al., 2022, p. 33)

So, for Harriet, climate change education to date has tended not to include a strong focus on climate science at school, rather the climate crisis is framed more so with a social science lens to inform sustainable living. But, importantly, Harriet does point out that as school students, they were supported to value climate science but only in a passive sense of forming an audience for the climate scientists.

Niamh tells a similar story:

> I went through mainstream education, public school in Castlemaine and I learnt about climate change, but not at a deep level, other than it existed. Even doing Year 12 chemistry in 2020, you learn about fuels, both renewable and non-renewable, and that carbon dioxide is causing the enhanced greenhouse effect. But the course did not address the need to phase out the fossil fuels that cause the detrimental effects of human-induced climate change…Although I am a maths and science person, it wasn't until I got involved in the movement that I took a deeper dive into the science. I initiated learning the science myself and I was exposed to the science as part of the movement. (White et al., 2022, p. 33)

So, for Niamh, while she experienced climate science at a superficial level as part of climate change education at school, it was only through her participation in the School Strike 4 Climate movement that she developed a deep understanding of climate science and what it could do for her and her community in productively negotiating the climate crisis. In addition, Niamh points out that the epistemic power of this science to inform responses to the climate crisis was blunted as it was not connected with the social, economic, and cultural factors. These school stories of Harriet and Niamh indicate that climate science in the classroom is generally not included as part of climate change education in an integrated (and thus meaningful way) with other ways of knowing and being in the world. In other words, climate science in its full richness seems not to be valued as part of climate change education in the current school context.

As we know, what takes place in schools is strongly shaped by the curricula, and the situation is no different with climate science as part of climate change education. In their recent study, Dawson et al. (2022) show that across the compulsory middle-school years in six countries (Australia, Israel, Finland, Indonesia, Canada and England) that regarding science and geography:

> (1) the term 'climate change' appears in the formal curriculum of all six countries in science or geography; (2) approaches to climate change in the curriculum differ substantially across different countries; (3) climate change is often presented as a context, example or elaboration for other science concepts rather than a discrete topic; (4) the presence of climate change in most curriculum documents is scattered and spread over multiple years and (5) knowledge about causes of climate change predominates over action and behavioral changes. (Dawson et al., 2022, p. 1,379).

As such, when it comes to science curricula, we propose that an aesthetic is operating that does not value climate science and social injustices as part of the science discipline, indeed there seem to be a plethora of value judgments that explicitly exclude climate change as a matter of concern. In addition, climate science as part of climate change education has historically been absent from policy and curricula documents that extends beyond local, regional, and national contexts to the international arena of testing and related education processes and protocols (OECD, 2009). Our message here is clear; the problematic state of climate science as part of climate change education (in our case in Australia) is a result of an aesthetic operating at policy level that trickles down to curricula and classrooms that values neither climate science as part of climate change education nor its entanglement with other disciplines. This is a disturbing situation as it denies young people the opportunities to develop an appreciation for climate science, how science can and should inform social practices, and what it can do for their activist-citizenship. In this way, aesthetics is central to enacting politics for climate justice (White et al., 2022).

Change is coming…

There is hope; the increasingly bright glimmer that we mentioned earlier. To once again return to the words of Harriet.

> Now I am at a different school, and in our science classes we did a unit on climate change and ecology, as well as learning about the politics of climate change in other classes, that did not used to be part of the science curriculum at the school. I thought it was exciting to see that the curriculum is beginning to adapt to communicate the important issues of our time, particularly as it is a very mainstream school. (White et al., 2022, p. 33)

And Niamh:

> Although education has come a long way and in junior levels the curriculum is more flexible for teachers to address climate change on a deeper level, the sense of urgency surrounding the issue means while the science behind it must be taught so students

understand the reasons to act and to create further public pressure, what needs to be taught is the socio-economic impact of climate change on the groups that already face systemic disadvantage. (White et al., 2022, p. 33)

If we read these climate change stories of Harriet and Niamh alongside Dawson et al's (2022, p. 1,394) finding that there are opportunities in the form of various aspects of science and geography curricula to activate climate science as the basis for an "interdisciplinary and deep-learning experience," then we become aware of a potential shift in the aesthetics that frames our enactment of climate change education and the role of climate science.

The potential to realize such an aesthetic shift is perhaps best reflected in the recent forming of the *Environmental Science Expert Working Group* (of which second author, Peta White, is a member) as part of the latest work on the 'PISA 2025 Science Framework'. This group was tasked with developing a construct to measure "the degree to which 15-year-olds are knowledgeable of, concerned about, and able to act on environmental issues as a result of their science education" (White et al., 2023, p. 1). The outcome of this group's work is a positioning of climate science as part of climate change education in the form of a focus on "Agency in the Anthropocene", which they define thus:

> Agency in the Anthropocene requires understanding that human impacts already have significantly altered Earth's systems, and they continue to do so. Young people with Agency in the Anthropocene believe that their actions will be appreciated, approved, and effective as they work to mitigate climate change, biodiversity loss, water scarcity, and other complex issues and crises. Agency in the Anthropocene refers to ways of being and acting within the world that position people as part of (rather than separate from) ecosystems, acknowledging and respecting all species and the interdependence of life. Those with Agency in the Anthropocene acknowledge the many ways societies may have created injustices and work to empower all people to contribute to community and ecosystem well-being. They demonstrate hope, resilience, and efficacy in the face of crises that are both social and ecological (socio-ecological). Moreover, they respect and evaluate multiple perspectives and diverse knowledge systems and demonstrate their ability to engage with other young people and adults, across the generations, in civic processes that lead to improved community well-being and sustainable futures. Young people with Agency in the Anthropocene work individually and with others across a range of scales, from local to global, to understand and address complex challenges that face all beings in our communities. (White et al., 2023, p. 7)

We consider this statement as advocating a transformative aesthetic. The *Environmental Science Expert Working Group* values climate science as part of a "new" science education that forms part of climate change education as an interdisciplinary undertaking that is focused not on fabricating disciplinary boundaries (yet at the same time it respects the epistemic integrity of each discipline) but rather is focused on addressing the socio-ecological issues that constitute the climate crisis. Our aim in the remainder of this paper is to explicate in our own way the form and function of this emerging aesthetic of climate change education for climate science (and thus for science education), and to make clear what it is that we offer that is new in

terms of such an aesthetic as framed by a Peircean/Deweyan pragmatism.

A "new" pragmatist aesthetics of climate change education

We argue that a shift in the aesthetics of science education is required, and indeed has already started to emerge in climate change education, in order for young people to enact climate science in transformative ways for them and the planet. We propose that to do so it is necessary to enrich Dewey's (1934/1987) take on aesthetics with Peirce's (1903/1998) notion of the three normative sciences, with "normative science in general being the conformity of things to ends" (CP 5.129)[1]. Such an approach determines, in a radical way, that aesthetics ought not be considered in isolation as they always have ethical and logical implications. And more than this, from this perspective, we must realize aesthetics, ethics and logic as normative (as opposed to relative) in nature which means that there are ways of making value judgments, conducting ourselves and thinking which are better than others. Climate change education emerges from our efforts/endeavors as a necessary aspect of climate science as practiced in informal as well as formal science education settings. In doing so, we propose that the pragmatist approach to aesthetics still has much to offer science education, despite recent calls by Toscano and Quay (2021, p. 147) to go "beyond a pragmatic account of the aesthetic of science education" due its "limitations and shortcomings." However, to realize these opportunities requires us to seriously engage with the writings of Peirce and undertake the challenging academic work required to put his ideas into action in ways that can meaningfully inform our educational theory and practice. We hope to go some way to doing so in this paper, expanding on our previous Peircean work.

As such our paper has two main threads: (1) introducing the reader to the fundamentals of Peirce's aesthetics and thus his ethics and logic, (2) mapping the contours of a transformative aesthetics of climate change education. While the latter is the primary focus for us here, it can only be undertaken if we first address the former.

Normative sciences

Peirce divides his philosophy into phenomenology, normative sciences and metaphysics (CP 5.121), and then further divides the normative sciences into aesthetics, ethics and logic (CP 1.575). Peirce's architectonic philosophy is grounded upon, and brings into being, objective idealism to account for the nature of truth and reality, such that: "The one intelligible theory of the universe is that of objective idealism, that matter is effete mind, inveterate habits becoming physical laws" (CP 6.25). So, Peirce is an idealist in that reality (including materiality) springs forth from the mind, but this is mind as general and indeterminate (Lane, 2018). He is an objectivist in that material objects exist independently of the individual observer and so (partially) constitute reality (Lane, 2018). Such a theory is distinct from both

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1 CP x.y=*Collected Papers of Charles Sanders Peirce (1932, 1935, 1958),* volume *x.* paragraph *y.*

materialism and idealism in its subjective form, and directly relates to Peirce's position as a scholastic realist in asserting the reality (although not existence) of generals and rejecting nominalists' prioritizing of discrete individuals (Forster, 2011). Peirce's philosophy is synechistic and tychistic in nature, meaning that the evolution of the universe is considered as continuous and punctuated with generative chance (CP 4.584). Most importantly for our current concerns, Peirce proposes: "The opinion which is fated to be ultimately agreed to by all who investigate, is what we mean by the truth, and the object represented in this opinion is the real" (CP 5.407). To be clear, this does not mean that the (infinite) community of inquiry determines the truth in any causal way, but rather that the community of inquiry is destined, as long as it appropriately executes the method of science, to indefinitely 'arrive at' the truth (Mayorga, 2007). This is truth as the ideal limit of inquiry, with the relationship (between truth and inquiry) appearing to be asymptotic but ultimately it is not (Cárdenas, 2018).

By a normative science, Peirce means that which "distinguishes what ought to be from what ought not to be" (CP 1.186), or "the science of the laws of conformity of things to ends" (CP 5.129). It's important to point out here that while for Peirce it is imperative for aesthetics, ethics and logic to be normative, we do not always meet this standard in our daily lives. In our efforts to realize the ultimate aesthetic, ethical and logical forms (more on this below), we progress through a series of imperfect forms. The point Peirce is making is that there are definitively (i.e., normatively) "good" and "bad" ways for us to be aesthetic, ethical and logical, and we need to do more of the former than the latter. Indeed, in order to realize the perfect forms, we must only do the good and not the bad; we must strive for the ideal. As we progress down this normative path, we should keep in mind Peirce's comment about the diverse ways in which aesthetics, ethics and logic play out despite (or perhaps because of) their normative nature:

> Normative science ought to examine all questions relating to the possible ends of phenomena. Not merely what the ends are and what are the conditions of conformity to those ends, or their mere quantity of goodness and badness, but also, the diversity in the different paths by which such ends may be pursued, and the different stadia in those paths: as well as the different ways in which the ends may be missed. [Peirce (1903/1998), draft of *Harvard Lectures*: 9, as cited in Liszka (2021), p. 3]

From an educational perspective, this means that we need to enact science education such that it gives us a humanity that has the potential to appreciate a diversity of aesthetics, ethics, and logic.

So how does Peirce define aesthetics, ethics and logic? He does so in a way that is aligned with Dewey's work, but which is more logical than psychological in nature: "Esthetics considers those things whose ends are to embody qualities of feeling, ethics those things whose ends lie in action, and logic those things whose end is to represent something" (CP 5.129). As Liszka (2021, p. 2) proposes, "Peirce strikes out his own path for the unity of truth [logic], goodness [ethics] and what ends are best to pursue [aesthetics]." These normative sciences form an onto-epistemological triptych for Peirce as framed by his broader semiotic pragmatism:

> …if, as pragmatism teaches us, what we think is to be interpreted in terms of what we are prepared to do, then surely logic, or the

doctrine of what we ought to think, must be an application of the doctrine of what we deliberately choose to do, which is Ethics…. But we cannot get any clue to the secret of Ethics…until we have first made up a formula for what it is that we are prepared to admire. (CP 5.35)

Liszka (2021) unpacks what Peirce means by this triptych in terms of the normative form:

> Esthetics is the study of admirable ideals, and what makes ends worthy of pursuit. Ethics is the study of which ends ought to be deliberately adopted, that is, those that are good for no ulterior reason or interest, but simply good in themselves. It also has the job of determining right conduct in pursuit of those ends. Logical - or scientific reasoning broadly - would be *in this context of normativity* concerned with reasoning from means to ends, that is, what is likely to attain the ends-in-view" (Liszka, 2021, p. 65).

To put this in a simplified form, for Peirce; logic (how we ought to think) rests on ethics (how we ought to conduct ourselves) which is grounded in aesthetics (how we ought to value). So, it's not just the dependence of ethics on aesthetics and in turn the dependence of logic on ethics (and thus on aesthetics) that is key to Peirce's revolutionary philosophy, but also that each of these is normative in nature and thus there are ideal ways for us to make value judgments, conduct ourselves and reason. To be sure, Peirce is building on the work of key philosophers such as Kant and Hegel (among many others) in delineating this triptych. But particular to Peirce is his insistence on the primacy of aesthetics as a normative force in driving inquiry on the path to the truth in an objectively ideal world, that is a world that is devoid of things-in-themselves (so non-Kantian) and consists of actions and feelings (so non-Hegelian) as well as laws (Cárdenas, 2018).

The question then, of course, is what are these ideals and how are they determined? And further to this, what is the relationship between these ideals and our daily aesthetics, ethics and logic? As we will explore next, and as we have already hinted at, Peirce determines ideals in a logical way, and argues that the individual will never realize these ideals (in their daily practices) but rather it is only the community (which for Peirce has a very specific meaning) that can do so (in general and indefinitely). In what follows, we aim to make clear that the norms of aesthetics, ethics, and logic are determined by the truth, in that what we ought to value, how we ought to conduct ourselves, and how we ought to think, must be aligned with inquiry as the road to the truth. However, for Peirce, this ideal process is always filtered through the more practically philosophical lens of sentiments and intuitions, thus sidestepping Hume's guillotine, which drive our everyday beliefs and actions (Atkins, 2016). All of which speaks to the complex nature of the practice/theory nexus (and indeed the is/ought nexus) from the Peircean perspective (CP 1.616).

Peircean aesthetics

The philosophical situation is complicated when the three normative sciences are explicitly stated in ideal terms as dictated by Peirce's approach. In the case of aesthetics: what we ought to ultimately value (i.e., what ends are best to pursue) is what is "admirable *per se*" (CP 1.613) or "admirable in itself" (CP 1.614), which for Peirce is "a quality of feeling" (CP 1.614) that "must, no doubt, be general" (CP 1.613) due to its ideal nature. Peirce goes on: "…since we are

seeking for that which is fine and admirable without any reason beyond itself, pleasure, bliss, is the only object which can satisfy the conditions" (CP 1.614). It is in this way that aesthetics, for Peirce, is concerned with "kalos" (CP 2.199), as Liszka (2021, p. 189) explains: "*To kalon* connotes something more than beautiful appearance for Peirce. It is something noble, good, admirable, and loveable." As such, what we ought to feel as kalos in itself is what is admirable *per se*. It is important here to remind ourselves that in striving to realize this ultimate aesthetic form in our daily lives that we are constantly considering "what it is that we are prepared to admire" (CP 5.36); this is aesthetics in action. The full meaning of what Peirce means by the perfect aesthetic form is only comprehensible in relation to what he states about the normative nature of ethics, as Liszka (2021, p. 179) puts it: "..the primary role of aesthetics is to determine what design, form, or organization of things would best fit its end, and ethics has the role of determining which ends are good." So, it is ethics that we must now explore.

Peircean ethics

Peirce considers the normative nature of ethics in terms of the *summum bonum*, which is the "ultimate end" (CP 1.588), so the highest or ultimate good. As such, the summum bonum constitutes also the actions that are required to realize this ultimate end, for ends are defined by the actions that make them possible. We must remember that for Peirce, ethics is about "what is the ultimate end to be pursued, and what sort of conduct is most conducive to that end" (Liszka, 2021, p. 67). Peirce argues that our actions ought to be directed toward "the development of concrete reasonableness" (CP 5.3), in such as "the highest of all possible aims is to further concrete reasonableness" (CP 2.34). By concrete reasonableness, Peirce means:

> ... the ideal of conduct will be to execute our little function in the operation of the creation by giving a hand toward rendering the world more reasonable whenever, as the slang is, it is 'up to us' to do so" (CP 1.615)

As such, how we conduct ourselves ought to be aligned with the aim of making the world more reasonable, so that ideal conduct is conduct that begets "purposive, self-correcting conduct" (Liszka, 2012, p. 63). As Liszka (2012, p. 64) puts it, "it is the goal of continuing to make one's life reasonable that matters." In this way, Peircean ethics is concerned with "self-controlled, deliberate conduct" (CP 1.191) in that our conduct ought to "conform to a purpose or ideal" (CP 573). Our conduct comes in the form of habits that we are aware of and can change in ways aligned with the ultimate aim. To be clear, this is not the meaning of habit as a set of predetermined actions (which threatens the agency of entities including humans), but rather habits as dispositions to likely act in particular ways in particular circumstances. Not only can we become aware of our habits, but we can change them in purposeful ways; this is what makes us human. In this way, we can talk of Peirce's "definition of ultimate meaning as habit" (Liszka, 2012, p. 141) and further to this the "improvement by means of habit-change, conscious modification of existing habits and even deliberate planting of relatively new habits" (Liszka, 2012, p. 140). The implications of Peirce's position on ethics are clear; to a large extent, we determine our own actions, how we conduct ourselves. But there are ways of conducting ourselves that

we ought to realize as they are ideal, which we can think of as "adequate habits" (Liszka, 2012, p. 141). For Peirce, just as there are good and bad value judgments, there are good and bad habits (relative to the ultimate ends). And, as we now know, for Peirce, our conduct is dependent on our value judgments, with our conduct in turn determining our reasoning, as Peirce explains; "it is only after the moralist has shown us what is our ultimate aim that the logician can tell how we ought to think in order to conform to that end" (CP 8.158). So, it is logic that we now consider.

Peircean logic

As Liszka (2021, p. 64) states, "logic is a study of right and wrong reasoning," with Peirce framing logic "as the art of reasoning" (CP 5.363). But what does Peirce mean here by right and wrong, in other words what is ideal reasoning for Peirce? We must remember here that concrete reasonableness is the ideal of ethics, so we need to know more of what Peirce means by reasoning if we are to properly understand his ethics and in turn his aesthetics. We must first understand what Peirce means by reasoning, which for him is "to find out, from the consideration of what we already know, something else we do not know" (CP 5.365). Humans, according to Peirce, are driven to resolve doubt (i.e., not knowing) by replacing it with beliefs in the form of habits (i.e., our beliefs determine our actions). Logic is a matter of ethics in the sense that reasoning concerns habits of thinking (good and bad thinking); how we conduct our thoughts is a logical as well as an ethical matter. It is in this way that Peirce claims, "the irritation of doubt causes a struggle to attain a state of belief" (CP 5.374), with Peirce referring to this process as "inquiry" (CP 5.374). Now, for Peirce, the ultimate end of inquiry, or in other words the ideal limit of inquiry, is the truth. So, for Peirce, "truth is that concordance of an abstract statement with the ideal limit toward which endless investigation would tend to bring scientific belief" (CP 5.565). Thus, we can say that inquiry is the pursuit of the truth, and so logic as a matter of reasoning concerns the truth. The reasoning that is manifest in ideal ethical form as concrete reasonableness is the method of science.

This statement by Peirce about the nature of truth reveals his argument that truth can only be realized by a community that enacts reasoning according to "the method of science" (CP 5.384), which is aligned with reality as "that mode of being by virtue of which the real thing is as it is, irrespectively of what any mind or any definite collection of minds may represent it to be" (CP 5.565). Peirce in this way talks of the method of science as accountable to "some external permanency" (CP 5.384). His notion of community as an "unlimited community" (CP 2.654) or "indefinite community" (CP 2.655) is radical in the sense that this community is not constituted by a definite collection of individual humans, but rather is composed of an indefinite number of intelligent entities capable of thinking (i.e., reasoning) as/through signs. At this stage it is important to remind ourselves that reasoning, for Peirce (1894/1998, p. 10), is a semiotic phenomenon and so "the art of reasoning is the art of marshalling such signs, and of finding out the truth." Peirce's framing of community in this way leads to a radical conclusion:

> Thought is not necessarily connected with a brain. It appears in the work of bees, of crystals, and throughout the purely physical world; and one can no more deny that it is really there, than that the colors, the shapes, etc., of objects are really there… (Peirce, 1906, p. 523)

We argue that Peirce can be read here as suggesting that intelligence in the sense of thinking as reasoning for meaning making is not limited to humans, but rather is undertaken by all entities that are capable of semiosis that includes biotic and abiotic entities. As such, reasoning is not strictly a human affair, even if logic is (for logic is the art of reasoning as opposed to reasoning in itself). However, humans are capable of particular forms of reasoning that are not undertaken by other entities, in particular the generation of arguments, but this does not devalue other forms (e.g., terms and propositions).

Now it is our turn to make a provocative claim; in order for humans to realize reasoning in its ideal form, we must form a "quasi-mind" (CP 4.536) with all other biotic and abiotic entities capable of semiosis. We thus suggest that there is a more-than-human element to Peirce's notion of logic as the outgrowth of ethics and aesthetics. In doing so, we fully endorse Legg's (personal correspondence, April 20, 2023) notion of "pan-species realism" to characterize Peirce's account of meaning and being in/of the world as sign-centered (not human-centered). However, we stop short of suggesting that Peirce is a post-humanist scholar *per se*, but nevertheless we argue that there is a potentially productive synergy between Peirce's work and the current burgeoning of post-humanist scholarship, particularly when it comes to the current climate change crises. As we continue to explore this conceptual territory, we endeavor to engage with the work of Peircean scholars such as bio-semiotician Stjernfelt (2014) who highlight the potential to go beyond the human in Peirce's work.

We are now able to more clearly state what we mean when we say that the norms of aesthetics, ethics, and logic are determined by the truth. If the summum bonum is concrete reasonableness, then the ultimate form of this is the truth, and so the norms of logic, ethics and aesthetics ought to align with this aim of the truth that is the ultimate opinion of the indefinite community eventually determined through scientific reasoning. In doing so, we must necessarily propose that the truth in this form is admirable in and of itself, in order for aesthetics to maintain its position at the base of the normative sciences.

Aesthetic, ethical, and logical imperatives of climate change education

de Mesa (2018, 249) points out that Peirce's account of the three normative sciences has important implications for education:…"if aesthetics is normative for ethics and logic, in the sense that it establishes the admirable *per se*, an aesthetic education should be at the basis of any pedagogical endeavor." We invert this statement to emphasize that a full understanding and appreciation of an aesthetic of climate change education is dependent on determining the ethical and logical entailments of this aesthetic. To enact an aesthetic of climate change education is to necessarily enact an ethics and logic of climate change education, which must be normatively grounded if we are to stay true to Peirce and to be responsive to our collective ideal for climate change education in the Anthropocene. While in this paper we can make explicit these links between aesthetics, ethics and logic for climate change education, it is beyond our scope to present in any definite form these aesthetic, ethical and logical elements as they ought to manifest in climate change education to align with the ideal forms.

To reiterate a point that we alluded to earlier; ideal forms are by their very nature absolute and so transcend disciplinary boundaries. Therefore, the focus of demarcating the aesthetics of any particular

discipline is to determine the value judgments that would align with the aesthetic ideal (i.e., admirable *per se*). And, as we are invoking Peirce's aesthetics to do so for climate science as part of climate change education, then we must also determine the conduct and reasoning that would align with the ideals of ethics and logic (i.e., concrete reasonableness and scientific method). This work of demarcating aesthetic, ethical and logical boundaries to align with the ideals will only emerge from the community, of which we are but two members, as we explain in our conclusion to this paper. Before exploring these "new" aesthetics, ethics and logic for climate change education, it is worth pointing out that as we shift from aesthetics to ethics to logic that these disciplinary forms increasingly align with the ideal forms (e.g., the logic of climate change education is the method of science albeit in an imperfect form).

A new aesthetics

We thus invoke Peirce's (1903/1998) three normative sciences to argue that we cannot stop at aesthetics *per se*, but must extend to ethics and logic if we are to realize a transformative aesthetics of climate change education; a new taste for climate change education. We draw on Dewey (1934/1987) to propose that teachers, and other adults in the role of educator, need to work with young people to develop those value judgments which explicitly include climate science and its particular objects as part of science education. It is essential that this shift in valuing of climate science as part of climate change education (and vice versa, so climate change education as part of climate science) is systematic in nature in that it plays out at the curricula and policy levels which impacts both formal and informal educational settings. We propose that this process of inclusion leads to climate change education, and climate science as part of this undertaking, as a transdisciplinary endeavor that focuses on addressing those socio-ecological challenges that define the Anthropocene.

This is not climate change education as just another "subject", but a reimagining/re-realization of science education that acknowledges the importance of disciplinary boundaries but not at the cost of an overarching transdisciplinary aesthetic. Our conclusion here is clear, at least in regard to an aesthetics of climate change education; we need to understand and value distinct disciplinary aesthetics, but these must be positioned relative to a transdisciplinary aesthetic that innervates each and every disciplinary aesthetic in different ways. Such a transdisciplinary aesthetic is all about valuing the contributions that distinct ways of knowing and being can make to addressing the socio-ecological challenges of the Anthropocene. It is only by doing so that we can realize the beauty (in the sense of kalon) of climate science on the path to experiencing bliss of the admirable *per se*.

A new ethics

If we adopt such an aesthetics of climate change education, then from our Peircean (1903/1908) perspective we must take particular actions that set us on the path to realizing specific ends. We argue that these ends for climate change education ought to be the activation of climate science by young people with us (intergenerationally) to firstly understand the socio-ecological challenges and then to resolve these issues such that the integrity of all entities' existence is assured in a form of harmony/homeostasis. These are ways of acting, including most importantly reasoning, that not only enable understanding of the science of climate change but afford informed practices of changing our (as humans) relationships with the rest of the biotic and abiotic world to respect all beings' quiddity (i.e., the essence of each being).

Such ethics underpins the important role played by climate science as part of climate change education to foster the development of young people as scientifically-agentic citizens of the Anthropocene. We, and our science education colleagues, like to talk about science education as inducting students into science as a way of being in the world; we now suggest that such a manifesto only makes sense if framed as an ethical endeavor as grounded in aesthetics.

Climate change education from this Peircean perspective on ethics ought to be an intergenerational endeavor (involve adults working with young people, and vice versa) to become aware of our existing habits of climate science in order to alter these dispositions such that they better align with the desired ends. In this way, climate science as part of climate change education is the ongoing and purposeful development of a set of particular habits. We argue that such habits and ends (see paragraph above) are aligned with the ultimate ethical ideal of concrete reasonableness because climate science is activated as part of climate change education so that young people can make meaning of the world in a caring way (more about this in our conclusion to this paper).

A new logic

What about the final member of our normative science triumvirate, that is the logic of climate change education? We proposed earlier that, for Peirce (1903/1998), the reasoning that is manifest in ideal ethical form as concrete reasonableness is the method of science. As such, we propose that climate science as part of climate change education ought to involve young people working together and intergenerationally as a community to undertake reasoning in the form of abduction, induction and deduction as informed by evidence about climate science phenomena that affords explanation of certain aspects of such phenomena. Young people need to be supported to tune into the climate 'surprises' of the natural world so they can generate and test hypotheses to explain the current crisis and take informed action in forms other than reasoning (remembering that ethics encompasses all habits). Only by doing so can young people effectively argue for climate justice.

However, as we flagged earlier, while Peirce (1894/1998, 1907/1998) limits argumentation to humans, he asserts that reasoning and thinking more generally (including terms and propositions as well as arguments) are undertaken by all intelligent entities to varying degrees to determine the truth. The radical entailment of this notion of truth for a logic of climate change education as grounded in climate science is that young people ought to not just collaborate with all humans but with all biotic and abiotic entities capable of semiotic activity for meaning making. Climate change education must be grounded in the community, and this community must expand well beyond the walls of the school classroom such that young people can enact climate science with the more-than-human. This is the only logic of climate science as part of climate change education that can align with the method of science as an ideal, which if we remember is an imperative of our transformative aesthetics of climate change education.

A new aesthetical-ethical-logical triptych for climate change education

We present in Figure 1 a new perspective on aesthetics and thus ethics and logic for climate change education, and in particular a provocation as to the important role that climate science ought to play

in such a science education for the Anthropocene. In exploring this model, we aim to provide the full range of climate change educators with suggestions as to going about realizing climate science as a driving force of climate change education for loving and hopeful futures (more on this in the conclusion). In addition, in presenting this model of the triptych, we agree with Wickman (2017) that aesthetics, ethics, and logic are intertwined in practical experience, including in the context of science education. However, we differ in arguing that this ordering of the normative sciences (starting with aesthetics) is not simply an arbitrary convention of the analytic tradition in philosophy, but rather it reflects a fundamental aspect of being that makes possible a satisfying and worthwhile life.

We propose, following Peirce, that enacting climate change education ought to begin with aesthetics and in turn develop ethics and finally embrace logic. Such an ideal is exemplified by the young people of Youth for Sustainability/School Strike 4 Climate as they take as their starting point for activism/education how they value, which determines how they conduct themselves that in turn leads to how they think, all in relation to human-induced climate change. The stories of Niamh and Harriet in our recent paper (White et al., 2022) are testament to the power of this radical version of climate change education to make our world better, as they come to know and put into practice the epistemic power of climate science (logic) through the need to act in ways to "save" their communities (ethics) as necessitated by their loving of all entities on Earth including climate science as part of climate change education (aesthetics).

Young people can enact the normative sciences in this way because they consider climate change education and more specifically climate science as a matter of addressing socio-ecological issues by putting into action any and every discipline, as opposed to artificially siloing ways of knowing and being (including climate science). This is not to say that such climate change education ought to demolish all disciplinary boundaries; to the contrary, the specific aesthetics (and so epistemic integrity) of all disciplines must be respected at the same time as

FIGURE 1
The dynamic linking of aesthetics, ethics and logic for climate change education.
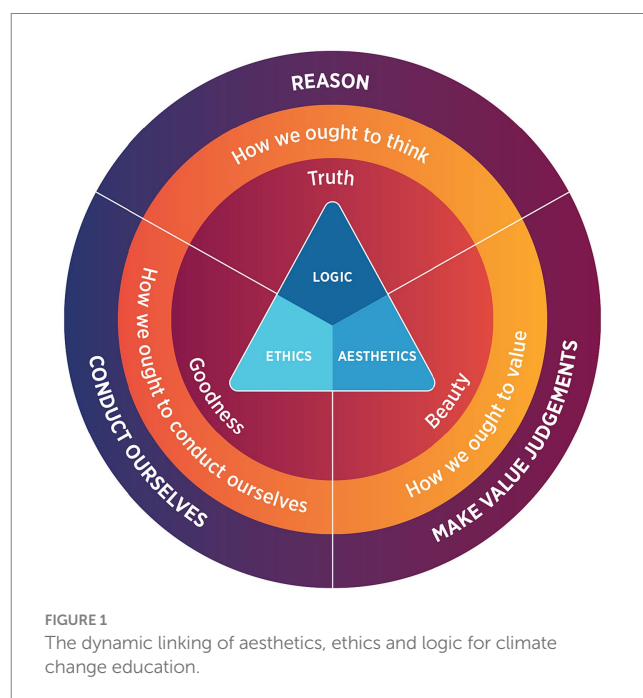
we embrace an aesthetic for interdisciplinarity (i.e., epistemological pluralism). We also emphasize that there is always more that can be done to bring us closer to the aesthetical-ethical-logical ideal. In the case of the young people of Youth for Sustainability/School Strike 4 Climate, they are in need of intergenerational collaborators who can support them to bolster their logic by realizing the method of science (in particular the knowledge and practices of climate science) in more complete ways. Climate scientists are faced with the contrasting challenge as while their logic is fully formed (they know well the science of climate change and its grounding in the method of science) they are in need of guidance to bolster their aesthetics and ethics when it comes to climate change education (i.e., valuing climate science as part of valuing the Earth to guide caring actions). As such, there is always scope to change our habits; it will take time and energy to develop this new taste for climate science as part of climate change education.

All of this is a reminder that those involved as students and teachers in climate change education will vary in terms of their starting points for enacting climate science; some will start with logic, others with ethics and still others will ground their being with/as climate change in aesthetics. It's up to us as advocates for transformative climate change education to work with young people and their adult allies to acknowledge these different starting/entry points and to map out ways to move between logic, ethics and aesthetics, for this triptych is not linear and static but rather dynamic and non-linear. In doing so, we stress the need to prioritize and foreground aesthetics, but always with ethics and logic in mind (as well as in body and spirit). And, as advocated by Peirce, we must go about all this as a process of (endless) semiosis; "all this universe is perfused with signs" (CP 5.448).

A radical pragmatist meliorism for the future

We conclude our paper on a hopeful and loving note, as we endeavor to contribute to efforts to realize a much needed "praxis of radical love and critical hope for science education" (Torres Olave et al., 2023, p. 1). We propose that if we adopt our transformative aesthetics of climate change education that this makes possible - once again by fusing Dewey (1934/1987) with Peirce (1894/1998, 1903/1998, 1907/1998) – a radical pragmatist meliorism to productively negotiate the challenges of the Anthropocene intergenerationally and with the more-than-human. This is a meliorism that is underpinned by the three normative sciences, the most fundamental of which is aesthetics, and which emerges from the pan-species and intergenerational community of inquiry.

Meliorism, according to Peirce, is the:

(1) improvement of society by regulated practical means: opposed to the passive principle of both pessimism and optimism.
(2) doctrine that the world is neither the worst nor the best possible, but that it is capable of improvement: a mean between theoretical pessimism and optimism. Peirce (1899), entry for Century Dictionary, as cited in Bergman (2012, p. 127).

Dewey similarly considers pessimism and optimism as paralyzing forces when it comes to making changes for the better, and so advocates for meliorism as:

…the belief that the specific conditions which exist at one moment, be they comparatively bad or comparatively good, in any event may be bettered. It encourages intelligence to study the positive means of good and the obstructions to their realization, and to put forth endeavor for the improvement of conditions. [Dewey (1899-1924/1980), in The Middle Works of John Dewey, pp. 181–182, as cited in Bergman (2012, p. 128)].

Bergman (2012, p. 128) refers to Dewey's meliorism as an "explicit activist conception of meliorism." We propose that to avoid utilitarianism that Dewey's account ought to be complimented by Peirce's insistence on the importance of all actions (not just 'practical') including those which are theoretical/philosophical in nature.

We are all aware in our work as science educators with young people that the socio-ecological issue of human-induced climate change is a strong cause for pessimism and that optimism often leads to "toxic positivity" (Lobo et al., 2021, p. 1,496). As such, this pragmatist meliorism offers genuine hope in that we can - through the changing of our aesthetic, ethical and logical habits of climate science as part of climate change education – realize ways of valuing, conducting ourselves and thinking that make this world better for all. Indeed, we have witnessed, and will continue to do so, this meliorism in action as the youth climate movements. We follow Liszka (2021) and Anderson (1995) in highlighting the all-encompassing nature of this meliorism in that it is realized by a community that is not only intergenerational but also pan-species in nature; it involves all entities capable of semiosis in the here and now, and the future. We concur with Liszka (2021) that such a community committed to meliorism is a force for what Peirce refers to as "evolution by creative love" (CP 6.302), which he conceptualized with his notion of "agapism" (CP 6.302). It is worth quoting Peirce at length here to make clear what he means by agape/love:

The movement of love is circular, at one and the same impulse projecting creations into independency and drawing them into harmony. This seems complicated when stated so; but it is fully summed up in the simple formula we call the Golden Rule. This does not, of course, say, Do everything possible to gratify the egoistic impulses of others, but it says, Sacrifice your own perfection to the perfectionment of your neighbor. Nor must it for a moment be confounded with the Benthamite, or Helvetian, or Beccarian motto, Act for the greatest good of the greatest number. Love is not directed to abstractions but to persons; not to persons we do not know, nor to numbers of people, but to our own dear ones, our family and neighbors. "Our neighbor," we remember, is one whom we live near, not locally perhaps but in life and feeling. (CP 6.288)

It is imperative here to reiterate Anderson's (1995) point that by "neighbor" Peirce does not just mean humans but all entities capable of semiotic activity, such that agape is love for all in a benevolent/altruistic and not self-serving way. As Liszka (2021, p. 138) argues: "It is a willingness to contribute to present and future communities, to make things better and pass it on to those that follow, even if one does not benefit oneself from such contributions." We believe that a transformative aesthetics of climate change education can put us and young people on the path to love through the power of climate science for hopeful futures.

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Aesthetic surprises and considerations when researching marine science education with art

Shelley M. Hannigan[1]*, Cátia Freitas[2] and Prue Francis[2]

[1]School of Education, Faculty of Arts and Education, Deakin University, Burwood, VIC, Australia, [2]Deakin Marine Research and Innovation Centre, School of Life and Environmental Sciences, Deakin University, Queenscliff, VIC, Australia

Introduction: Why was the study undertaken? What was the research question, the tested hypothesis or the purpose of the research? The research question is: What are the implications of disciplinary aesthetics when marine science meets art in educational research? Children in schools from Victoria, Australia were engaged in a series of marine science fieldtrips, workshops and lessons based on the Great Southern Reef, a temperate marine environment of Australia. They created drawings based on provocations, to depict their knowledge of marine species, before and after these education experiences.

Methods: When, where, and how was the study done? What materials were used or who was included in the study groups (patients, etc.)? This paper shares the mixed methodology used by focusing on the qualitative methods used, that arose out of a need to understand the role of aesthetics in this research project. This paper documents the analysis of data that included children's drawings and dialogue between researchers and children from interviews. We discuss insights into the role of aesthetics that were revealed in the visual and narrative data from perspectives of children's learning and how the researchers were able to understand this. These findings are discussed considering the teaching intentions and procedures used, the importance of this multimodal approach to research that revealed aesthetics of science, visual art and language in education.

Results: What answer was found to the research question; what did the study find? Was the tested hypothesis true? The research reveals the important role drawing has when trying to understand the students' varying degrees of understanding marine science education. Variables include: their prior experience with marine environments, students' drawing abilities, stylistic elements (that can render an image 'confident' or 'sketchy'), compositional devices and use of perspective that their drawings depict (looking at a pier from underwater or through snorkel goggles). It also includes interpretations and explanations of their drawings and other uses of language such as the use of written labels to reinforce or clarify parts of their drawings.

Discussion: What might the answer imply and why does it matter? How does it fit in with what other researchers have found? What are the perspectives for future research? This research reveals the important role of multi-modal approaches in science learning and the significant and dependent role of visual art and words, for students to communicate their learnt content knowledge. It highlights the aesthetic experiences that must be taken into consideration when teaching, learning and when understanding what has been learnt.

KEYWORDS

aesthetics, art, marine science, teaching, learning, methods, Australia, Great Southern Reef

Introduction

This study forms part of a marine science education programme that was developed for primary schools by a team of marine scientists and researchers, in southern Victoria, Australia. The aim of this programme was to increase teachers' and students' awareness and understanding of their local marine environment, the Great Southern Reef (GSR). The GSR remains unfamiliar to most people and receives less media attention and grant funding, compared to tropical reef systems such as the Great Barrier Reef (Bennett et al., 2016). The GSR is a temperate rocky reef system made up of dense kelp forests that are interconnected along 8,000 km of Australia's southern coast (Bennett et al., 2016). The GSR is characterised by its high species richness and endemism and plays a significant role in Australia's economy, culture, and environment. Thus, it is vital for the Australian community, including children, to develop an understanding for and build valuable connections to the GSR.

To evaluate the students' understanding of the GSR, drawings and focus group interviews were conducted before and after the marine education programme. Here, we describe how both quantitative and qualitative methods were used to analyse students' understanding of their local marine environment and report on the qualitative method to evaluate the aesthetic experiences expressed through art and narrative dialogue. The qualitative method outlined highlights the importance of both qualitative and quantitative analyses to evaluate the students' science understanding in the context of this local marine environment. We share our methodology and methods by presenting examples of our analysis from one of the participating classes and examples from three student experiences.

Connections of place, aesthetics, and interestedness

One of the unique benefits of the marine education programme was the proximity of the school to the local marine environment. Place-based environmental education is one way to engage children as it enables them to explore their own local environment that they are somewhat familiar with and therefore be able to make connections between what is being studied and their own lives (Lai, 2021; Wright et al., 2022). In this sense, the marine education programme aligns with Dewey's (1958) theory of the interconnection of nature and experience, as the students were immersed in their environment and engaged in a continuity of communicating and learning about the marine aspects of their environment.

Whether or not participants are interested or have a 'taste' for the topic being studied is a well-documented feature of research in aesthetics for teaching and learning (Wickman, 2005, 2017; Silvia, 2012; Anderhag, 2017; Hannigan et al., 2021). Wickman (2017, p.32) explains a persons' process of learning as a 'simultaneous transformation' of a person 'as a whole', which is 'a transformation of taste'. He writes:

> Both Dewey (1913) and Bourdieu (1984) have employed the notion of taste to emphasise the continuity of all three faculties for learning as the transformation of habits (habitus of Bourdieu) of making certain distinctions (cognitively, normatively, and aesthetically) about what objects, events and actions should be included and excluded.

This quote is applicable to the aim of the marine education programme where students participated in immersive, place-based experiences relating to their local marine environment where there was opportunity to develop a 'transformation of taste'. Encouraging children to learn about the GSR contributes to Australia's push to create an ocean literate society (Freitas et al., 2022). The GSR is facing rapid climate change impacts and urban development pressures (Bennett et al., 2016). Recent data indicates there is a high risk of extinction of endemic reef species in southern Australia (Edgar et al., 2023). Raising awareness of the GSR and the threats it is facing is imperative to help children understand and appreciate their local marine environment and to foster ocean stewardship (Freitas et al., 2022). In addition, knowing their local natural environment has been shown to influence young people's imagined spatial futures and ongoing education interests (Rönnlund, 2020). Through the place-based opportunities and classroom activities offered in the marine education programme, we seek to analyse the students' interconnection with their marine environment, through aesthetic evaluation developed in the qualitative approach of our mixed methods research.

The significance of art in the research methods

Diagrammatic representations are used as learning strategies in science education to improve or help students engage in classes and learning process (a multi-modal way of learning), to represent science (this might involve art tuition on learning to draw science systems or specimens) and communicate or reason (Ainsworth et al., 2011). Drawing and other arts are used to recall or demonstrate learning in performed or visual ways. For example, in an art and environmental science project, puppets were created to depict students' understandings of endangered species then performed in small portable theatres to communicate animal extinction (Hannigan et al., 2021; Hannigan and Ferguson, 2022). Drawings have been introduced for school students to represent science and scientists (Finson, 2002), their science learning (Tytler et al., 2013; Flowers et al., 2015; Roseler and Dentzau, 2017) and specific models of science experiments (Neumann and Hopf, 2017). Drawings have also been used to explore primary school children's mental models of marine environments (Atasoy et al., 2020) and to assess their learning over time (Cainey et al., 2012).

This marine education programme was focused on the science curriculum rather than the art education curriculum. As is common in science education, propositional knowledge (species, environment, etc.) was taught with justifications of this knowledge being assisted in experiential ways of teaching and learning such as: teachers and researchers facilitating students to experience their local environment on field trips, using illustrated swap cards and being taught by locally-based marine scientists. Brock and Hay (2019) explain the value of experiential engagement to acquire knowledge, arguing that 'non-propositional knowledge is a significant component of scientific experience' (p.995). The inclusion of non-propositional knowledge, experiential learning, arts epistemology and propositional knowledge were important pedagogical considerations in this study.

At the heart of the study was the notion of change, as children would be learning (which is change) but also, in this climate change environment scientists are constantly discovering new insights so knowledge is not static. It could be said that climate change influences education about: species, their habitat, their numbers and even in some cases their colours (as their colouring changes to adapt to heat or loss of their habitat). The very nature of creating art is that things change (being creative artistic processes). Therefore, art epistemology was useful to help understand and map these changes in students' learning.

Before and after the programme, children were provided with coloured chalk-pastels, to show their learnings about what their local marine environment looked like and the marine species within it. Drawing on Reiser's (1950) discussion of a philosophy of symbolism or semiotics to art, we construct a model of the three phases the students engaged in as part of art epistemology in their learning process. The model is based on the letters H, I and E (which do not stand for any particular words):

(H) The student as artist and the subject matter learnt about the GSR (fish, kelp, environment etc).
(I) 'The cluster of signs (propositions, ideas with a feeling tone, etc.) which arise in the mind of the (artist) as a result of looking (and learning about H) (i.e., images, ideas)' (Reiser, 1950, p.696).
(J) (E) the drawing created as a result of these processes.

The children's drawings are not mere copies of (H) or imitations of reality. They have been processed through the opportunity in (I)–to respond to the prompt by the teachers to 'draw a picture of what you would expect to find if you were snorkelling on your local beach' to use the materials provided (crayons, paper), given time and a degree of artistic freedom to do this task. '(E) proceeds genetically from (I) and (I) is complex and includes all the propositions of the artist about H' (Reiser, 1950, p.699). Another way of framing it is that 'It may be sometimes true that the psychological intention of the artists is to make our of (E) a duplicate of (H), but what he does it not true to (H), but true to (I), that is, to what he thinks about (H)' (p.699). Theories of materiality in the creative process would add that the engagement with and consideration of the materials available have an impact on this whole process as well.

Throughout this process of (H), (I) to (E), children have been learning first about science in connection to the subject matter of (H) including propositional knowledge. We capture their learning through their drawings and through interviews with them about all three phases of this process.

Brooks (2017) highlights how young peoples' visual representations through drawing are connected to their thinking skills rather than verbal language skills and abilities. This means if language skills aren't fully developed, words (for marine species in this example) aren't known, or children have other languages, then art can also be a powerful way to communicate knowledge, feelings and ideas.

Choi and Pak (2006) define interdisciplinary education as interactive because it 'analyzes, synthesises and harmonises links between disciplines into a coordinated and coherent whole' (p. 351). Interdisciplinary education was achieved through generating new science knowledge using artistic epistemology approaches under the banner of a marine education programme. In addition, this research

was multi-modal as it invited students to learn and explore the topic through children's story books, identification cards, field trips, conventional classroom teaching and learning as well as drawing their learning and discussing both drawings and learning with the researchers.

Using art in education can encourage knowledge to 'emerge through the multiple ways in which we engage with and in our world: movement, touch, emotions, intuition and making' (Shields et al., 2016, p.46). However, understanding artworks requires conversation and checking in with the creator—we cannot assume our own. This was considered and addressed with the inclusion of the qualitative methodology of arts-based and narrative inquiry and methods of cross referencing our analysis and understandings of each drawing's content/subject matter, employing a hermeneutic approach and bracketing out our own assumptions by sharing these with each other, to understand the relationship between (H), (I) and (E) above.

The design of the research, the methods, the particular prompt (which was quite open) for children to draw their learning, and the opportunities provided to share their place and environment as part of this learning, were the key elements of the project. Place was also an important consideration and art has been well documented to help engage students to understand their environment and themselves within it (California Department of Education, 2019). The many place and identity references in artists' work and arts-led research (see Casey, 2005; Jokela, 2008; Byrne et al., 2010; Dear, 2011a,b) and their claims of the interconnection of place and identity and the role of the creative process in this, suggest art is about making sense of place and self in some form. It is after all through art that artists (and students engaged in making art) make sense of their world and themselves within it (Heidegger, 1969; Malpas, 2018). As Sullivan (2005) notes, there is an 'emphasis on identity construction in the visual arts, as artists in particular search for self and place' (p. 172).

Aesthetic considerations in assessing, interpreting, and analysing art

Dewey (1934) critiques the notion of High Art or Museum Art, because these notions of art, tend to be separated from 'ordinary everyday modes of experience and activity'. Dewey promoted a more natural or ecological notion of aesthetics, which fits into this project given it explores an eco-marine environment and involves children, their art and use of words. He believed that being able to express rhythms from our ecology or interconnection with our environment, through the forms of art (line, shape, tone, balance etc.) is how artistic form emerges. Dewey (1934) writes, 'Underneath the rhythm of every art and of every work of art there lies, as a substratum in the depths of the subconsciousness, the basic pattern of the relations of the live creature to his environment' (p. 150). This is a consideration for the aesthetic analysis and discussion of this paper given we used art and words (conversation and labels on drawings) with a focus on environmental science learning.

As above, children's art is not being judged as 'high' or 'museum quality' art. Seeley (2015) also highlights different categories of 'art' suggesting there are 'anti-aesthetic conceptual artworks, works designed primarily as objects of aesthetic contemplation, and everything in between' (p.39). These different kinds of art suggest we should re-think the way we interpret, respond or make sense of an

artwork given that some art is not even 'intentionally designed to produce aesthetic experiences in consumers' (Seeley 2015, p.39). This point and Dewey's critique above about being open to individual's experiential ways of creating and understanding art, such as rhythms from our ecology became paramount in this project.

Children's depictions of their learning through their own style of drawing meant we needed to be aware of different categories of art that might influence us. We needed to be careful about how we, as researchers, responded to the children's artworks and how our responses might inform our interpretations and potential misunderstandings of their drawing content (e.g., correct or in-correct species). That is, we might be seduced by the brilliance of a drawing's style, when in fact the intention of the child-artist was to depict maximum correct species following the lessons and prompts they were given. We need to not go looking for 'great works of art' but instead understand the art and words in context to the educational and research programme.

The researchers aimed to seek evidence through the students' drawings of the ideas embedded in the marine education programme, with a particular focus on the local marine environment and species found there. Assessing the content of young students' art to check if they have included correct animal species, or plants relative to the environment they are studying, is fraught due to the cultural and world views of students which might influence their choice of colour and the way they choose to depict an environment (e.g., the sea from a boat, from a pier, from underwater, through snorkel goggles etc.) depending on their own experiences. Additionally, those viewing or assessing the art might be influenced by ideas of what constitute successful art or they might find that they have a preference for a particular genre, style or aesthetic preference. Some assessors might inadvertently allow such preferences to influence their opinions or assessments of children's art. For example, even if researchers or assessors are looking for evidence of 'correct marine species' in children's drawings, they might also inadvertently start judging how well these species were drawn (and perhaps miss some if they were not easily recognisable), or judge how well they are composed with other elements of the drawing (colour, lines, shape, shading)—therefore making more sense aesthetically to the assessor.

Another consideration for assessing children's learning based on their drawings, is that some might value art and art education practices that are more about students developing their art over time, where the creative processes is more important than the end result. Art that is more about the creative process than the end result is quite common in contemporary art practices and art education. Part of its preference in art education is Deweyan in that it is based on 'a desire to democratise artmaking within communities rather than within elite groups and to evaluate the impact of process rather than to prioritise aesthetic judgements about products' (Hyland-Russell and Groen, 2013, p.59). Such art or creative processes can potentially impact the researcher/assessor's interpretations or judgements when observing students creating art, or at the interview stage when students explain their work. An example of this is if a child was explaining that they had not quite finished the drawing, or what they were hoping to do next in the drawing.

These are all considerations that came into play as we considered the methods and engaged in the methodological considerations when conducting this research.

Methods

Methodological considerations

As has already been mentioned, this paper documents a research project that involved a marine education programme study to enhance ocean literacy in the primary/elementary classroom by promoting a greater understanding of the Great Southern Reef (GSR). The methodology and methods of this research were based on the effectiveness of this marine education programme on the students understanding about the GSR.

Initially, the method of analysis was focused on quantitative evaluation, however, it soon became important that qualitative analysis was required, given the aesthetic nature of the drawings and the researchers' awareness that some of the drawings were open to interpretation. Therefore, we complimented the quantitative method with a qualitative analysis; making it a narrative and arts-based inquiry. This became a mixed methodology (Creswell and Creswell, 2003). We describe both methods in more detail in the research programme and analysis section below.

This paper documents the qualitative aspect of our mixed methodology to highlight how and why the aesthetic evaluation became a valuable complement to quantitative analysis for evaluating science understanding.

Our mixed methodological approach incorporates constructivist/interpretivist worldviews as children make sense of their marine environment through learning at school and during school excursions, as well as their own place-based and lived experience living in local seaside towns. Our methods considered this worldview by providing opportunity for students to incorporate their own experiences in their accounts of learning (through their own perspectives and stylistic approaches to drawing, and open question interviews where they could explain these).

Qualitative research is non-linear and complex (Stake, 2010). It was important for the researchers to provide opportunity for students to express their perspectives and learning and explain them in the interviews. As Josselson (2011) reminds us,

> Narrative inquiry approaches recognise that narrators are constructing ordered accounts from the chaos of internal experience and that these accounts will likely be multivocal and dialogical in that aspects of self will appear in conversation with or juxtaposed against other aspects. There is never a single representation (p. 226).

It was important for the researchers to triangulate their interpretations and understandings of the data through the mixed methods used. Techniques to do this include making individual notes about interpretations and observations of participant data during the analysis phases. These help researchers to be more conscious of individual interpretive thinking. By sharing these with each other there is the potential to open up discussions about how each researcher is making sense of the data and therefore how the researchers can arrive at understandings as a team. By writing down individual thoughts, observations and assumptions, these become more concrete and are able to be reflected upon or shared then bracketed out (Moustakas, 1994) so they do not subconsciously influence researcher interpretations and analysis.

This process of checking in with one anothers' interpretations is called engaging in a hermeneutic circle. People engage in a hermeneutic

circle because of their need to find out why people behave and the significance with which people interpret their own actions (Geertz, 1971). Davidson's (2006) explains the usefulness of learning of peoples reasons, which can then help explain why they might have acted (or drew a drawing) in a particular way. He highlights the importance of setting up the right investigation to help understand and interpret a person's actions and accounts of experience. However, in addition to setting up the right investigation, the hermeneutic interpreter and researcher will need to challenge their own focus on their own issues, as Gadamer (2004). explains:

> A person who is trying to understand a text is always projecting (they) projects a meaning for the text as a whole as soon as some initial meaning emerges in the text. Again, the initial meaning emerges only because (they) is reading the text with particular expectations in regard to a certain meaning. Working out this fore-projection, which is constantly revised in terms of what emerges as (they) penetrates into the meaning, is understanding what is there (p. 267).

Interpreting and developing meaning from the point of view of each participant is fundamental to understanding each participant's experiences, interpretations, and understandings. For this reason, the hermeneutic approach to researching place and identity is compatible, useful, and necessary to understanding and learning new knowledge. We felt this complimented the quantitative methods as a solid inquiry into the children's learning; as Palinkas et al. (2011) point out, mixed methods are more successful to reveal research issues, than qualitative or quantitative methodologies on their own.

The research programme

Teachers involved in the marine education programme participated in a 3-day workshop (approximately 25-h contact) with the researchers prior to conducting ocean-themed activities in their classroom. The research team supported the teachers and school by providing a teachers' guide (freely downloadable at: www.pruefrancis.com/science-3-4/) along with a sample of 6 nonfiction ocean-themed picture books that represent the GSR. These texts were selected based on an in-depth analysis of the ways in which the text and illustrations accurately communicate marine science concepts to the reader (Freitas et al., 2023). The classroom teacher and school supplied additional resources that formed the weekly ocean-themed activities that were implemented in the classroom. The research team supplied the drawing materials that included A4 artist paper, coloured soft pastels, and pencils.

The marine science programme was conducted over a three-month period, from June to September 2022 in one classroom that included a mix of both grade 3 and 4 students (aged 8–10 years old). The classroom teacher integrated ocean topics at least once a week in their lessons based on guidance from the teachers' guide (Freitas et al., in review).[1] Some example activities that were conducted, included

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1 Freitas, C., Hannigan, S.M, Bellgrove, A., Venzo, P., and Francis, P. (in review). *Diving into a sea of knowledge: Empowering primary school students in ocean literacy and raising awareness of the great southern reef.*

reading and discussion of ocean-themed picture books that represented the local marine environment, creation of a map of the GSR and artwork to decorate the classroom walls, and creation of identification cards for local marine organisms as a way to increase students' familiarity with the marine life found on the local rocky shores. In addition to the weekly activities implemented by the classroom teacher, the research team also visited the school to conduct ocean science activities. This involvement included two classroom activities and one excursion to their local coastal environment.

To determine the students' attainment of learning outcomes, the researchers obtained drawings before and after the marine education programme as well as conducting small, focus group interviews to discuss the drawings with the students. For both these before and after drawings, students were asked to 'draw a picture of what you would expect to find if you were snorkelling on your local beach'. The pre-and post-drawings were evaluated quantitatively by a marine science educator and an experienced arts-based researcher following methods developed by Bowker (2007) and later modified by Cainey et al. (2012). Individual evaluation of breadth, extent, and detail were conducted by both researchers and then results shared and discussed.

The pre and post drawings were also analysed qualitatively in conjunction with the transcripts of the interviews. The students were interviewed about these drawings a week later, respectively. This involved students' being invited to participate in a focus group discussion with groups of 3 to 5 children, where they had the opportunity to offer contributions about what was included in their drawings and why. The interviews were important to clarify some of the correct species in the students' drawings as well as their reasonings about why they included particular features and subject matter and the compositions of their drawings. To capture the multiple perspectives of the students and their reasoning for including images (knowledge, time and materials) or depicting images (style and materials), thematic narrative analysis was conducted (in addition to the quantitative analysis). Group interviews were conducted in a meeting room with their classroom teacher present and were audio recorded and transcribed for analysis. The drawings were photographed with ethics permissions approved.

Pseudonyms were used to de-identify students, teachers and places mentioned in interviews. The three researchers were coded as R1, R2, and R3 (in no particular order in relation to the authorship of this paper).

Analysis

In the quantitative phase of analysis, the pre and post drawings were analysed by scoring across the three categories; breadth, extent and detail. The scores from each category were then added together for each drawing to achieve a mastery score overall for each drawing. These scores were then compared between pre and post drawings. Breadth corresponds to the 5 themes identified in the drawings in relation to the presence of fish, non-fish marine animals, humans, habitat and surrounding environment (e.g., air). Each theme in the drawing received a score of 1. Extent was scored in relation to the number of different species of animals in the picture to a maximum score of 5. A negative score was given to species in the incorrect environment (e.g., clownfish in the GSR). Detail was scored between 1 to 5 according to the level of accuracy in the pictures as per Cainey et al.'s (2012) method. Accuracy was assessed in terms of the representation of marine organism with distinguishable features, the

correct use of colours, the representation of ecological relationship between organisms and their habitat (e.g., animals hiding from predators and hunting for food) and the attribution of human emotions to animals (anthropomorphism).

The qualitative analysis emerged when the two researchers (when undertaking the quantitative analysis) found they needed to note down their aesthetic responses such as the techniques or style some students used to depict moving water, dark kelp forests, juxtaposition of scale or different types of perspective used. On the occasion where the two researchers came up with different estimates of species depicted by the students in their drawings, there were realisations that qualitative and aesthetic interpretations of some drawings (the placement of fish, seaweed or goggle frames in the picture plane etc.) differed and therefore added further understandings to the former quantitative analysis. The two researchers had made separate notes about their aesthetic responses and interpretations as well as other comments that had been decided from their qualitative analyses. Often these different interpretations were due to abstract drawings of species or unusual perspectives (such as a tail on the edge of the page). Conversations between the two researchers were important to discuss the different interpretations and raised the issue of aesthetics when using the arts—particularly drawings in educational research for teachers, researchers and students. Referring back repeatedly to the interview transcripts often helped confirm what the students meant or were trying to communicate through their drawings and the role of the researcher. For example, Figure 1 shows two fish drawn in a similar way, yet one is coloured purple and the other orange. These different colour variations suggested they could be different fish species or could also be the same fish species. In Figure 2, Peta has drawn a blue fish tail disappearing off to the right of the page. The researchers had to do a bit of guess work figuring out what this could potentially

be based on its position on the page, its form, colour and the way it was drawn in context to other elements on the page. These different aesthetic observations and interpretations highlighted the need to conduct a thematic and aesthetic qualitative analysis into both the drawings and interview data.

Results

Thematic nodes

An analysis of all the interview transcripts ($n = 13$ students) following the students' first drawing, revealed the 8 thematic nodes based on a wide range of aesthetic responses and uses in the interview dialogue and in connection with the first drawings (see Table 1; nodes 1–8). The nodes are ordered randomly in Table 1 and represent no particular sequence of preference or frequency of nodes.

An analysis of all the transcripts following the students' second drawings, found the above 8 nodes as well two additional thematic nodes 9 and 10 (Table 1). These 10 nodes represent a diversity of aesthetic experiences (from both the learner and researcher), types of responses and reasonings for the aesthetic occurrences in the data. They emerged from searching for aesthetic experiences generally rather than a particular criteria such as 'students' accounts of aesthetics' or 'researchers use of aesthetic languages' because we started to see overlaps with aesthetic occurrences in the data early on. We could identify multiple themes in some statements of researchers and of students so we did not want to just present aesthetic experiences of children's learning separately because (1) this would not be true to each set of narratives as a whole, and would take the narratives out of context, (2) we could identify numerous
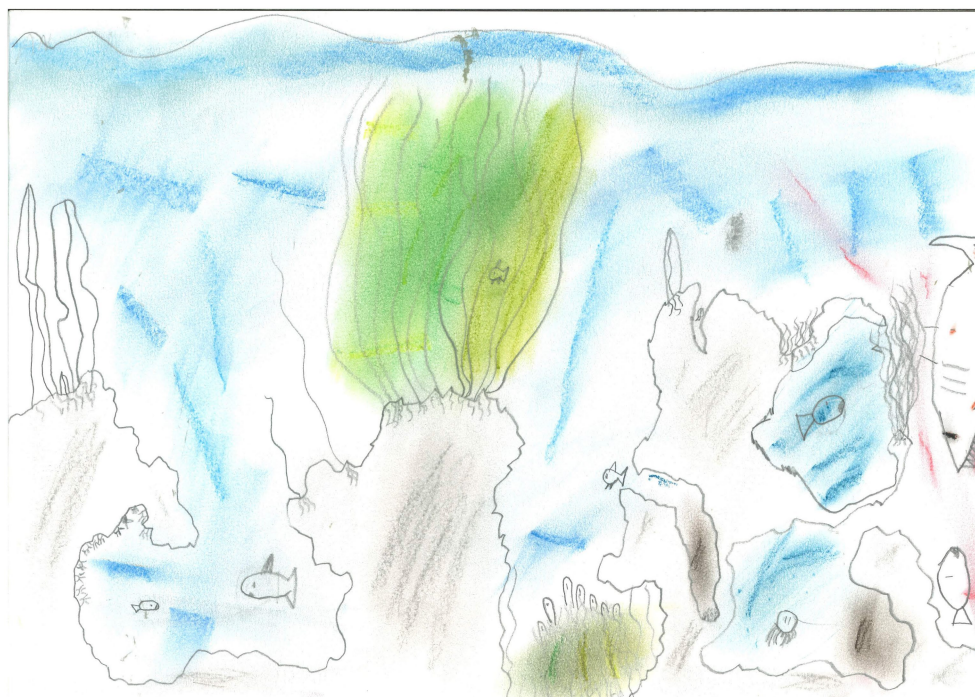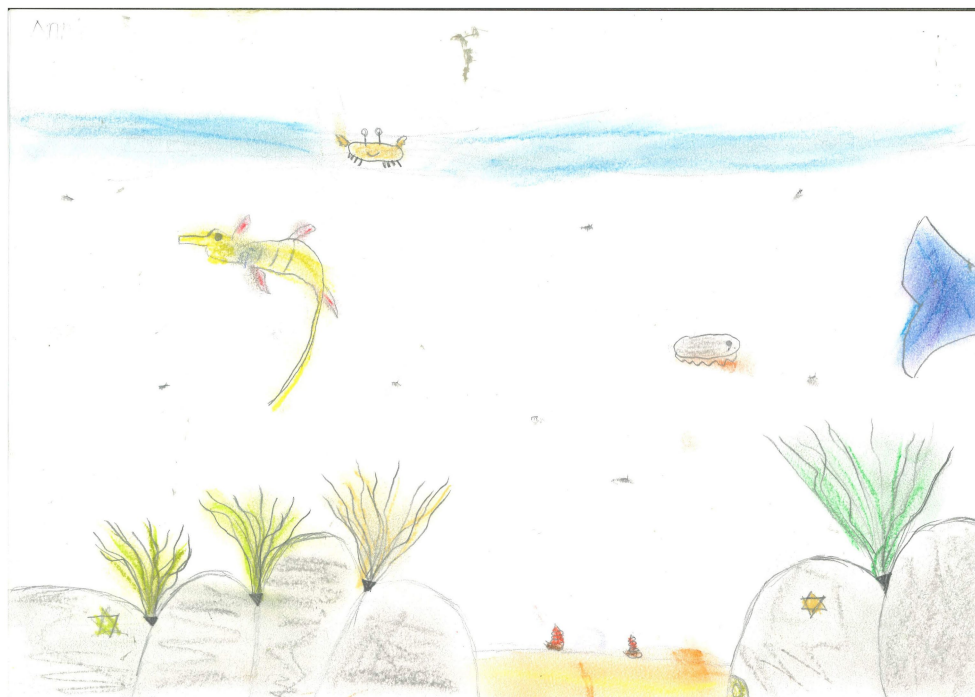

FIGURE 1
Joe's 2nd drawing.

FIGURE 2
Peta's 2nd drawing.

TABLE 1 Thematic nodes based on aesthetics from pre and post student's drawings following a marine education programme.

The 10 thematic nodes:	Example from transcript
1. Aesthetic experiences and communication	**Joe:** And it felt really, hmm.
	R1: Like sandpaper?
	Joe: Slimy.
	R1: Ah slimy. Lucky you, that sounds like a good adventure.
2. Researchers checking student learning/knowledge	**R2:** And the decorator crab is here.
	Joe: I cannot really see it.
	R1: Well, that's the point, is not it? Because the decorator crab must be camouflaged.
	R2: It means you drew it really well.
3. Researchers prompting students to think a bit deeper/explore what they already know (e.g.,: So, you have looked under the ocean. Do you think that what you saw there, might be similar to what might be out here?)	**R2:** So, is the eel hiding in the hole as well?
	Rob: Yeah.
	R1: Yeah, it is almost a very camouflaged this one, whereas this one is still hiding, but you can see a little more, because of the colours you have put there. I like the idea of the mask too.
	R2: Me too, really great idea.
4.Students/artists non-comital about their drawing—a kind blaming lack of ability or not sure about what they were supposed to draw? Or shifting away from being judged/assessed?	**Joe:** The shark mouth, this one looks a bit weird [first drawing], but this one looks a bit better [second drawing] … and the seaweed.
	R1: Yeah, so you have got bigger seaweed in your second picture, do not you?
5. Using knowledge or familiarity with or experiences of place (local names/ identity with place/ knowledge of place etc.)	**Joe:** Excuse me, this is not around here, but I remember when I went up to SeaWorld, no, not SeaWo…, I think… sorry, hmm. And I went to the stingray area, and there was this stingray that was half shark half stingray and I got to feed it.
6. Students explain visual language such as design elements (incomplete colouring) to clarify 'correct' depiction of marine environment (as was required by the project)	**Joe:** I tried to make a different colour with the red and blue, but it did not turn out good the first one.
	R1: So it looks like you have a bit of experimentation with the pastel as well, at the same time, which is great.

(Continued)

TABLE 1 (Continued)

The 10 thematic nodes:	Example from transcript
7. Researchers explain/use visual language to guide the student through the composition & layers of the marine environment.	**R1:** Talk us through what you have got there Peta, what's up the top, what's in the middle and down the bottom there. Because I can see a lot of different things. **Peta:** At the top is like kind of like this purple sledgy stuff, and then there's some birds and then down the bottom is like the ocean, and what I can see down there is pink shells and like rock and fishes and blue and green ocean.
8. Association to popular culture (books, films).	**R1:** And I think what I've also started to see is that you have got a few different other animals present in your second picture too, that… One, I guess, picking out the sea star and picking out the sea urchin, where did you learn that might be sea stars or sea urchins on the GSR?
	Alice: There is a rock pool book.
	Rob: 'Rock Pool Secrets'?
	and another example:
	R1: That's ok. And the East Australian Current, when did you pick up that it exists?
	Peta: When I watched 'Finding Nemo'.
	R1: Ah, the EAC. And so how did you know that a crab potentially might be something that would travel in the EAC?
	Peta: Because in Nemo I saw all like the turtles going in and I did not know where to put the crab, because I did not want to put it down here, so I just draw the EAC and put the crab in there.
9. Seeking insight into learning comparing first and second drawing.	**R1:** So, the sea stars, is that something you have seen more of this term as well?
	Peta: Yeah.
	R1: And so, where have you seen the sea star or learned about the sea star?
	Peta: I learned about the little green sea star when we did the…
	Rob: The ID cards?
	Peta: Yes, the ID cards.
	R1: Sounds like the ID cards were pretty fun.
	Rob: Yeah.
	Peta: Yeah.
10. Researcher/educators clarifying with students their learning (comparing first and second drawing – also including here clarification of 'names')	**Referring to Peta's 1st drawing,** Figure 4 **and 2nd drawing,** Figure 2:
	R1: And I've noticed you mentioned you have got holdfast in your second picture.
	Peta: Yeah.
	R1: Which I'm looking at your first one, can you see if there is any holdfast?
	Peta: No,
	R1: Is that something that you have learned during the term?
	Peta: Yeah
	R1: And where did you learn the term 'holdfast'? Do you remember how you learned about that?
	Peta: At the start of the term, we were all learning about kelp, and I saw one of those at the beach, and I started swinging the seaweed around.
	R1: Fantastic.
	R2: We have also seen it when we went down to the beach, did not we?
	Peta: Yeah.

Student names have been changed for anonymity and R1 and R2 are the interviewers from the research team.

examples of influence such as researchers using aesthetic language which potentially influenced the way students thought or spoke about their work, (3) we could see that aesthetics is embedded in subtle and surprising ways through the relationships of teacher/researcher/ students, artefacts create, experiences, connections to place, style and more. In line with the holistic approach of narrative and arts-based inquiry, we appreciated the whole message being communicated, rather than drawing conclusive understandings from parts of texts.

Josselson (2011) explains that 'it is not the parts that are significant in human life, but how the parts are integrated to create a whole' (p. 226).

We therefore share this full list of 10 thematic nodes here to reveal these findings from early on in our qualitative analysis.

Images of the six students' drawings (a before and after drawing for each student) are provided. Their quantitative analysis scores are presented below to show the differences between pre and post drawings—particularly in relation to including more correct species in their second drawing than in the first drawing:

Joe's 1st drawing (Figure 3).
Quantitative score:12 (breadth:5; extent:4; detail:3).
Joe's 2nd drawing (Figure 1):
Quantitative score:13 (breadth:4; extent:5; detail:4).
Peta's 1st drawing (Figure 4):
Quantitative score: 10 (breadth:4; extent:3; detail: 3).
Peta's 2nd drawing (Figure 2):
Quantitative score: 14 (breadth:4; extent:5; detail:5).
*Rob's 1*st *drawing* (Figure 5):
Quantitative score: 8 (breadth:2; extent:4; detail: 2).
Rob's 2nd drawing (Figure 6):
Quantitative score: 14 (breadth:5; extent:5; detail: 4).

As our discussion for this paper is based more on the qualitative and aesthetic analysis of the methods used, we focus our results and discussion on four findings from Table 1, based on the three student data sets of drawings and analysed transcripts:

1. The need to acknowledge the aesthetics of the drawings in conjunction with words and meanings.

2. The aesthetic experiences and communication.
3. The role of aesthetics in student learning evident in the children's reasonings about their drawings and subject matter.
4. Student's place experience.

The need to acknowledge the aesthetics of the drawings in conjunction with words and meanings

The analysis presented in Table 1 clarified to the researchers that those conducting the interviews used aesthetic language (see thematic node 1, 2, and 3 in Table 1) to encourage the students in their drawing ability, confidence and provide re-assurance. This was important given that the focus of the research was about students recording knowledge of correct species and correct representations of their surrounding environment in their drawings and that a number of students were found to be making 'excuses' for their drawing ability (Table 1, thematic node 4 and Table 2, line 3). These excuses could be viewed on the one hand as depicting the correct species in the correct way and therefore being right or wrong in their assessment, and on the other hand about insecurities about their actual drawing ability as in this example with reference to Joe's first drawing (Figure 3):

R2: And you said this is a great white? Joe: Yes, I did its mouth a bit weird though.
R1: Well, that's hard is not it to draw a fish? You've all done a wonderful job. Joe: And the smudging, I did not do a good job.
R1: Yeah, it is hard to do the smudging. You've done pretty good though. Came out really well.

FIGURE 3
Joe's 1st drawing.

Peta's 1st drawing.

During the first phase of analysis when drawings were assessed quantitatively, we had realised that we also needed to consider some of our own aesthetic contributions to the research process such as clarifying and checking our own interpretations of what students were communicating in their drawings, against the transcripts. We also made our individual notes about some of the uniquely aesthetic ways in which each student recorded, depicted, represented, and therefore understood the marine environment and species in their drawings. These notes were helpful at this quantitative analysis stage to be more conscious of our interpretive thinking through the writing process of researchers' note-taking, then being able to share these excerpts with each other. This practice was derived from 'bracketing out' when conducting phenomenological research analysis. This bracketing out our own assumptions through journal or diary writing was put forward by Moustakas (1994) as a way to express and make more conscious our own interpretations and assumptions, so they do not subconsciously start to influence our researcher interpretations and analysis. A case in point is with reference to Figure 5, Rob's 1st drawing and the comments that the two researchers made following their quantitative analysis of this drawing:

R3's analysis noted that: Interesting perspective through snorkel goggles. I like how the drawing of the black round fish can be seen. It's as if they started drawing it big then decided to make it smaller (maybe thinking of things in proportion to each other?) Or is this sketchy drawn circle an air pocket of some description they have learnt about? I love the little fish coming out of the rock and the coloured thing that seems to weave or lie behind the plankton on the right.

R2's analysis noted that: This is a great drawing, and all the marine organisms have distinguishable features. In terms of the marine habitat, the variety and strong colours used indicate a representation of a tropical marine environment, rather than a temperate one.

Whilst such reflective notes on this example, did not counter the quantitative analysis, it did reveal to the researchers that differing interpretations and individual aesthetic responses, combined with the unique style of each child's drawing, needed careful consideration to really understand what the students recalled and learnt during their marine education programme. It was important to consider some of the children's reasons for placing marine species where they did in their drawing, depicting them as a particular size compared to others, and their use of words (labels
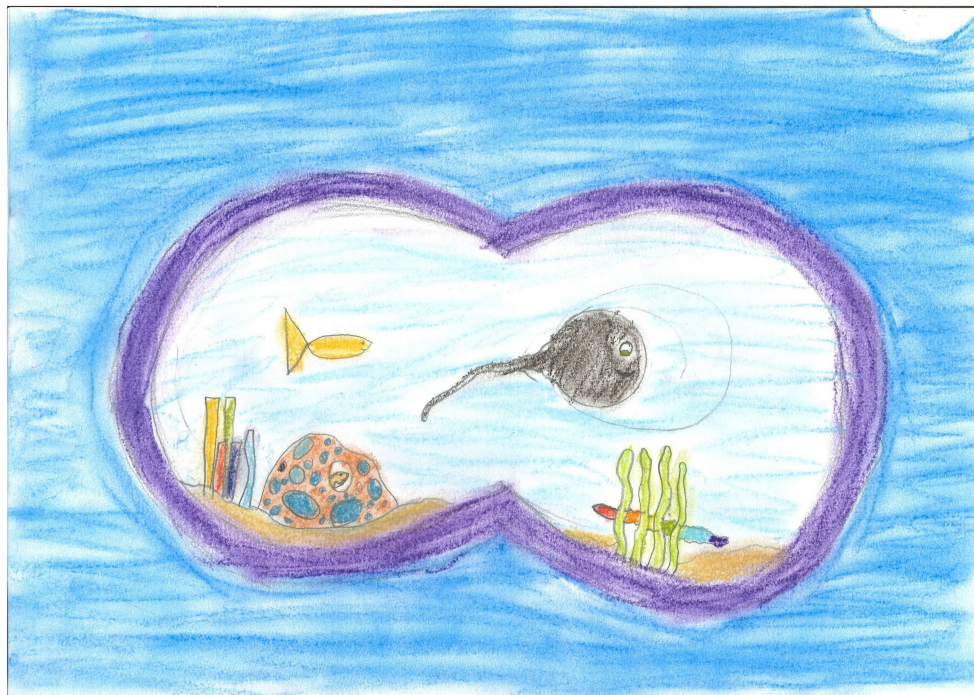
FIGURE 5
Rob's 1st drawing.
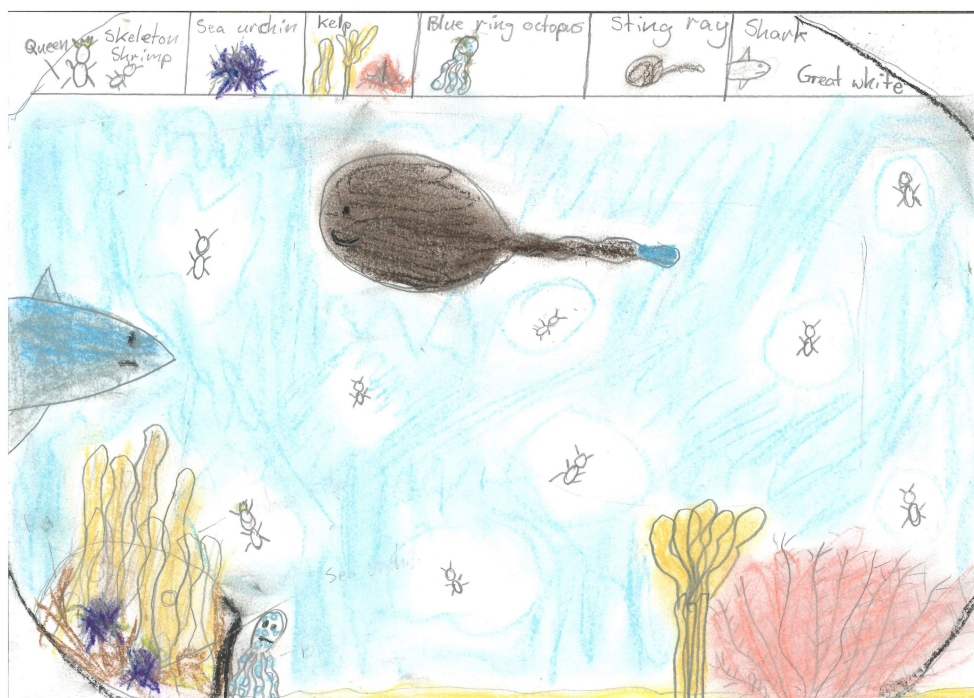
FIGURE 6
Rob's 2nd drawing.

and descriptions). Examples of this are seen within Rob's drawing and interview (see Figure 6; Table 3, line 38) and Joe's drawing and interview (Figure 3; Table 4).

What the research analysis here required was a little like Tinio's (2013) Mirror Model of Art whereby the aesthetic experience of

someone perceiving an artwork can be in reverse order of the steps the artist took during their creative artistic process. This could also be understood in terms of the model presented earlier of (H), (I), and (E). Tinio's (2013) concept involves understanding layers of materials that go together to create the final result, starting with an initial idea

TABLE 2 Rob's 1st interview.

1 *Rob: So, I have like the snorkel surrounding and that's just the ocean, and that's in*
2 *the ocean and there's a stingray. I tried to make it a bit cartoony because I don't want*
3 *to make it real, because it's hard to draw.*
4 *R1: Fair enough.*
5 *Rob: And then I have two eels here, one's in seaweed, and there's one in this little*
6 *rock thing like (referring to another student's drawing), with all these holes, and then*
7 *there's just a fish there and then some coral and seaweed.*
8 *R1: So this is, over here—some coral and seaweed?*
9 *Rob: Yes*
10 *R1: Yeah, fantastic.*
11 *R2: So, is the eel hiding in the hole as well?*
12 *Rob: Yeah.*
13 *R1: Yeah, it is almost a very camouflaged one this one, whereas this one is still*
14 *hiding, but you can see a little more, because of the colours you've put there. I like the idea of the*
15 *mask too.*
16 *R2: Me too, really great idea.*
17 *R1: And have you snorkelled out here before?*
18 *Rob: No, never snorkelled.*
19 *R1: So, this is what you imagine you might see.*
20 *Rob: Yes. I've snorkelled like out of Australia, but not in Australia.*
21 *R1: Aww, lucky you, that sounds like a real adventure that one.*
22 *R2: Is this similar to what you've seen before while snorkelling?*
23 *Rob: Hmm, no, not really.*
24 *R2: So, this is what you imagine it would be down here?*
25 *Rob: I just draw what I might see.*
26 *R1: Brilliant, love it. Thank you for sharing.*

in reverse order. Vartanian (2017) suggests this model has the potential to bridge 'the gap between psychologies of creativity and art appreciation' which 'will contribute to the challenge of explicitly contextualising art appreciation by linking viewer characteristics to the intentions of the creator—in reverse order' (p.29). This applies to the children's drawing in this project as they had an intention for their drawing (which was based on the prompt 'draw a picture of what you would expect to find if you were snorkelling on your local beach') and knew they were being assessed on correct species contained in their drawings.

As the researchers were looking for correct and incorrect species depicted in the student's drawings, the researchers were viewing, interpreting, judging and understanding the drawings with this shared intentionality in mind.

Like the scholars above Dewey (1934) also believed that to understand art requires 'discovering the nature of the production of works of art' (p. 11). Gulla (2020) notes how,

> Through their own creative expression, students enter into a transaction with the works of art they are studying. A good deal of the questioning and discussion process involves understanding how the choices made by an artist, writer, musician, dancer, or filmmaker comprise the aesthetics of their work. These discussions of aesthetics help students recognise their own agency in creating work in which they are truly invested (p. 209).

Although this example might relate more to students of art classes, it was important in the interviews to gain an understanding about student's reasoning for the subject matter, perspective and compositions of their drawings and the processes students went through to build these drawings up, from their interviews. Evidence of rubbing images out (see Figure 3) or attempting to colour in a small drawn fish with chunky chalk-pastel (see Figure 6), revealed stages of such creative processes. Interview transcripts offered the researchers further insight into how and why the drawings were created in these particular ways and to clarify some of the subject matter within the drawings from these creative processes.

Furthermore, the conversations in interviews were important in context to the aesthetic dimensions of drawings, for students to clearly show their learning. An example of this is in Table 3 (lines 24–27) where Rob communicates that he had learnt the actual correct colours and was able to include this correct information in his second drawing compared to his first drawing.

The aesthetic experiences and communication

The use of words and images in this research process included children communicating their knowledge and what they learnt, but at the same time communicating aspects of their environment and related activities such as holidaying in other marine environments, snorkelling in other locations, boating and fishing with their parents at their local pier. As the interviewers were also the researchers who taught them on field trips and in some of the classroom workshops, the interview transcripts and drawings that accompanied these could be seen both as part of the science/art education experiences for students as well as forms of assessment. This dynamic could be understood in terms of 'language games' (Wittgenstein, 1967, cited in Wickman, 2017, p. 22) with art. Wickman (2017) explains 'language is action and part of shared activities such as buying clothes, travelling on a bus, or for that matter taking part in science class' (p. 22), language games 'can be seen as habits, customs and institutions through which meaning happens' (p. 23).

An example of the 'language games with art' can be seen in Rob's explanation of his first drawing (Figure 5) and the researchers attempts to understand his 'words' and his drawn imagery (Table 2, lines 1–15).

This Table 2 transcript reveals the aesthetic experiences and ways of communicating by Rob (e.g.,: lines 1–3). It also shows aesthetic use of language was used by the interviewers when encouraging (e.g.,: lines 10 and 26) and validating (lines 13–16) this drawing for Rob.

With reference to Joe's first drawing (Figure 3) below, RI reinforces how well Joe has drawn the decorator crab in its correct environment re-iterating the factual knowledge 'the decorator crab must be camouflaged'. R2 follows this up with an encouraging statement about Joe's drawing ability and the correctness of the species, 'It means you drew it really well'.

These transcripts offer insight into the way the interviewers (who had also taught them some of this knowledge) were inquiring about the students learning and getting each student to use words in conjunction with the drawing content, to confirm this learning. Bringing the drawings and words together around this common purpose of learning about the marine environment allows the aesthetic experiences, expressions and knowledge to come through. It offers insights to student learning that we would otherwise not

TABLE 3 Part A of Rob's 2nd interview.

1   R1: All right, Rob, you want to explain your second drawing for us, please?
2   Rob: Yes, I have some skeleton shrimps just everywhere, basically.
3   R1: Yeah, wow!
4   Rob: I also have a great white shark over here… a stingray, some golden kelp on the
5   rock shore. I've got some sea urchins and a blue ringed octopus and some bull kelp
6   and coralline kelp.
7   R1: Ahhh, coralline. And tell us what you have got at the top of the picture there.
8   Rob: Oh, just like all the species that are down here. Instead of like naming them
9   down here, I just put them up there.
10   R1: So, it is like a key?
11   Rob: Yes.
12   R1: Fantastic.
13   R2: Really good.
14   R1: And so, in terms of… I see there's a couple of things that is mentioned twice in your picture… the stingray. Can you explain to me why you sort of kept that in there
15   this time around in the second picture?
16   Rob: Because, at the start I knew there were stingrays like in (town name), but now I
17   actually know that there's stingrays in the GSR.
18   R1: Sounds like the stingrays are quite iconic for the (town name) pier, yeah?
19   Rob: Yeah.
20   R1: And so, looking at your picture, because you did the drawing through the lens of
21   a snorkel mask, have not you?
22   Rob: Yeah.
23   R1: So, this time around, what differences do you see that you have changed?
24   Rob: I did not do like… just play around with the seaweed and the eel. I did the actual
25   colours and I knew the actual colours, and… yeah, that's…
26   R1: I think it's a lot more specific in terms of the animals and the creatures you have
27   drawn.
28   Rob: Yeah.
29   R1: Because I see you have got the fish in your first drawing, but whereas now, this time
30   when you explained your drawing, you said 'this is a great white shark, this is a blue
31   ringed octopus, this is a skeleton shrimp' You've given names to what you have drawn
32   this time around.
33   Rob: Yeah.
34   R1: And do you think that's from something that you have learned?
35   Rob: Yeah.
36   R1: So where would have you may pick up those names?
37   Rob: I've got the skeleton shrimp from the ID cards.
38   R1: Ah, yeah.
39   Rob: And the stingrays I always knew, the blue ringed octopus, I knew they were in
40   Australia, but I did not think much of them, and when I went away on my trip, I learned
41   more about them.
42   R1: Fantastic. And what about the kelp and the seaweed you mentioned before? Did
43   you learn more about those?
44   Rob: Yea, I learnt them sort of when I came back from my trip.
45   R1: Ok, fantastic.

TABLE 4 Joe's interview with reference to his first drawing, Figure 3.

1   R1: I also noticed you even labelled some of the things you've got here. You
2   labelled the crab and the crayfish too I see.
3   R2: And the decorator crab is here.
4   Joe: I can't really see it.
5   R1: Well, that's the point, isn't it? Because the decorator crab must be
6   camouflaged.
7   R2: It means you drew it really well.
8   Joe: that's why I labelled it. Everyone would think that it's just pile of
9   seaweed but it is where the animals live.

be aware of. As Wickman (2017, p. 23) notes, we 'need to be given agency and act in relation to purpose to be deemed to have learned anything of value by others and ourselves'.

The role of aesthetics in student learning was evident in the children's reasoning about their drawings and subject matter within these drawings

Learning involves change over time. The two drawings created before and after the educational programme for each student were a way to see and hear evidence of this student learning across time. In

Rob's 2nd interview about his 2nd drawing (Table 3; Figure 6) he explains and names the different species more confidently than in the first interview (Table 2, lines 37–45). He is also able to explain where he learnt this from (he mentions The ID cards and also reflections from going away on holiday and coming home again)—see Table 3 line 38. It is possible that without the drawing experiences, and reflecting on the drawings through these interviews, that we as researchers or the children might not have the opportunity to reflect on these diverse aspects of their learning. It seems having the drawing in front of them, and prompts by the researchers, provide opportunity for each child to talk about these multi-modal experiences that all contribute to their learning over time.

At this interview about his 2nd drawing, Rob is able to explain why fish, kelp and other species are placed on his drawing composition, in connection or relation to each other—therefore presenting both contextual and aesthetic knowledge about his learning of the marine environment. From the transcript in Table 3 Rob explains, 'I have some skeleton shrimps just everywhere' (line 2). This suggests his understanding of how shrimp might appear in the ocean 'everywhere' (as opposed to sitting on a rock or floating on the top of the sea) and also not in a regular patterned 'school formation'. This shows how Rob has captured this knowledge and image as a formal element of his drawing; pencil-drawn creatures randomly placed on the page surrounded by white. Whilst this 'form' is not factually correct, we can understand the different drawing-treatment of shrimp from the way other species are drawn and coloured (fish, seaweed, rocks), as differentiated from other species. Making something look different by using a different drawing technique can be a way to show knowledge and learning.

The quantitative analysis of how many species were correct in the drawings was complimented by checking where the student had learnt particular knowledge or information and to confirm more learning had occurred when comparing the 1st drawing to the 2nd drawing. Rob's two drawings, and the above transcript show that a progression and accrual of knowledge took place over the course of the project. The student's knowledge and experiences of the two different locations of tropical waters in the north of Australia (where 'Nemo's' exist and where some students holidayed) and the GSR, needed to be teased out in this research process and it was important for the researchers to identify this and address it. For example, it was found that students had less tropical fish, turtles and coral species in their second drawings than in their first. This accrual of knowledge evident from the first drawing to the second could be seen in this example.

Student's place and experience

As discussed earlier, the place was an important consideration given the research was focused on a specific region of the world (the GSR) and therefore it made sense to teach and research with the children who lived near this marine environment. The research revealed that most of the students were experienced with their local ocean environment through surfing, snorkelling, fishing and exploring the rock pools and seashore. With reference to Table 2, Rob's 1st interview, even though Rob had not snorkelled in Australia or at his local beach, he had snorkelled in other parts of the world, and used that experience to depict this perspective through the shape of snorkel goggles. Within this goggle frame (Figure 5) he visually expressed and depicted what he 'might see' from his learning of his local marine environment. The prompt from the marine science

researchers for the students' drawing tasks had been 'draw a picture of what you would expect to find if you were snorkelling on your local beach'. The word 'imagine' was not used so it was interesting in the transcript of Rob's 1st interview (Table 2), that he did not use the word 'imagine' as the researchers did, instead choosing the word 'might'. This could be understood as 'you cannot always see what you hope to see when you snorkel—chance plays a part in what marine species you could actually put into this drawing perspective through snorkel goggles at any one time'. This is because the ocean, through currents, is always moving therefore the use of the word 'might' is applicable in this context. This of course also relates to word games with art as mentioned earlier.

Place and experience (Malpas, 2018) was also evident in the following transcripts where Rob is discussing his second drawing (Figure 6). Table 3 excerpt shows how learning about stingrays has taken place in the local environment of the student and how the new knowledge he has learnt enhanced his knowledge about local marine species. He is also able to make connections with studying the ID cards and his trip away to other places (see Table 3). This raises the issue of how this kind of programme might work for communities that are far away from a marine environment. Singhal (2019) writes about a 12 h trip that 40 students from far west NSW took to visit the beach: 'For many of the Aboriginal students from Brewarrina, Weilmoringle, Bourke and Goodooga, it was their first time seeing the ocean' (n.p). Whilst it is possible that a taste or interestedness in a topic may not necessarily be connected to what you are already familiar with, the ability of students to reflect on contrasting environments as part of their learning in this study, shows how the strategy of depicting before and after drawings in and out of one's environment or place, over time, are beneficial for students to engage in reflective learning and provide evidence of this as has occurred in the drawings in this study. As most of the arts involve the body in spaces and places and doing things (Brook, 2008), the body is an important consideration of this research and the learning experiences children had. Rodaway (2005) explores the body as a 'sense organ' in place, which is a reminder that place is a sensory experience (Tuan, 1977) as well as an aesthetic experience. Remembering and recalling knowledge and places are also important. As Casey (2001) points out, the body remembers: 'the lingering of place in body once it has been established there by experience' (p. 719) which also has an impact on learning.

Discussion

We have shared in this paper the design and implementation of this marine education programme with a focus on the methodology and methods used. We have discussed some of the findings of disciplinary aesthetics where the focus was marine science incorporating art and narrative. This research resonates with Krechevsky et al.'s (2013) statement that 'the beliefs that learning is purposeful, social, emotional, empowering, and representation provide a pedagogical basis for making learning and learners visible' (p.58). Specifically, this was achieved through focusing on children learning about their local marine environment initiated by professional researchers as teachers, and empowering environmental stewardship.

Whilst art (drawing) was primarily used to get students to draw, compose, express and present their learning, the anticipation to conduct the drawing activities and then engage in creating the drawings, were

also part of the learning experiences. Art was not used embedded in the science teaching experiences to the extent it could be, such as in drama where stem cells are enacted in embodied and social ways (White and Raphael, 2023) or lab experiments documented through drawings, photographs during scientific experiments (Evagorou et al., 2015). However, the opportunity to combine: experiences of environment, place, reflecting on own lived experiences, propositional and non-propositional knowledge, creating pre and post drawings then talking about these, involved learning in aesthetic and multi-modal ways. Drawing their knowledge and being able to discuss these drawings, were some of the ways students' learning in this project became visible as we could see their development within each drawing and through comparing both drawings as well. Our analysis shared in this paper shows how we need to consider the aesthetic implications of such visible learning opportunities at intervals and during the process of an educational programme in both teaching and research.

For the pre and post drawings used in our methods, it is important to note that there wasn't a restrictive template to use, or (as there might be in art classes) a limitation of a colour palette or a stylistic criteria, that students were required to meet. This is an important distinction to make in the design of these lessons and the assessment process of the drawings. The alternative would have been to have templates where children draw and fill in species, which would have been less of an aesthetic (and potentially enjoyable) experience for the students but probably easier to analyse quantitatively. We believe that enabling students to draw in an expressive and aesthetic way, rather than merely illustrate what is already out there, or fill in a template, can actually generate more insight into student learning, provided the time and considerations of interpretation, is put into understanding what the students mean by their imagery. Enabling students to have more aesthetic experiences, present their own unique perspectives (goggles on Figure 5) and their own stylistic preferences (as can be seen by the different styles of each drawing) may be potentially harder and complicated to understand and analyse but provides more insight into children's different perceptions and multi-modal learning.

As this special issue will reveal, in both teaching and research, aesthetic experiences can be hidden and they are useful to go searching for to understand education better. We have shown examples of the individual aesthetic experiences for the child participants as well as the researchers and how important these were to understand more about how and what the children learnt and the important role of aesthetics and interpretation for all involved. The aesthetic language the students and interviewer/researchers used, as well as the aesthetics of each drawing (style, mood, composition, perspective, scale, colours, tone theme) are highlighted in this paper to show the value of providing aesthetic opportunities for all involved in teaching and research—particularly when art and language (which traditionally are aesthetic) are combined with other subjects like science to enhance teaching and learning opportunities. Attending to aesthetics in such work can reveal greater insights into learning and the dynamics of relationships between teachers, researchers and students.

We have shared our methodology and methods employed, which helped us to decipher meaning from the data. Whilst interviews in research methods are common, our paper highlights the need to combine interviews or opportunities for students to explain their art when it is being assessed in education contexts and/ or in research. When art is combined with other subjects in education or research, students and participants need to be able to

explain it and data needs to be interrogated with careful consideration of interpretations. When doing so, researchers in particular need to carefully consider the exchange of aesthetic language through conversation, drawings and words in drawings (i.e., labels) that could influence our interpretations. There are many different interpretations a person could make from a view of the ocean through snorkel goggles—interpretations that could draw on our psychological knowledge, experience, place, prompt and aesthetic choices and preferences. having the opportunity to describe and explain drawings in context to the prompt and the environmental experiences the student (artist) has, allowed the student (artist) to exercise their own aesthetics sensibilities whilst processing, communicating and expressing their learnt knowledge as rob did (see Tables 2, 3, 5; Figure 5). They then allow the researcher or teacher to exercise their own ability to bracket out their own interpretations and assumptions that might be loaded with aesthetic preferences, and really hear and see what the student is learning in a more holistic and place-based/environmental and ecological way.

Place and environment were important to this study. This research has revealed the importance of students learning about local knowledge through drawing, allowing for reflection on their other experiences of the topic (trips away to other marine environments, snorkelling, surfing, fishing at the pier). These more holistic and place-based experiences create opportunity for the learning to be relevant for students' lived experiences and therefore more able to retain the knowledge learnt in a more applied and relevant way. However, as mentioned above, the way students reflected and contrasted their local GSR knowledge, experiences and interest with other place-based experiences (i.e.,: holidaying in tropic regions of northern Australia) and the role of memory and place-based experiences in this, reminds us of the need to provide opportunities for students to make these aesthetic links to other aspects of their lives. This might help them engage and relate more to topics and help them to find a taste or interest in science topics (Anderhag et al., 2015; Anderhag, 2017).

Finally, as a result of the positive outcomes of this project, including an outstanding level of teacher engagement, a new ocean education inquiry unit, focused on coastal sustainability, was developed by the teachers in the school for Foundation to Year 7 students. This exceeded the initial expectations of the research team, particularly considering the main obstacles described in the literature to incorporate ocean literacy in classrooms such as the absence of ocean topics in the school curriculum and teacher's limited understanding of marine science (Gough, 2017; Freitas et al., 2022).

TABLE 5 Part B of Rob's 2nd interview.

1 *R2: Rob, can I just ask one more thing?*
2 *Rob: Yeah*
3 *R2: I think I remember from the first drawing that you mentioned that these*
4 *would be coral, right? This time around, I see that you did not include corals, is that right?*
5 *Rob: Yes.*
6 *R2: And also, you kept the snorkel mask, did not you?*
7 *Rob: Yeah.*
8 *R2: It's just much bigger now, and you have much more detail in your*
9 *drawing.*
10 *Rob: Yeah.*
11 *R1: Fantastic, all right, thanks Rob.*

We look forward to hearing how our methods and methodologies shared in this paper are adapted by the teachers for their teaching and assessment processes and the future surprises we might learn about the role of aesthetics in the nexus of teaching, learning and research.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor P-OW declared a past co-authorship with one of the authors SH.

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Foregrounding co-artistry in an aesthetic and plurilingual/pluriliteracies approach to additional language teaching and learning

Diego L. Albuquerque* and Emilee Moore*

Universitat Autònoma de Barcelona, Barcelona, Catalonia, Spain

In this article, we propose an aesthetic and plurilingual/pluriliteracies approach to additional (or second, foreign…) language teaching and learning. The research reported on took place in a secondary school in Barcelona where young people take on the role of teachers of the host languages (i.e., Catalan and Spanish) to adult migrants. We focus on a plurilingual poetry workshop offered in this program as an empirical foundation for the proposed approach. Data was collected ethnographically during the poetry workshop (i.e., through participant observation, field notes, conversations, video, photography) allowing the exploration of processes and outcomes. We consider, on the one hand, the opportunities for language learning made possible by incorporating arts-based methods and plurilingualism/pluriliteracies in the workshop. On the other hand, we ask what an aesthetic lens, combined with a recognition of plurilingualism/pluriliteracies, can offer to our understanding of language learning outcomes. Our results suggest that co-artistry is an opportunity for enhancing additional language learning in our aesthetic and plurilingual/pluriliteracies approach to additional language teaching and learning.

KEYWORDS

plurilingualism, pluriliteracies, creative inquiry, language education, poetry, adult migrants, co-artistry

1 Introduction

The concept of aesthetic education foregrounds the significance of beauty and the arts in the development of the self (Denac, 2014). Among other aspects, aesthetic education aims to: foster beauty in interpersonal relationships; develop an aesthetic sense and the perception of beauty; and promote the experience, creation, and expression of the aesthetic. Historically, aesthetics and affect have been viewed as distinct from cognition. There is a need to further investigate the connection between aesthetics, affect and the learning of different subjects/disciplines (Wickman et al., 2022). Together with the other

articles in this monograph, our contribution aims to help fill this gap, focusing on the field of additional language education.[1]

In the context of a service-learning project based at a secondary school in Barcelona, we focus on a plurilingual poetry workshop as an empirical foundation for an aesthetic and plurilingual/pluriliteracies approach to additional language teaching and learning. We ask, on the one hand, what opportunities for language learning are made possible by incorporating arts-based methods and plurilingualism/ pluriliteracies in the workshop. On the other hand, we ask what an aesthetic lens, combined with a recognition of plurilingualism/ pluriliteracies, can offer to our understanding of language learning outcomes. We focus on the aesthetic and plurilingual nature of the social interactions among program participants and on the collaborative processes and outcomes of the workshop. We frame these collaborations in terms of 'co-artistry', a concept we introduce below.

We continue this introductory section (1.1 and 1.2) by framing language teaching and learning as aesthetic, plurilingual/pluriliterate action and interaction, or co-artistry. Section 1.3 reviews scholarship on plurilingual poetry, to contextualise and justify the workshop at the centre of our empirical work. We then set out the main methodological considerations guiding our research (section 2). In section 3, we analyse the interactions and artefacts produced during the workshop, followed by the discussion and conclusions (section 4).

1.1 Language teaching and learning as aesthetic action and interaction

Piazzoli's (2018) approach to action and artistry in additional language education, framed within her own work on drama in language teaching, is highly influential to our understanding of aesthetics in our disciplinary field (see also Moore et al., 2021). In her work, Piazzoli frames language teaching and learning as art forms, materialised in the design of lessons, in the improvised interactions between teachers and learners (who she refers to as 'co-artists'), and between learners, in the artefacts used and produced, and so on. Piazzoli follows Eisner's (1985, p.154) broad definition of 'art' as spontaneous, aesthetic activity: "the process in which skills are employed to discover ends through actions." She also draws on Winston (2010), who develops beauty as an educational concept, examining the cognitive, affective, and moral consequences of the experience of beauty. Conceptualising language teaching and learning in terms of aesthetics, according to Piazzoli (following Immordino-Yang, 2016 and others), means recognising that the actions of teaching and learning "involve not only cognition, but also affect, imagery, sensation, different forms of memory, emotion and embodiment" (2019, p. 8).

Piazzoli's understanding of language teaching and learning echoes previous calls in the field of additional language education to give greater recognition to learners' experience, affect and emotions in research and practice (e.g., Kramsch, 2009; Dewaele, 2012). As Garret

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1 We prefer the term 'additional' language over others such as 'second' or 'foreign' language as we believe the former best represents the diversity of language socialisation processes.

and Young (2009, p. 209) point out, "affect and emotion are terms that have been in the shadows of discussions of classroom foreign language learning, where the primary focus has been on the development of knowledge and use of the new language." Piazzoli's work also aligns with sociocultural understandings of language learning as situated action and interaction (e.g., Lantolf and Thorne, 2006), implicating other people, the material environment, and so on. Adopting a sociocultural approach, in the analytical section of this article (section 3) we consider the artefacts produced in the workshop, as well the collaborations between different actors (adult language learners, secondary school students acting as language teachers, adult facilitators), focusing on the importance of what we refer to as co-artistry in additional language learning.

In our research, we are also inspired by Cook's (1997) work on the importance of language play (play being understood as related to aesthetics and affect) in language learning and in human life more generally; speakers and writers play with meaning, play on words, and so on. Such language play, according to Cook (1997, p. 230), might be considered "language for enjoyment, for the self, for its own sake." Current communicative approaches to additional language education foreground the communicative objectives that language teaching and learning seek to achieve. Cook's essay, however, invites us to recognise that language teaching and learning might sometimes not be strictly goal-oriented, but rather be "sometimes play and sometimes for real, sometimes form-focused and sometimes meaning-focused, sometimes fiction and sometimes fact" (Cook, 1997, p. 231). In the analytical section of this article (section 3), we will see examples of this language play as learners craft poetry through collage, mixing elements from poems in different languages to make their own.

Finally, we position our research and educational practice in the emergent field of creative inquiry in applied linguistics. Creative inquiry is frequently defined as "any social research or human inquiry that adapts the tenets of the creative arts as a part of the methodology" (Leavy in Jones and Leavy, 2014, p. 1). We, however, follow Bradley and Harvey's (2019) identification of three categories of creative inquiry work in language education: working *through* the arts, *with* the arts, and *into* the arts. Language education research and practice enacted *through* the arts is broadly concerned with how arts-based methods promote language learning. Teaching and researching *with* the arts refers to how an aesthetic lens (e.g., that of the artist) can help understand language learning. Working *into* the arts refers to how the tools of applied linguistics might offer insights into artistic practices and processes (e.g., how language is used in the arts). In the analytical section of this article, we consider both the affordances of arts-based methods for teaching and researching language (i.e., working *through* the arts), and how adopting an aesthetic lens allows learning processes and outcomes to be understood in new ways (i.e., working *with* the arts).

Based on her investigations of children's plurilingualism in schools in Canada and France, Prasad (2018) affirms that creativity, aesthetics, and plurilingualism are indissolubly connected. Prasad uses collage to ask: 'how does it look and feel to be plurilingual?'. Her research integrates social theories of language representation and plurilingualism to explore not only the linguistic aspects of the children's artwork, but also the aesthetic detail of their collages. Based on her analysis of the students' collages and narratives, Prasad concludes it is impossible to separate their emotional experience from the cognitive process involved in language learning, and the aesthetical

aspect of the process can expand one's plurilingual repertoire. She argues that plurilingual repertoires can be viewed as a multi-layered collage of language(s) and linguistic activities, and the collage enables the students to create art that is aesthetically provocative, associating their feelings, ideas, experiences, and words.

Inspired by work such as Prasad's connecting aesthetics and plurilingualism, we now turn to our understanding of language teaching and learning as practices which necessarily implicate teachers' and learners' plurilingualism/pluriliteracies.

1.2 Language teaching and learning for plurilingualism/pluriliteracies

The sociolinguistic complexities of the 21st century are well documented in academic literature (e.g., Blommaert, 2010). 'Historical' forms of plurilingualism[2], as well as those resulting from demographic mobilities and transformations in communication technologies, are a reality of (especially urban) social life (Appadurai, 1996; Castells, 1996; Blommaert, 2010) and of language classrooms (García, 2009; Conteh and Meier, 2014; May, 2014). In recent years, researchers and teachers have considered how to harness the affordances of plurilingualism for enhancing language teaching and learning. Different terms have been proposed to this end, including *didactics of plurilingualism* (Gajo, 2007, 2014; Llompart et al., 2019), *pluralistic approaches to languages and cultures* (Candelier et al., 2013), *translanguaging pedagogies* (García and Li, 2014; Cenoz and Gorter, 2022), or the *multilingual turn* in language education (Conteh and Meier, 2014; May, 2014).

These approaches share two common principles: the first is the need to de-privilege monolingual ways of 'languaging' in language education. The monolingual 'native speaker' (e.g., as reflected in Chomsky's (1965) classic notion of the 'ideal native speaker') has traditionally been the benchmark against which language competence has been measured. Heller (1999) used the term 'parallel monolingualisms', while Cenoz and García (2017), following Cummins (2008), used the term 'multilingual solitudes', to refer to the traditional understanding that individuals should learn and their languages in isolation from the others in order to attain and display competence. More recently, the notion of plurilingual competence (e.g., Coste et al., 2009; Council of Europe, 2001, 2020; Lüdi and Py, 2009) has been proposed to reconceptualise the full range of knowledge, skills and attitudes (as well as the contextual affordances/restrictions) which allow plurilingual people to mobilise their whole linguistic repertoires to communicate and to learn, including to combine resources from different languages to build meaning.

Similar to this approach to plurilingualism, in recent years what counts as being literate in current contexts of increasing linguistic and cultural diversity, and of transformations in communication technologies, has been called into question. The notion of

pluriliteracies accounts for the ways plurilingualism comes into people's lives in their language practices across media and modes (García et al., 2007; Moore and Vallejo, 2018), including in their writing of poetry, the focus of this article. The pluriliteracies perspective places the integration of language systems and the hybridity of language practices at the forefront of theory and practice, and builds on scholarship from traditions such as New Literacy Studies (Heath, 1983; Street, 1984, 2003), multiliteracies (New London Group, 1996; Cope and Kalantzis, 2000, 2009), biliteracy and multilingual literacies (Hornberger, 2000; Hornberger and Skilton-Sylvester, 2000; Martin-Jones and Jones, 2000).

The second principle common to recent approaches to plurilingualism in language education is the need to overcome the simple separation of languages into different (school) subjects. Different languages are commonly treated as distinct disciplinary sub-fields; they are taught (and researched) in isolation and learners' competence is considered in terms of their ability to 'know' and perform in their different languages separately. So-called *integrated approaches* (e.g., Candelier et al., 2013; Gajo, 2014; De Britos, 2016; Masats and Noguerol, 2016) have been offered as a holistic alternative to traditional language teaching and use learners' whole language repertoires for developing new plurilingual competences.

The poetry workshop at the focus of this article set out from an integrated, plurilingual/pluriliteracies approach to additional language teaching and learning by mobilising learners' whole repertoires for producing poetry. We now discuss previous scholarship on the use of poetry in language education which has inspired the design and interpretation of the workshop.

1.3 Plurilingual poetry

Poetry is commonly part of school (first) language arts curricula; however, it is often approached in an instrumental way (e.g., to enhance writing and reading comprehension) (Simecek and Ellis, 2017).[3] In additional language teaching, poetry is often overlooked (Hanauer, 2014; Kuru Gönen, 2018). Like first language education, when poetry *is* considered, it is mainly described as a useful genre for promoting reading and writing skills in the additional language (e.g., Seargeant and Greenwell, 2013), disregarding its aesthetic value. Hanauer (2011, 2014), however, developed the concept of meaningful literacy in relation to writing poetry in the additional language classroom, referring to phenomenological experience and personal meaning construction. Other scholars have since built on the meaningful literacy learning approach, including Chamcharatsri (2013), Garvin (2013), and Iida (2016).

Hanauer points out that learning a language is embedded in the physical, intellectual, and emotional lives of the individual language learner. The author considers the individual learner to be socially and

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2   We use the notion of 'plurilingualism' to refer to people's knowledge and use of resources from different named languages. Researchers use notions including 'bilingualism' and 'multilingualism' to refer in a similar way to the communicative repertoires of linguistically diverse people, and 'translanguaging' to refer to the use of this repertoire.

3   As pointed out by one of the anonymous reviewers of this article, who we thank for their input, this is the case, for example, of the National curriculum in England: English programmes of study, which contains 17 mentions of the word 'poetry' but does not mention enjoyment or appreciation. See: https://www.gov.uk/government/publications/national-curriculum-in-england-english-programmes-of-study).

culturally contextualised with an extended history of personal experience. Hanauer uses poetry as a way of teaching language because it not only motivates the learner to learn a new language (including figures of speech, rhythm and rhyming, relations of signs and symbols, functions, among others), but it also supports an emotional association with that language. Hanauer proposed four principles to frame his meaningful literacy approach: (1) autobiographical writing; (2) emotional writing; (3) personal insight; and (4) authentic public access. The first principle supports creative writing to explore and comprehend oneself by drawing on memory, imagination, and personal experience. The second encourages students to write in a way that stimulates their emotions and those of the reader and supports the expression of students' feelings. The third integrates a reflective process that results in higher comprehension of the human situation in the long run, as well as deeper appreciation and understanding of one's own experience. The final principal places writing in the context of a social process that involves communicating personal views, understandings, and emotions to others in the language learning classroom and with individuals and communities that are meaningful for the writer. In the analysis section of this article (section 3), we will see that the poetry workshop uses themes that help participants write poems based on their personal experiences, and the poetry is meant to be shared with the broader community. Unfortunately, due to time restrictions, we were not able to reflect with the participants on the process, but our analysis considers the emotional, social, and cultural context of the language classroom.

It is important to note that the aforementioned scholarship is concerned with using poetry to teach a particular language, while our plurilingual poetry workshop was also concerned with using poetry to engage learners' full linguistic repertoires. Following Niaz (2021), we define plurilingual poetry as that in which a poet may use their different languages (and/or their different language varieties) in a single composition. Plurilingual poetry is not new; so-called 'macaronic poetry' by Anglo-Saxon poets in the late 15th century mixed Latin and local vernaculars (Demo, 2018). Arboleda Toro (2017) affirms that plurilingual poetry was also produced during decolonisation processes in the 19th and 20th centuries. More recently, the academic literature includes examples of contemporary plurilingual poetry crafted by diasporic and linguistic minority poets, among others. Domokos (2013), for example, analyses translanguaging (plurilingualism) in poems written by Cia Rinne, a contemporary poet born in Sweden from a Finnish family and raised in Germany. Moore and Tavares (2020) analyse their conversations around Ginalda Tavares' use of dialogue in non-standard varieties of English in her poetry. As Teterina (2014) highlights, plurilingual poetry is not debate-free, with linguists, literary critics, poets, educators, and so on contributing different perspectives on it. Niaz (2019), for example, points to the challenge of understanding poems written in multiple languages. The interpretation of plurilingual poems is a methodological challenge for our research and we thus return to this point in section 2.2.

Different educational projects have used poetry to promote plurilingualism. For example, the *Mother Tongue Other Tongue (MTOT)* project, originally developed by staff in the Faculty of Arts and Humanities at Manchester Metropolitan University and Routes into Languages North West, aimed to value cultural diversity and the various languages used in UK schools (Britos De Britos, 2016). The multilingual poetry project had two distinct sections: *Other tongue*,

allowing young people to write poetry in a language they were learning in school, and *Mother tongue*, inviting non-native English speakers to compose poetry in their mother tongue. The main objectives of MTOT were to celebrate and promote plurilingualism, encourage the use of mother tongues, and foster poetic expression. Also in the UK, Frimberger et al. (2018) used poetry with adult English as a Second or Other Language (ESOL) students from refugee and asylum-seeking backgrounds. Their project used an affirmative approach through poetic mappings of the process of creating what they called 'identity boxes'. The purpose of creating an identity box was to get to know participants: who they are, their desires, and so on. While the adult learners were crafting, the project team (including college educators and researchers) interacted with them through conversations, poetic reflections, etc. Beyond language, the project thus focused on the aesthetics of the making process. Considering some parallels with our workshop, we also foreground the aesthetics of processes and outcomes.

2 Methodology

2.1 Context

2.1.1 Research site

The research reported on in this article is part of a larger research project entitled *constructing a collaborative understanding of learning and teaching for the XXI century*.[4] The project, which runs from 2021–2024, is part of an ongoing collaboration with the AFEX-AFFM[5] program led by Casa Asia[6] and involves different sites at schools in and around Barcelona. AFEX-AFFM is an intergenerational, plurilingual, and inclusive language education project aimed at promoting adult migrants' learning of the local languages (Catalan and Spanish) and literacy. AFEX-AFFM sessions are generally led by a facilitator who shares linguistic and cultural origins with some of the adult participants. In this article, we focus on an experience carried out at a secondary school in Barcelona in which 9th grade students (i.e., 3rd year of compulsory secondary education, approximately 15 years old) act as language teachers for the adults as part of a service-learning project, accompanied by an AFEX-AFFM facilitator and teachers from their school. Spanish was the main language that the adult learners at the site wanted to learn, although Catalan was also present.

Every year, the AFEX-AFFM program proposes different activities for World Poetry Day. Participants need to create plurilingual poems around a specific theme, which are collected in what is called the

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Mostra de Poesia Plurilingüe (Plurilingual Poetry Display) hosted by Casa Asia and shared with the public. Each year the event has a different theme; in 2022 (when the workshop we report on here took place), it was *El meu primer dia* (My first day). As part of this event, a plurilingual poetry workshop was developed by one of the co-authors of this article (Diego L. Albuquerque), two language teachers from the school and the AFEX-AFFM facilitator at the site. Ten young students from the school participated in the implementation as student 'teachers'. A second researcher (Claudia Vallejo) assisted with data collection during the workshop.

The adult language learners in the workshop included ten women and one man. The participants were originally from Pakistan (7 people), India (2 people), and Morocco (2 people). Darija (the Moroccan variety of Arabic), Standard Arabic, Urdu, Punjabi, English, Spanish, and Catalan were spoken. Some of the languages spoken or being learned by the adult learners — i.e., Urdu, in addition to Spanish and Catalan — were spoken also by the participating secondary school students acting as teachers. The AFEX-AFFM facilitator at the site spoke Urdu, Punjabi (Pakistan), Catalan, Spanish, and English, and she could read some Arabic.

2.1.2 Plurilingual poetry workshop

A four-day poetry workshop was designed to help the adult learners write their poems on the theme of *El meu primer dia* (My first day). The activities were:

1 *First words*: Learners were asked to divide an A4 sheet of paper into four parts and write different words as per the instruction given (see Table 1). Then, learners were asked to write a sentence that connected all the words. They were also invited to represent their sentence with an illustration.
2 *Collage*: Poems were selected in the languages that the learners spoke and were distributed to them. Learners read the poems and cut out sentences or words they would like to use to compose their own poems, creating a collage. This activity aimed to encourage the leaners to use their full linguistic repertoires to create poetry and to play with the aesthetics of language.
3 *Writing own plurilingual poem*: Learners wrote their own poem, using the collage poem as a model, but adapting it and incorporating their own words and ideas.

It is important to highlight that in the writing process participants were free to write their poems in the way they wanted. They received no intructions on how to compose a poem, although the collage activity afforded examples of poems that the participants could use for their own writing.

One of the problems faced during the workshop was the lack of attendance by learners (a regular problem at the site). However, this was anticipated by planning activities that could be done without having done others. A shared reading activity and a conversation

about the process were planned, but unfortunately could not be carried out due to time constraints. None of the learners completed all the activities, and only four of them wrote poems due to the others missing sessions. The analysis in this article will examine the written poems completed by these four adult learners and the processes of their creation.

2.2 Methodology

The research presented in this article adopted the principles of collaborative linguistic ethnography in the data collection and analysis (Lassiter, 2015; Ballena et al., 2020; Creese and Blackledge, 2023). Prior to the workshop, researcher/facilitator/co-author (Albuquerque) participated as participant observer at the site for approximately 4 months, during which time he established relationships, carried out informal interviews, participated in activities and kept fieldnotes. Furthermore, the design and implementation of the workshop allowed ethnography to be more than a method of data collection; the school teachers, the AFEX-AFFM facilitator, the researcher and the secondary school student 'teachers' worked together to design the sessions and/or support the adult learners in the process. The data collected during and after the workshop include audio and video recordings of the sessions, interviews, photos, and the poetry collages. Informed consent was obtained prior to the data collection based on procedures approved by the ethics board at the authors' university.

The project also uses creative inquiry or art-based methods, as introduced in section 1.1. Research *through* the arts was used in the project, aiming to inform us about the affordances of the creative activities done in the workshop for promoting plurilingual language learning. This research also works *with* the arts by exploring how an aesthetic lens allows learning processes and artefacts to be interpreted in new ways. Linking arts-based approaches and (linguistic) ethnography has attracted scholarly interest in recent times (Creese and Blackledge, 2023), particularly in educational research (see, among others, contributions to Ferro and Poveda, 2019; Moore et al., 2020). The idea, following Pahl (2014, p. 48), is to understand "the way in which the collaborative space of inquiry that crosses the boundaries of arts practice, ethnography and education can open up new epistemological spaces." Creese and Blackledge [(2023), essay 2] discuss the challenges of incorporating what they call an *ethical-aesthetic perspective* in linguistic ethnography, writing:

> For the linguistic ethnographer, it is a challenge 'not to know' when working with language. […] we are used to tracing language through actions to wider ideologies. In language we categorise, label, position, judge, name and know. […] Now, however, we find ourselves moving away from a position in which we claim to be able to explain the lives of those who are the subject of our research. An ethnographic perspective claims to understand the perspective of the 'other' through their eyes. Linguistic ethnography aims to make audible the voices of those who participate in research. A creative approach to ethnography allows us to stand with those whose voices we represent, to stand beside them but not above them, resisting the urge to say 'I know'.

This position of 'not knowing' is relevant to the process of interpreting the plurilingual poems included in this article.

TABLE 1 Instructions for the *First words* activity.

Write here your favourite word in your mother language	*Write here a word that describes yourself in your second language*
Write here the first word that you learned in Spanish/Catalan	*Write here a word that can describe the best day of your life (in any language)*

Niaz (2019), writing from the field of translation, refers to the 'extra processing effort' required when part of a poem is written in languages unknown to the reader. Our extra processing effort meant seeking transliteration and translation assistance from speakers of the languages used,[7] and paying attention to the authors' use of different languages and rhetorical devices. Furthermore, our interpretations of the poetry foreground the aesthetic qualities of plurilingual poetry and the co-artistry of the process.

The data are presented in section 3 as brief, situated stories or case studies of four adult learners (Norton, 2000; Schwandt and Gates, 2018). The adult learners who are the protagonists of these cases were those who completed a poem as part of the workshop. Broadly speaking, their stories are presented in the form of narratives or vignettes, together with transcripts of the video data, and photographs and transliterations of the learners' work. Bloom-Christen and Grunow (2022, p. 2) link the renewed interest in using vignettes in ethnographic writing to what they call the 'affective turn', which is coherent with the aesthetic approach we take. According to these authors: "Affective scholarship has induced focus on how writing not merely seeks to transport lived affects from the field onto paper, but how it aims to evoke a sense of these affects in the reader." In some cases, we are also able to reconstruct part of what Kell (2009, 2015) refers to as the trajectories of the poems (see also Bradley and Moore, 2018; Moore and Bradley, 2019), by identifying poetic resources, themes or ideas that travel across workshop activities.

Before focusing on the analysis in section 3, we would like to briefly summarise the role of the co-authors in the study. Albuquerque, as we have already mentioned, co-designed and co-delivered the workshops. He also collected the data, transcribed it, and translated it with the support of different collaborators named in this section. Moore acted as advisor during the design, delivery, data collection and treatment phases. She led the integration of the theoretical and methodological frameworks used to approach and interpret the data in this article. Both authors contributed to the analysis of the data, which we now present, and to writing and editing the article.

3 Analysis

In the following sections we present the case studies of four adult learners: Zaya (3.1), Aram (3.2), Zakia (3.3), and Hasbia (3.4).[8]

3.1 Zaya

Zaya is a student of Pakistani origin who speaks and writes Urdu, Punjabi (Pakistan), English, and is learning Spanish. She was present for two of the 4 days of the poetry workshop. In the *First words* activity, Zaya had the support of Bete (a secondary school student 'teacher'). Bete identified as speaking Spanish and Catalan and she sought the help of the program facilitator (Mara) to explain the activity and offer translations to Zaya using her other languages. Recalling the *First words* activity described in section 2.1.2, students divided a piece of paper into four parts and in the different sections wrote: their favourite word in their mother tongue; the first word they learned in Spanish/Catalan; a word describing themselves in their second language; and a word describing the best day of their lives in any language. In the end, they had to create a sentence using all the words and ideas. Figure 1 is of Zaya's completed activity.

As can be seen in Figure 1, Zaya's favourite word is "Ub" in Urdu, which translates to "mother." This is interesting because, as we will see, she uses her connection to her mother and her country in her final poem. The word that she uses to describe herself is "active," which she wrote in Punjabi. Not only Zaya, but also other participants chose "hola" as the first word they learned in Spanish/Catalan. At one point, Mara helps Zaya to spell "hola" (see Extract 1). We assume that Maya names the letters "h," "o," "l" and "a" in the extract in English, a language that she shares with Zaya. Extracts 1–3 in this section are representative of the collaborative nature of Zaya's process.

Extract 1

01 MAR: h ((/eɪʃ/)) o ((/oː/)) (.) l ((/əl/)) (.) a ((/eː/))

Moments later in the session (see Extract 2), when Diego (facilitator/researcher/co-author of this article) approaches the pair, Mara explains to him that Zaya had translated the sentence in the final box, "el mejor día es el día del Eid" (the best day is the day of Eid), from Urdu to Spanish. She explains to Diego in the exchange (line 4) that Eid is a "fiesta" (party") and claims that the word "Eid" should be kept in the translation. Zaya listened on to the conversation between Mara and Diego.

Extract 2

01 MAR:	**ha escrito (.) que el mejor día de su vida (.) sí (.)**
	she has written (.) that the best day of her life (.) yes (.)
02	**el mejor día de (.) ha puesto que el mejor de día de su**
	the best day of (.) she put the best day of her
03	**vida es el día del eid (.)**
	life is the day of eid (.)
04	**bueno (.) es una fiesta (.)**
	well (.) it is a party (.)
05 DIE:	**vale (.) no passa res (.)**
	ok (.) that's ok (.)
06 MAR:	**y (.) entonces (.) yo supongo que la palabra (.) sería eid**
	and (.) then (.) I suppose that the word (.) would be eid

In doing the final part of the *First words* task, Zaya needed to write a sentence in Spanish linking her words. As Bete did not know how to help Zaya, she asked another secondary school student 'teacher',
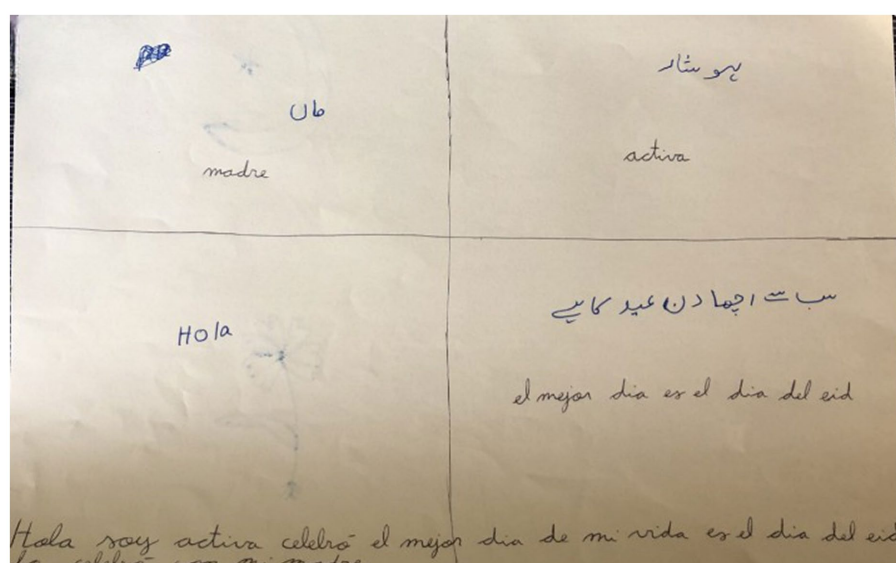
FIGURE 1
Zaya's completed *First words* activity.

Jessica, to assist. Jessica identified as speaking Spanish and Catalan. The conversation in Extract 3 takes place between Bete, Jessica, and Zaya in Spanish:

Extract 3

01 BET: **yo no sé cómo ayudarle (.) a hacer una frase (.)**
I don't know how to help her (.) make a sentence (.)

02 **cómo la ayudo?**
how do I help her?

03 JES: **((incomprehensible))**

04 BET: **pero cómo se las explico?(.)**
but how do I explain them to her?(.)

05 **no se lo puedo escribir yo (.) tiene que escribir ella (.)**
I can't write it for her (.) she has to write it (.)

06 JES: **qué palabras son? (.)**
which words are they? (.)

07 BET: **éstas (.)**
these ones (.)

08 JES: **vale (.) vale (.) sí (.)**
ok (.) ok (.) yes (.)

09 **hola (.) madre (.) activa (.) es el día de (.)**
hello (.) mother (.) active (.) it is the day of (.)

10 BET: **eid(.)**
eid(.)

11 JES: **eid (.) eid.(.) qué es eid? (.)**
eid (.) eid.(.) what is eid? (.)

12 BET: **una cosa de su país (.)**
a thing from her country (.)

13 JES: **ah vale vale (.) hola mi madre es activa (.)**
ah okay okay (.) hello my mother is active (.)

14 ZAY: **fiesta (.)**
party (.)

15 JES: **ah una fiesta vale (.)**
ah a party okay(.)

16 **hola (.) madre activa (.)**
hello (.) active mother (.)

17 **soy activa no? (.)**
I'm active right? (.)

18 **hola (.) soy (.) activa (.)**
hello (.) I'm (.) active. (.)

19 BET: **hola soy activa (.)**
hello I'm active. (.)

20 JES: **y celebro (.) el (.) día (.) de (.) eid con mi madre**
and I celebrate (.) the (.) day (.) of (.) eid with my mother.

We see in Extract 3 how the two secondary school student 'teachers' actively take on the role of supporting Zaya to write her final sentence in Spanish. At the same time Zaya, who carefully listens to the conversation in Spanish between them, speaks up to explain that Eid is a "fiesta" (line 14) — seemingly taking up the description she had heard Mara previously give to Diego — which in turn helps Bete and Jessica to suggest incorporating the idea of a celebration in the sentence.

During the workshop sessions, the secondary school student 'teachers' who helped the adult learners in the process of co-artistry were not always the same for all the activities. In writing her poem (untitled), Zaya had the support of a different student, Arial. Arial's parents were from Morocco, and Arial identified as speaking Spanish and Catalan. Figure 2 is a photograph of Zaya and Arial's completed poem. Below the photographs of all the poems we have included transliterations and translations of them.

Transliteration of Zaya's poem (*untitled*):

میری ماں بہت پیاری ماں ہے۔
Mi madre tierna, tú eres mi centro en centro en este mundo.
میرا ملک پاکستان بہت اچھا ہے۔
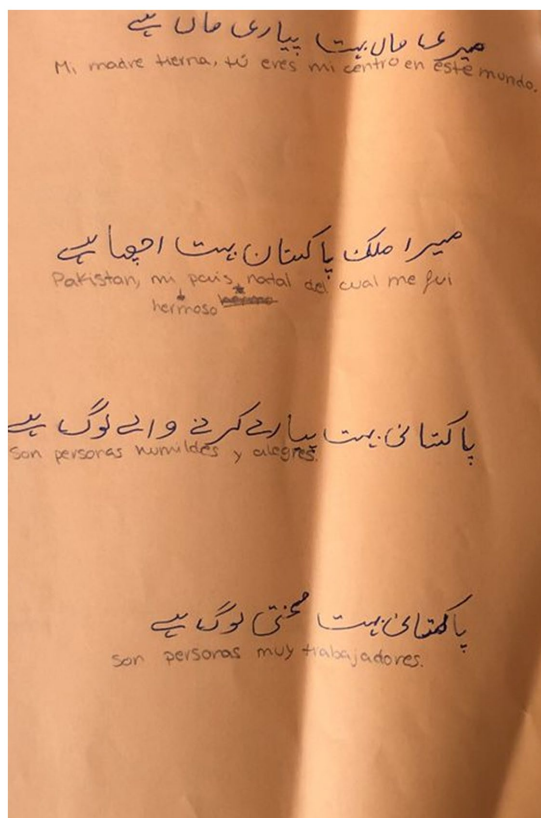Pakistan mi hermoso país natal del cual me fui.

FIGURE 2
Zaya and Arial's poem (untitled).

پاكستانى بہت پيار كرنے والے لوگ ہيں۔
Son personas humildes y alegres.
پاكستانى بہت محنتى لوگ ہيں۔
Son personas muy trabajadoras.

Translation of Zaya's poem (*untitled*):

My mother is a very sweet mother.
My tender mother, you are my centre in this world.
My country Pakistan is very good.
Pakistan my beautiful birth country which I left.
Pakistanis are very loving people.
They are humble and cheerful people.
Pakistanis are very hardworking people.
They are very hardworking people.

The first thing we might notice about Zaya and Arial's poem is that it is untitled, which might have different explanations (e.g., she could not think of an appropriate title, or she forgot to add one). Interestingly, we find traces of Zaya's response to the *First words* activity in the poem: Zaya's poem describes her mother, her country of origin (Pakistan), and Pakistani people. Zaya's poem does not describe a specific first day, in accordance with the theme of the *Mostra de Poesia Plurilingüe* (Plurilingual Poetry Display). Rather, Zaya's poem expresses her emotions and makes connections to her roots.

While Zaya is fluent in English and Punjabi, she only uses Urdu and Spanish in her poetry. The poem is written in two different scripts, with lines in Urdu (bold font in the translation) followed by ones in Spanish (standard font). Zaya first wrote her poem in Urdu; however, the activity was to write a plurilingual poem. Arial thus helped her to express her ideas in Spanish. As Arial did not speak Urdu, she and Zaya called on the facilitator (Mara) to translate lines from Urdu to Spanish. However, the translation is not a literal one, with the lines in Spanish adding ideas, actions, and emotions to the Urdu original (e.g., compare "My country Pakistan is very good" in Urdu with "Pakistan my beautiful birth country from which I left" in Spanish). The plurilingual poem was thus the result of collaboration between the adult learner, the secondary school student 'teacher', and the facilitator. In incorporating Urdu and Spanish in the poem, the co-artists engaged emotionally and aesthetically with the task, going beyond the literal, word-for-word meaning of the lines to jointly craft the plurilingual poem.

3.2 Aram

The day of the collage activity (activity 2 of the workshop, see 2.1.2.) was the first day for the Moroccan siblings, Aram and Safira, in the AFEX-AFFM program. They joined the sessions to learn Spanish. They decided to do the collage activity together with the help of Arial (a secondary school student 'teacher' introduced in section 3.1). Arial suggested that Aram and Safira complete the collage activity by cutting out letters from the poems provided in different languages to make sentences about their first day in their new country and in the program:

Extract 4

01 ARI:	**eh (.) recortamos así las frases y (.) vamos (.)**
	eh (.) we cut the sentences like this and (.) we go (.)
02	**cortando las letras (.) para**
	cutting the letters (.) to
03	**poder hacer palabras (.)**
	be able to make words (.)
04 SAF:	**sí (.) mejor letras (.)**
	yes (.) better letters (.)

Safira, in Extract 4 (line 4) agrees to Arial's suggestion as to how to do the task. As there were no other Arabic speaking adult learners in the group, and Aram and Safira were not expected, the workshop leaders had not prepared poems in Arabic. Thus, Aram and Safira had to write their own words in Arabic to complete the plurilingual collage task. Their completed collage is depicted in Figure 3.

Transliteration of Aram and Safira's collage:

el primer dia me seti.
في أول يوم أحسست بكل شيء غريب.

Translation of Aram and Safira's collage:

the first day i felt.
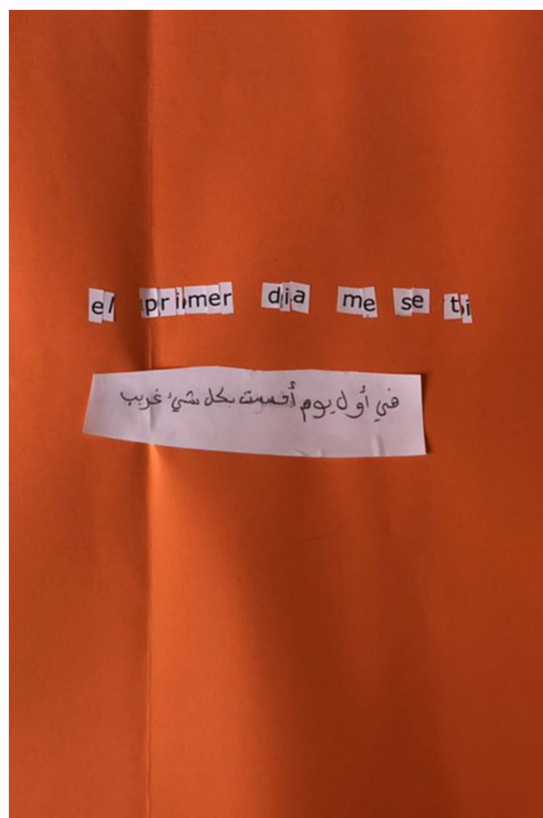**On my first day everything felt strange.**

FIGURE 3
Aram and Safira's completed collage.

FIGURE 4
Aram, Madu and Karina's poem (*Primer dia en Barcelona*).

We deduce that the first line of the collage, in Spanish (standard font in the translation), means "the first day I felt," although the "n" is missing in Spanish (i.e., the collague reads "seti" instead of "sentí"). The second line, in Arabic (bold font in the translation), reads: "On my first day everything felt strange." We do not know whether Aram and Safira were reflecting on the strangeness of their first day in their new country, or on the strangeness of their first day in the AFEX-AFFM program, although their collage would probably adequately describe both situations for them.

When it came to writing their own poems, Aram and Safira were put in different groups. Safira decided not to continue her writing process, claiming that writing poetry was difficult for her, and instead chose to do more traditional language learning exercises provided in the AFEX-AFFM sessions. Aram did continue and was assisted by two secondary school student 'teachers', Madu and Karina, who crafted the poem *Primer dia en Barcelona* (First day in Barcelona) with him. Madu identified as speaking Spanish and Catalan. In some sessions, he was very quiet. Working with Aram and Karina, however, he contributed ideas and wrote the poem with the other participants. Karina was born in Barcelona, but she identified as being from Ecuador. She spoke Spanish and Catalan. The poem is depicted in Figure 4.

Transliteration of Aram's poem *(Primer dia en Barcelona):*

Le gusta la ciudad.
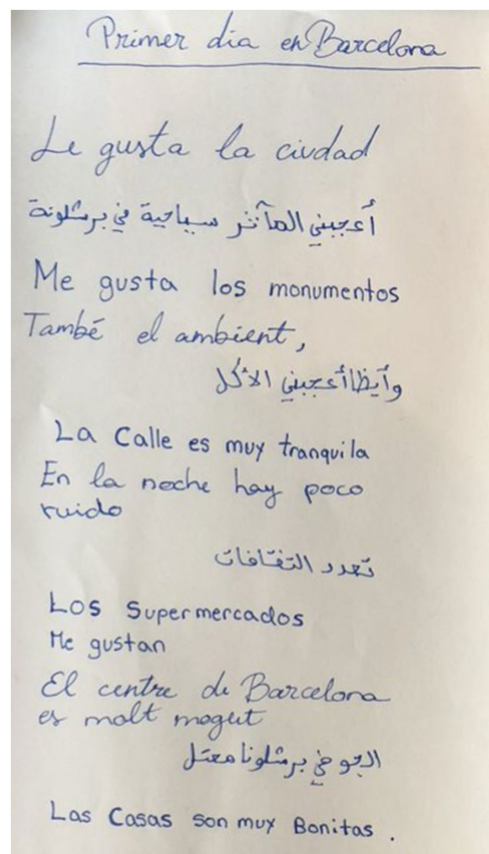.أعجبتني المآثر السياحية في برشلونة
Me gusta los monumentos.

També el ambient,
.وأيضا أعجبني الأكل

La Calle es muy tranquila.
En la noche hay poco.
ruido.
.تعدد الثقافات

Los Supermercados.
Me gustan.
El centre de Barcelona.
es molt mogut.
.الجو في برشلونة معتدل

Las Casas son muy bonitas.

Translation of Aram's poem *(Primer dia en Barcelona):*

He likes the city.
I liked the tourist monuments of Barcelona.
I like the monuments.
Also the atmosphere,
and I liked the food too.

The Street is very quiet.

At night there is little.
noise.
Multiple cultures.

The Supermarkets.
I like.
The centre of Barcelona.
is very busy.
The climate is mild.

The Houses are very beautiful.

Primer dia en Barcelona (First day in Barcelona) was not only the topic, but also the title of Aram, Madu and Karina's poem. The poem is written in Arabic (bold font in translation), Spanish (standard font) and Catalan (italics) and, as we can see in Figure 4, there are three different scripts. Each participant was responsible for writing in one language: Karina wrote the lines in Spanish, Madu in Catalan, and Aram in Arabic. Of the four poetic processes examined in this article, this one was the most collaborative. Indeed, the poem carries includes three voices in a single description.

Primer dia en Barcelona is a description of Aram's first day in Barcelona: the atmosphere, the monuments, the supermarkets, the food, and so on. Linguistically, there are some interesting features. The first line, in Spanish, talks about a third person who likes the city: the object pronoun "le" in Spanish indicates that "*he* (or she) *likes*." In the second line, in Arabic, the author is placed in the poem, affirming "*I liked* the tourist monuments." The third line, in Spanish, reads "*I enjoy* the monuments." It is interesting to observe that in three lines of the poem, both the indirect object pronouns (third- and first-person singular) and the tense (present and past) change. We do not know for sure, but the poem appears to be a conversation between three people. In the fourth line of the poem, the Catalan language appears for the first time to allude to the atmosphere of the city (note that "el ambient" should be written as "l'ambient," but this is not relevant to our analysis). The fifth line, in Arabic, reads "*I liked* the food," once again in the first person and in the past. The next stanza of the poem, written in Arabic and Spanish, includes a description of the streets, noises, and cultures of the city of Barcelona. The third stanza, written in Spanish, Catalan and Arabic, combines aspects of the previous two, including both affirmations of what the poet(s) like, and a description of the city. The last line of the poem, in Spanish, describes the city's houses.

The poem thus manifests a trialogue between the participants and their languages. Aram needed to collaborate with the secondary school student 'teachers' to help him include Spanish, the language he wanted to learn, in his poem, as well as Catalan. The incorporation of Catalan is also meaningful, both linguistically — as it exposed Aram to the other (official) language spoken in the city — and aesthetically, as it affords the reader a more realistic visualisation of the city of Barcelona, where at least two languages are constantly present.

3.3 Zakia

On the day of the collage activity, many of the secondary school student 'teachers' went on a school field trip, and activities needed to be adapted for the adult language learners who attended. Thus Diego (facilitator/researcher/co-author) partnered with Zakia. Zakia is originally from Pakistan and spoke Urdu, Punjabi (Pakistan), Arabic, English, and Spanish, while Diego is originally from Brazil and spoke Portuguese, English, Spanish and Catalan. Working together, the pair discovered they had several commonalities: both are English teachers, have a master's degree in English, and are writers and poets. Conversations between the two alternated between Spanish and English. Zakia commented to Diego that she joined the AFEX-AFFM program because she needed to learn Spanish to get her Spanish citizenship, for which she needed to take a language proficiency test.

In her collage, which Zakia worked on mainly independently, she mixed poems by Shakespeare, the English poet (underlined in the translation), Joan Maragit, the Catalan/Spanish poet (standard font in the translation), and two Urdu poems by the Pakistani poet Allama Iqbal (bold italics in the translation), as depicted in Figure 5.

Transliteration of Zakia's collage:

Las ventanas, de noche, con luz amarillenta,
La luna hacer brillar los cables negros.
But thy eternal summer shall not fade,
So long as men can breathe or eyes can see,
Nor lose possession of that fair thou ow'st;

دیار عشق میں اپنا مقام پیدا کر.
نیا زمانہ، نئے صبح شام پیدا کر.
خدا اگر دل فطرت شناس دے تجھ کو.
سکوتِ لالہ و گل سے کلام پیدا کر.
بو مرا کام غریبوں کی حمایت کرنا.

Translation of Zakia's collage:

The windows, at night, with yellowish light,
The moon makes the black cables shine.
But thy eternal summer shall not fade,
So long as men can breathe or eyes can see,
Nor lose possession of that fair thou ow'st;
Create your place in the land of love.
Create a new age, a new morning and evening.
If God grants you a heart that can understand nature.
Create words out of silence.
May my work be to support the poor.

When combining the poems, Zakia created a collage in which she portrays an event that occurs on a moonlit night. Later, in conversation with Diego (Extract 5), Zakia explained how she connected the poem with the day of her son's birth:

Extract 5

01 DIE: **eh (.) este poema es sobre qué? (.)**
eh(.) this poem is about what? (.)
02 ZAK: **eh (.) explico? (.)**
eh (.) shall I explain? (.)
03 DIE: **sí (.)**
yes (.)
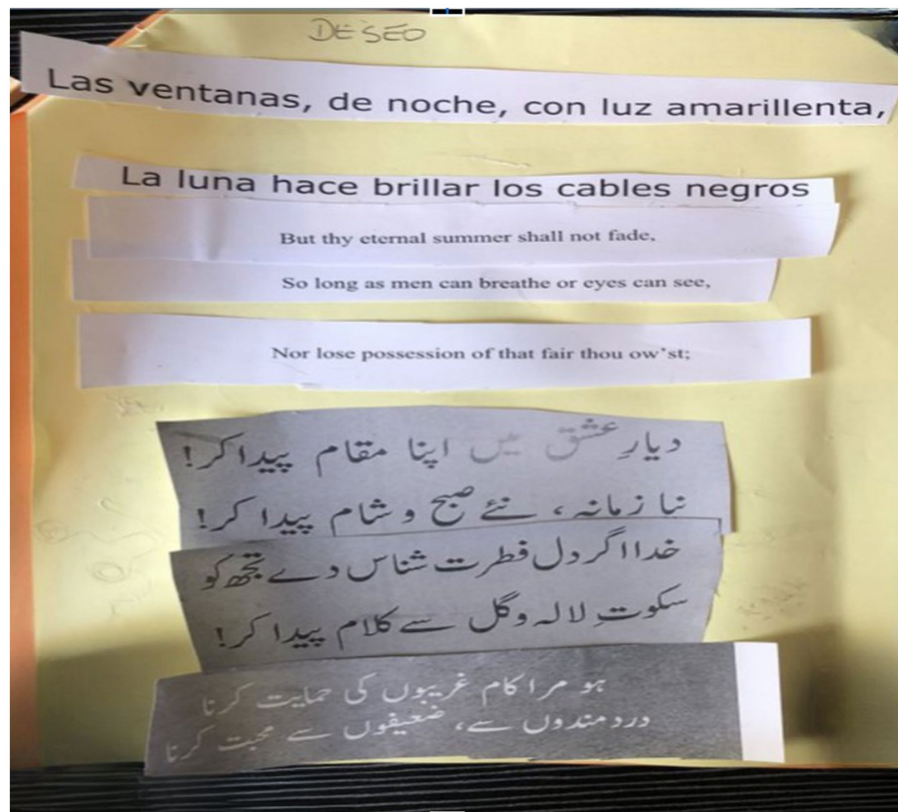**04 ZAK:** **ok (.) las ventanas (.) este del castellano sí (.)**

FIGURE 5
Zakia's completed collage.

ok (.) the windows (.) this from Spanish yes (.)

05 DIE: **no (.) pero (.) es sobre qué primer dia? (.)**

no (.) but (.) it's about what first day? (.)

06 ZAK: **ah (.) este (.) eh (.) yo (.) I was thinking of my son (.)**

ah (.) this (.) eh (.) I (.)

07 **when I was having (.) and I was thinking (.)**

08 **what is he doing in this world (.)**

09 **what (.) I wish for him? (.)**

Zakia explains in Extract 5 that as she was doing the collage, she remembered giving birth to her son and was thinking about her hopes for him. It is interesting to observe in this short extract of conversation, when the researcher asks questions in Spanish, Zakia tries to answer in Spanish, and changes to English when she can no longer continue. Later, when naming the collage, the following exchange takes place between the pair (Extract 6), in which Zakia asks Diego how to translate "wish" from Spanish to English, after which Zakia writes the title *Deseo* on her the collage:

Extract 6

01 ZAK: **eh (.) how (.) do you (.) write wish in castellano? (.)**

spanish

02 **wish (.)**

03 DIE: **deseo (.)**

wish

As mentioned, Zakia identifies as a poet and usually writes poems in Urdu. Zakia's final poem, which she also entitles *Deseo* (see Figure 6), does not describe the day of her son's childbirth, but the feelings and wishes that she has for him. The poem projects the future that she imagines for him and her role as a mother. Of all the poems crafted by the participants, Zakia's is the most plurilingual, combining five languages. In writing her poem, she also had help from a secondary student 'teacher', Míriam, who assisted her to write lines in Spanish (standard font in the translation) and Catalan (italics in the translation).

Transliteration of Zakia's poem *(Deseo)*:

I want to the world to be happy.
Para Todo el mundo.
کیسے اپنا حصہ ڈالوں۔
Puc fer de tot.
مینوں سب کجھ کرنا آنداں۔
سأقوم بنشر السلام۔
I can see a day in future.
Felicidad, paz, Tranquilidad.
جب سب رکھیں گے خیال دوسروں کا۔
Ningú no dominará els altres.
آوے گا جلدی اے دن۔
كل العالم سيكون في ذلك الوقت قريبا۔

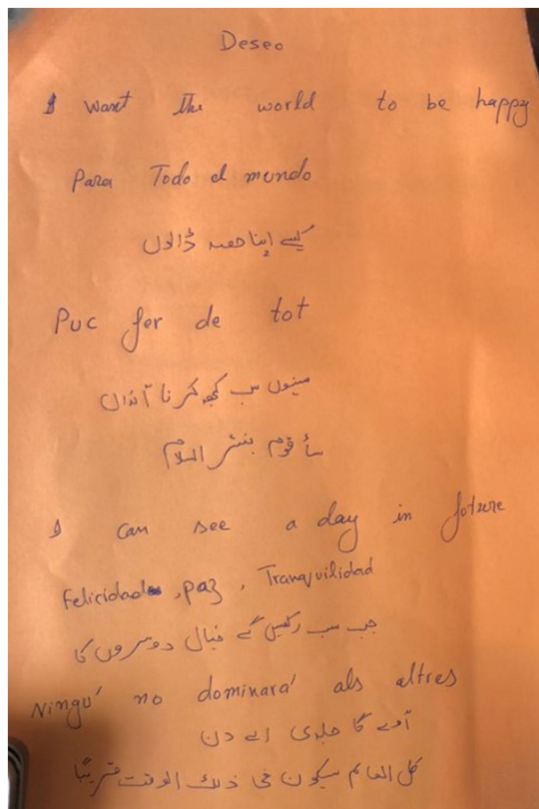**Translation of Zakia's poem *(Deseo)*:**

FIGURE 6
Zakia's poem *(Deseo)*.

I want the world to be happy.
for Everyone.
How do I contribute?
I can do everything.
I want to do everything.
I will spread peace.

I can see a day in the future.
Happiness, peace, Tranquility.
When everyone takes care of others.
No one will dominate others.
The day will come soon.
All the world will be there at that time soon.

Zakia's poem is divided into two verses, and every line is written in a different language. The two verses follow a pattern in terms of languages used: English (underlined in the translation), Spanish (standard font in the translation), Urdu (bold italics in the translation), Catalan (italics in the translation), Punjabi (bold, italics, underlined in the translation), and Arabic (bold in the translation). All the verses converse with each other, narrating the author's desire for her son and the world. Zakia introduces her poem desiring happiness for everyone, asking what she can do to make the world a peaceful place for her son. She projects a future with happiness, peace, and tranquillity where no one will dominate others. The poet reassures the readers that this day is

coming. It is interesting to note that the poem communicates in different languages without losing connection with the main topic. In short, in her poem, Zakia uses the languages she knows, including both Spanish and Catalan, thanks to the support of her co-artist Míriam.

3.4 Hasbia

Hasbia is originally from Pakistan, and she speaks and writes Urdu and English, as well as being a learner of Spanish. Her process during the workshop was very independent, and she did not seek help from the secondary school student 'teachers', only recruiting assistance briefly from a student named Rasheed for the collage task. It is interesting to point out that Diego (facilitator/researcher/co-author) tried several times to communicate with her in Spanish during the workshop, but she answered in monosyllables and appeared to be very shy. It was only when Diego discovered that she spoke fluent English that he was able to establish conversation with her.

In addition to Shakespeare's and Allama Iqbal's poems (also used by Zakia), Hasbia's collage (Figure 7) includes parts of a poem by Lope de Vega, a Spanish poet. She also includes a photo of the Allama Iqbal because he reminds her of her home country. Hasbia explained to Diego that the poet is very famous in her homeland, and she likes his poems.

Transliteration of Hasbia's collage:

Shall I compare thee to a summer's day?
نیا زمانہ، نئے صبح شام پیدا کر.
mostrarse, alegre.
Thou art more lovely and more temperate;
خدا اگر دل فطرت شناس دے تجھ کو.
And every fair from fair sometime declines,
سکوتِ لالہ و گل سے کلام پیدا کر.
So long lives this, and give life to thee.

Translation of Hasbia's collage:

Shall I compare thee to a summer's day?
Create a new age, a new morning and evening.
Show oneself, cheerful.
Thou art more lovely and more temperate;
If God grants you a heart that can understand nature.
And every fair from fair sometime declines,
Create words out of silence.
So long lives this, and give life to thee.

Hasbia's collage seems to be a description of a person. While most of the sentences are in Urdu (bold italics in the translation) and English (underlined in the translation), the languages she feels more confident using, there is one sentence in Spanish (standard font in the translation). In her final poem, however, Spanish disappears, and she composes a bilingual poem in Urdu and English. Hasbia completed her poem without assistance. The topic of her poem (Figure 8), entitled *My baby my whole world*, was her daughter Issa:
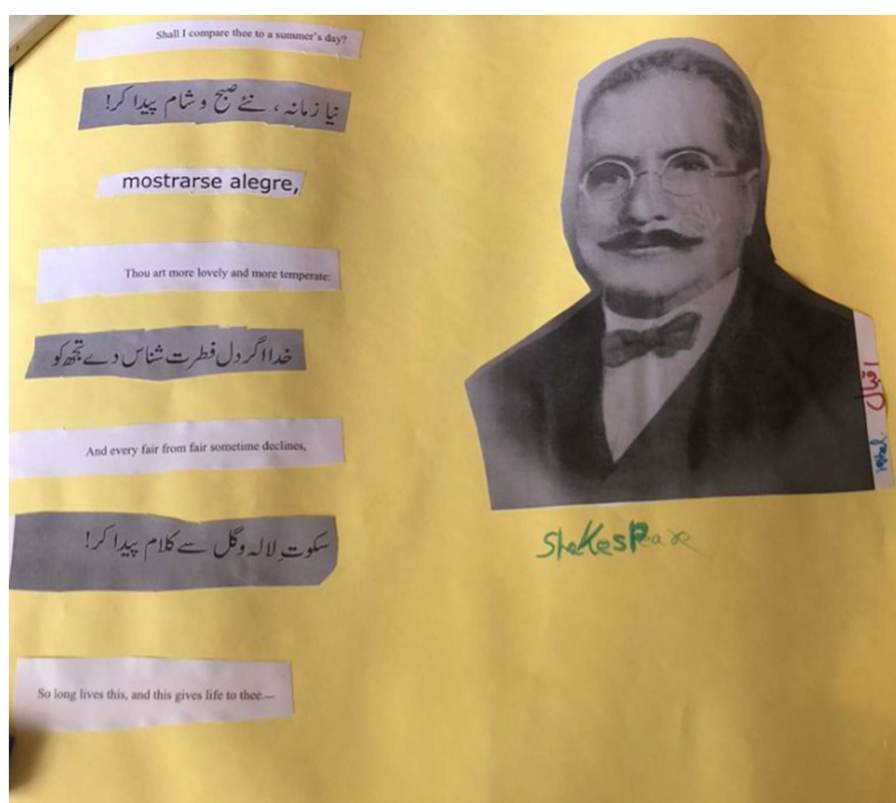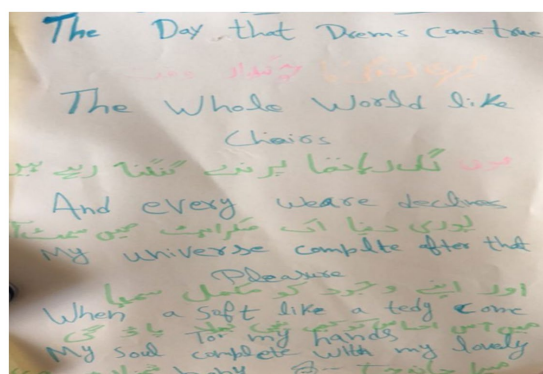
FIGURE 7
Hasbia's completed collage.

FIGURE 8
Hasbia's poem (*My baby my whole world*).

My universe complete after that.
Pleasure.

اور اپنے وجود کو مکمل سمجھا۔

When a soft like a tedy come.

میں اس احساس کو کبھی نہیں بھول پاؤں گی۔

For my hands.
My soul complete with my lovely.

شہزادہ۔ میرا چاند جیسا Issa، baby.

Translation of Hasbia's poem (*My baby my whole world*):

The Day that Dreams come true.
Happy time of my life.
The Whole World like.
Chairs.
It seemed like the birds were humming.
And every weare declines.
The whole world turned into a smile.
My universe complete after that.
Pleasure.
And considered his existence complete.
When a soft like a tedy come.
I'll never forget this feeling.
For my hands.
My soul complete with my lovely.
Issa *is like my moon* baby *princess.*

Transliteration of Hasbia's poem (*My baby my whole world*):

The Day that Dreams come true.

خوشگوار وقت میری زندگی کا۔

The Whole World like.
Chairs.

یوں لگ رہا تھا پرندے گنگنا رہے ہیں۔

And every weare declines.

پوری دنیا ایک مسکراہٹ میں سمٹ گئی۔

In her poem, Hasbia narrates her feelings about the birth of her daughter. The narrative intercalates verses in English (underlined in the translation) and Urdu (bold italics in the translation). She describes the day of her daughter's birth as the happiest day of her life. It is interesting to observe that she makes a comparison between the world and chairs sounding like birds singing. This sentence could allude to a hospital visiting room full of chairs, and her family was happy about her dream coming true. In the sentence "and every weare declines" (which could be an adaptation of Shakespere's "every fair from fair sometime declines" used in her collage; note that the misspelling of "wear" is not relevant to our analysis), Hasbia seems to be referring to the exhaustion of childbirth vanishing when she saw her baby, and the shared happiness with other people ("The whole world turned into a smile"). She continues by describing how her life and universe are complete now. She compares her daughter to a soft teddy bear (the misspelling of "tedy" is not relevant to our analysis) arriving in her arms. She finishes claiming that her soul is also complete and tells the readers her daughter's name: Issa, her moon, and her baby.

Hasbia did not use the host languages, Spanish or Catalan, in her poem, writing instead alone in the languages in which she felt confident. Her poem is heavily symbolic; the moment she describes is unique and personal to her and writing it with others was perhaps less meaningful to Hasbia than doing the activity alone.

4 Discussion and conclusions

The above analysis traces processes of crafting poetry by adult migrant learners, in a program aimed at teaching host languages (Catalan/Spanish), and the outcomes of this process. Reflecting on the case studies, the argument we will put forward here is that co-artistry — following Piazzoli (2018) — was central to promoting language learning. We see this co-artistry operating in two closely linked ways:

1) In the design and enactment of the workshop activities by the teachers, facilitator, researcher, and student 'teachers'.
2) In the improvised ways that the adult learners sought assistance and others supported them to incorporate the host languages in the workshop.

Regarding the first point, we see co-artistry operating in the collaborative design of the sessions, which drew on different professional and life experiences of those involved, encouraging the adult learners to use their full linguistic repertoires to make meaning, and foregrounding emotion and affect as educational resources. We also see it emerging in the ways the proposed artefacts were used in carrying out the activities. Arial, for example, suggested that Aram and Safira do the collage activity by cutting out letters from the poems provided in different languages to make sentences, which was different from the process followed by others, who used full words or lines, and resulted in a different collage.

Regarding the second point, we refer to how spontaneous interactions during the sessions supported language learning. The above analysis suggests the assistance provided by others (co-artists) supported the incorporation of the host languages in the learners' poems, alongside those already known, as in the case of Zaya, Aram and Zakia. These three learners actively sought and received linguistic

assistance. Hasbia's process was different from her peers in that she mainly worked alone, and she did not include the language(s) she was learning in her final poem. Thus, while we see point (1) above as being a fundamental starting point for supporting the aesthetic and plurilingual/pluriliteracies approach to additional language teaching and learning put forward in this article, in that it accounts for different ways of knowing and doing, we see point (2) as enhancing opportunities for learning new language within existing plurilingual repertoires.

It is vital to note that these improvised human interactions not only supported language learning, but also contributed to poetic production. Mara (the facilitator) and Arial (the secondary school student 'teacher'), in working with Zaya on her poem, built upon the concept and mood of Zaya's words, in addition to translating the Urdu lyrics into Spanish. They were able to comprehend, recognise, and interpret Zaya's thoughts and feelings in helping her to incorporate Spanish. In the case of Aram's poem, Madu and Karina not only assisted Aram in incorporating the Spanish and Catalan languages, but they also actively contributed to the poem's creation by contributing ideas and lines in a type of poetic conversation. When reading these two poems, we see different scripts connecting ideas and emotions, suggesting the collaborative nature of their artistry.

As we highlighted in the introduction to this article, our approach to teaching and learning languages as plurilingual and aesthetic practices responds to calls in the field of additional language education to foreground learners' experience, affect, and emotions. It is also consistent with Hanauer's (2011, 2014) concept of meaningful literacy in writing poetry in the language classroom, which emphasises how people's emotional lives play a role in how they encounter a new language. It is worth noting that the adult language learners' reactions to each activity making up the poetry workshop, and the trajectories of their texts (Kell, 2009, 2015), varied. We notice Zaya's ties to her mother and country in the *First words* activity; these ties re-appear in her final poem. In the collage exercise, we feel the strangeness and unease that Aram and Safira experience upon entering a new environment, whether it be the AFEX-AFFM program or their new city, followed by a more positive description of the new city in *Primer dia en Barcelona*.

In the analysis, we also see how Safira decides not to continue with the poetry writing, claiming the activity was too difficult for her. Chamcharatsri (2013) and Iida (2016) also observed the challenge for some students of using poetry to express their emotions in a language they are learning, and this is a point for continued consideration. We believe that our aesthetic and plurilingual/pluriliteracies approach to using poetry might offer some ways forward. On the one hand, learners can be encouraged to use their full linguistic repertoires, not limiting them to the languages they are learning. On the other hand, in our interpretation of the poems, we have foregrounded meaning over linguistic accuracy.

We would finally like to reflect on the position of 'not knowing' inherent to Creese and Blackledge's [(2023, essay 2] ethical-aesthetic ethnographic perspective, and the need for co-artistry also as researchers. In interpreting the poems written in languages unknown to us for their linguistic and aesthetic qualities, following Niaz (2019), 'extra processing effort' was required. This extra processing meant collaborating with speakers of those languages, without whom our research would not be possible, but it also meant accepting gaps in our

understanding as an inherent part of working with and through the arts.

Bringing these different discussion points together, our aesthetic and plurilingual/pluriliteracies approach to additional language education proposes: (1) active collaboration (co-artistry) in the design and enactment of language teaching and learning, both by those acting as teachers and by learners; (2) going beyond the teaching of languages in isolation from others to support learners' existing plurilingualism/pluriliteracies and their use of new languages; (3) a holistic approach to learners' linguistic repertoires which foregrounds aesthetic/meaningful use of the languages they know and are learning; 4) as researchers, reflecting on what we do not know, and being willing to engage also in co-artistic processes of building knowledge with others.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The study involving humans was approved by Comitè d'Ètica en la Recerca (CERec), Universitat Autònoma de Barcelona. The study was conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

DA: Conceptualization, Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Towards an aesthetics of grammar learning: lifting the veil on language

Steph Ainsworth* and Huw Bell

School of Education, Faculty of Health and Education, Manchester Metropolitan University, Manchester, United Kingdom

The last few decades have seen growing interest in the field of disciplinary aesthetics. While the physical sciences and mathematics have attracted significant interest in this area, relatively little attention has been given to the aesthetic potential of learning about the structure of one's own native language. Within this paper, we bring together ideas from evolutionary aesthetics, philosophy, psychology and neuroscience to explore the question of what might characterize an aesthetics of grammar learning. The paper connects our previous empirical findings with theoretical developments across these disciplines. We argue that explicit grammar learning has a particular potential to evoke aesthetic experience due to its role as a mediator between procedural and declarative knowledge. We suggest that by facilitating the transformation from knowhow to knowledge, grammar learning has the potential to generate cognitive consonance, experienced as an aesthetic-epistemic feeling of fittingness. The discussion draws parallels between the characteristics of grammar and the properties of entities more traditionally conceived to be aesthetic (such as art works and performances). In particular, we note that meta-linguistic labels (grammar terms) provide concrete tokens which facilitate virtual models, supporting the transition from 'automatism' to 'conscious reflection'. The paper concludes by exploring the implications for the field of disciplinary aesthetics and for developing pedagogies which maximize the aesthetic potential of grammar.

KEYWORDS

disciplinary aesthetics, aesthetics, grammar, declarative knowledge, procedural knowledge, epistemic emotions, aesthetic-epistemic feelings, cognitive consonance

Introduction

Background: towards an aesthetics of explicit grammar learning

> The day I learnt the basics of grammar as an eight year old was a joyous day for me […] I loved that there was a set structure that underpinned the language we all employed to communicate and to think (McMahon, 2015, p. 156)

Recent years have seen growing interest in the field of disciplinary aesthetics. Loosely, this can be defined as the ways in which aesthetic judgments, feelings and emotions are expressed or experienced in specific curriculum areas. The development of disciplinary aesthetics can be seen as a component of a wider 'affective turn' in education, the growing recognition of the

importance of affect and emotion as central to educational experience (Zembylas, 2021). While the aesthetic elements of physical sciences and mathematics have attracted significant interest, we believe that almost no attention has been given to the aesthetic potential of learning about the structure of one's native[1] language. In this paper we therefore consider this area of learning from a disciplinary aesthetics perspective.

Historically, in a philosophical literature stretching back to the ancient world, aesthetics as a field of investigation has been most closely associated with those areas which are typically held to have a close affiliation with 'beauty'–primarily art, music and drama, and the natural world (e.g., Ulrich, 1983). More recently, aesthetics has been explored across a broader range of disciplinary fields such as education (e.g., Dewey, 1934), psychology (e.g., Jacobsen and Höfel, 2003) and sociology (e.g., Bourdieu, 1984). There has been considerable interest in aesthetic responses to mathematics, which originally considered the aesthetic nature–the 'cold and austere beauty' (Russell, 1919, p. 60)–of mathematics itself. Recent interest has since widened to include the neurobiological explanations for aesthetic reactions in the study of mathematics (e.g., Zeki et al., 2014) and perceptions of beauty in mathematics among both experts (Hayn-Leichsenring et al., 2022) and laypeople (e.g., Johnson and Steinerberger, 2019). Similarly, there is a substantial body of work investigating the relationship between aesthetic responses and science education (for example, Chandrasekhar, 1979; Girod et al., 2003; Jakobson and Wickman, 2008; King et al., 2015; Wickman et al., 2022). Perhaps unsurprisingly, given their close relationship to mathematics, considerable attention has also been paid to aesthetics in chess (e.g., Margulies, 1977), information theory (e.g., Moles, 1973) and computer programming (e.g., Fishwick, 2006).

Where it directly addresses language, aesthetic theory has typically been preoccupied with the forms of or reactions to language: for example, the aesthetic engagement with literary works as a reader (e.g., Stockwell, 2009), or the language of literature in contrast to everyday language, either in general or in the works of 'great writers'. Analyses also exist of the ways in which some languages or language groups use grammar for aesthetic purposes (e.g., Williams, 2019), and of the individual features of 'beauty' in words and/or sounds (e.g., Crystal, 1995). In addition, over the last 40 years there has developed a substantial literature on affect and second language learning: early work (e.g., Horwitz et al., 1986) dealt largely with language learning anxiety, since which the field has developed considerably (Dewaele and Li, 2020, provide an oversight), and there has been some attention paid to emotional responses to teaching (rather than learning) grammar (Watson, 2012).

However, to the best of our knowledge there is no work dealing specifically with the affective or aesthetic implications of developing explicit knowledge of first language grammar, or of metalinguistic learning in general (which could be about first or other languages).

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1 We refer to 'native speakers' throughout this paper, despite the difficulties associated with the term (Cheng et al., 2021), as shorthand for the types of grammar learners typical of those in our classes. The vast majority of these are monolingual inhabitants of the United Kingdom who, like most English students (Hudson and Walmsley, 2005) had not studied the grammar of English at school.

Despite the lack of research specifically about aesthetic responses to learning about grammar, the similarities between grammar and mathematics, together with the convincing evidence that mathematics can induce aesthetic perceptions suggest that an aesthetic-emotional response to learning about grammar is possible, as McMahon's (2015) 'joyous' recollection suggests. It is not necessary to accept Lambek's assertion that 'to check the grammaticality of an English sentence is like finding the proof of a theorem' (Lambek, 1989, p. 271) to see that mathematical activities can indeed be 'quite analogous' to linguistic activities (Lambek, 1989, p. 257).

Within this paper, then, we explore the potential for explicit grammar knowledge to act as an aesthetic object. We suggest that learning about grammar has a particular potential to evoke aesthetic experience due to its role as a mediator between procedural and declarative knowledge. For clarity, in this paper we use the phrases 'learning about grammar' and 'grammar learning' to refer to the conscious development of explicit knowledge about grammar, rather than the implicit, unexamined knowledge which speakers of a language must have in order to merely use grammar. As a simple example, native speakers of English talk about events which happened in the past using a wide range of formal identifiers, including appropriate tenses, aspects and adverbials; but without specialized learning they are normally unable to state clearly if or how 'I went to see her' is different to 'I had gone to see her' or 'I was going to see her'. Developing the conceptual and terminological knowledge to distinguish them is learning about grammar, and grammatical metalanguage is the grammatical terminology which helps us do this.

Empirical motivation for a hypothesis about the aesthetics of grammar learning

Our interest in the aesthetic dimension of learning explicit grammar knowledge arose from our experiences teaching English grammar to student teachers who were preparing to deliver the National Curriculum (DfE, 2013) in primary schools in England. This curriculum contains a significant amount of explicit grammar terminology (e.g., *fronted adverbial*, *prepositional phrase*) which primary school teachers are required to teach to pupils aged 5–11. The inclusion of this terminology represented a fairly radical change to education in England after the decline of formal grammar education in the 1960s (Hudson and Walmsley, 2005), and our research initially explored how student teachers might respond to the challenge of mastering (and then teaching) a range of grammatical terms and related concepts that many of them had never encountered. What was most striking to us during this project was the fact that the students expressed strong emotional reactions when learning about the structure of their native grammar. Crucially, many of these reactions seemed to be of a distinctly aesthetic nature.

While this project has been reported in detail elsewhere (Bell and Ainsworth, 2019; Ainsworth and Bell, 2020; Bell and Ainsworth, 2021), we provide a brief summary below of the students involved in the project and the nature of the grammar sessions that they engaged with. This will help situate the discussion that follows, where we return to some of the data from the project to illustrate our thesis about the aesthetic dimensions of explicit grammar learning. The grammar sessions which we will refer to were offered to student teachers on the BA in Primary Education. They were offered as an

optional extra to the core program, providing an opportunity for the students to develop their subject knowledge in preparation for teaching grammar to primary school children. The data is drawn from group interviews with 29 student teachers who had attended the grammar sessions. The interviews took place at three time points, following three different iterations of the grammar course delivered to three cohorts of students. The maximum number of sessions available to students was 10 (across a 10-week period), although attendance varied due to the optional nature of the course and competing student commitments.

Within this paper, we speculate as to why the kind of learning that students engaged with within these grammar lessons, might lead to strong affective responses like those that we observed. We explore the hypothesis that *explicit grammar learning has the potential to evoke aesthetic-epistemic feelings associated with the transformation of procedural to declarative knowledge*, drawing upon theoretical ideas from a range of disciplines: evolutionary aesthetics, philosophy, psychology and neuroscience.

Before we present our arguments to support this hypothesis, we will briefly clarify some key terminology, namely the terms epistemic emotions, epistemic feelings and aesthetic-epistemic feelings. Epistemic emotions and epistemic feelings, which Olin (2018), p. 1 collectively calls 'feelings for knowing', are the terms given to affective states relating to epistemic aims or processes. A key distinction often made between emotions and feelings is that while emotions are physical reactions to the environment (e.g., an increase in heart beat), feelings are a person's conscious perception of emotions such as a conscious feeling of anxiety (e.g., Damasio, 1999). However, when it comes to epistemic emotions/feelings specifically, these terms are often used interchangeably with different distinctions being made across disciplines (Arango-Muñoz and Michaelian, 2014). For example, while Dietrich et al. (2020) refer to curiosity as an epistemic feeling, Vogl et al. (2019) categorize it as an epistemic emotion. For the purposes of this paper, we will use the term epistemic feeling in preference to emotion to reflect the fact that that our analysis is centered around students' reports of their (consciously experienced) feelings. The term aesthetic-epistemic feeling refers to affective states that have both an aesthetic and an epistemic character (Todd, 2018). In the discussions that follow we will argue that grammar learning has the potential to evoke such hybrid affective states in the form of a feeling of fittingness.

Towards an aesthetics of grammar learning

We will now embark on an attempt to identify some of the key characteristics of grammar learning which make it a potential source of aesthetic experience. For each of these characteristics we will try to unravel its epistemic and aesthetic dimensions. While grammar learning is often considered to be a rather dry and austere enterprise–what Hinsliff (2017) calls not 'bringing language to life but dissecting its cold corpse'–we will argue that it has the potential to evoke rich aesthetic experience. Specifically, we will argue that the intertwined epistemic-aesthetic experience of grammar learning has the potential to evoke a particular kind of 'feeling for knowing' (Olin, 2018, p. 1).

Analytic approach

In this paper we report a speculative exploration of the aesthetic potential of grammar learning, by bringing our previous data (Ainsworth and Bell, 2020) into conversation with ideas from evolutionary aesthetics, philosophy, psychology and neuroscience. In the discussion that follows, we draw heavily on Consoli's (2014) paper on evolutionary aesthetics, as we noticed remarkable parallels between the characteristics of aesthetic experience that Consoli identifies in the context of the evolution of early art/performance and the aesthetic characteristics of explicit grammar learning that seemed to be coming through within our data. While Consoli's ideas predominate in the ensuing points, we also integrate other concepts from a range of disciplines to illuminate our thoughts on the dual epistemic/aesthetic nature of learning about grammar. Table 1 represents an attempt to summarize the ideas that led us to the hypothesis central to this paper. It helps us to tell the story (albeit tentatively) of what might have been 'going on' during our grammar sessions. This table resulted from an iterative process of meaning making where we moved back and forth between our data (reported in detail in Ainsworth and Bell, 2020) and the relevant literatures from the disciplines listed above. We searched for ways to 'plug these texts into one another' (Jackson and Mazzei, 2013) in a search for clues as to how we might explain and find a language to talk about the strong affective responses which seemed to accompany our students' experiences of learning about grammar (reported in detail in Ainsworth and Bell, 2020). The connections we noticed across these literatures led us through a process of iterative

TABLE 1 An initial framework for thinking about grammar learning as an aesthetic experience.

Characteristics of grammar learning	Epistemic dimension	Aesthetic dimension
Explicit bringing into consciousness	Shift from procedural to declarative knowledge Cognitive consonance - > feeling of fittingness Resonance between external stimuli and internal, self-related processing	Novelty x familiarity Structure appearing from the shadows Harmony between the external world and the self
Language as an artifact	Abstraction anchored by metalinguistic labels	Materiality of concrete tokens supports aesthetic experience
Conscious monitoring and manipulation of language	Metacognitive tools for reflection and manipulation Knowledge of self	Aesthetic experience supports virtual realities through decoupled/simulative imaginings The self-relevance of aesthetic experience - being 'touched within'
(Tools for exploring) desired meanings grounded in socially shared understandings	Knowledge of others Declarative knowledge as a collective workspace to be shared	Aesthetic experience as a vehicle for mind-reading Aesthetic experiences as social glue

thematic analysis (Braun and Clarke, 2006) until we settled on Table 1 as an initial framework for thinking about the aesthetics of grammar learning. This framework is not posited as a definitive 'theory' of explicit grammar learning, but rather a first attempt to conceptualize what an aesthetics of grammar might look like, by bringing together ideas from across disciplines. In this way it aligns with a relational onto-epistemological stance (Rovelli, 2022), where we are not attempting to describe an objective 'reality' that we stand outside of. But rather, we are engaging in a process of meaning-making, that comes from identifying useful patterns, in this case between the different ways in which aesthetic experience is characterized across disciplines and the aesthetic responses that our students described.

An initial framework for thinking about grammar learning as an aesthetic experience

The framework takes as its starting point Myhill's definition of metalinguistic understanding as:

> the explicit bringing into consciousness of language as an artifact, and the conscious monitoring and manipulation of language to create desired meanings grounded in socially shared understandings' (Myhill, 2012, p. 250).

Within Table 1 and the surrounding commentary we have parsed this definition into four key characteristics of grammar learning, which we will explore in turn, considering both the aesthetic and epistemic dimensions of the type of learning involved. In this way, we provide evidence to support our speculative hypothesis that *explicit grammar learning has the potential to evoke aesthetic-epistemic feelings associated with the transformation of procedural to declarative knowledge.*

i. Explicit bringing into consciousness…

Learning about grammar represents a particular type of learning. Prior to our grammar sessions, the students were able to use language entirely fluently and correctly, but were unaware of how they did it. For example, they were proficient at producing speech which used the typical structures of English clauses (e.g., subject, verb, object) without knowing that they were doing this, much less the names for the structures or elements of clauses. In epistemic terms, this kind of learning is characterized by a shift from procedural (know *how*) knowledge to declarative (know *that*) knowledge (Ryle, 1949). This characteristic of grammar learning distinguishes it from many other academic activities (e.g., learning calculations in mathematics), where pupils are learning completely new facts or skills (such as number bonds to 10 or how to carry out long division), rather than shifting existing tacit knowledge into a more visible form.

One of the reasons why this knowledge transformation might evoke aesthetic experience is that it lies at the nexus of novelty (which generates interest) and familiarity (which generates feelings of pleasingness) (Dokic, 2016). In this way grammar learning is potentially double weighted in aesthetic terms. Novelty is experienced as students acquire a new set of explicit metalinguistic labels– transforming language structures that were previously hidden into 'glittering linguistic subjects' (Crystal interviewed by Marques, 2017, p. 1084). The familiarity, on the other hand, comes from the examples

of everyday language used to teach this new knowledge and the related dawning that they 'knew' this all along: 'Oh! Actually, well we do know that. We just did not know, like the correct word to describe it' (Ainsworth and Bell, 2020, p. 606).

Another way to conceptualize the moments of insight that students experience when they integrate their new declarative knowledge with their existing procedural knowledge is in terms of a 'feeling of fittingness'. This term is borrowed from Todd's (2018), p. 212 exploration of aesthetic evaluation in mathematics. Todd uses the term 'fittingness' to describe the pleasurable feeling mathematicians can experience when engaging with elegant mathematical proofs. Todd suggests that when the relation between certain properties of a stimulus and certain cognitive processes operating within the mathematician's mind are consonant with one another, the person experiences the perception of an 'inevitability of fit' (Kosso, 2002, p. 39). While for Todd, the stimuli of interest are mathematical proofs, here we suggest that similar feelings of consonance may be experienced when students 'fit' the newly learned structure of grammar onto their existing tacit representations and experience a sense of things falling into place.

Todd argues that this phenomenon of 'cognitive consonance' arises when the stimuli/processing relation is characterized by *coherence*, *breadth of scope*, *simplicity* and *fluency* (2018, p. 229). Upon reading Todd's work, we were struck by the fact that the metalinguistic map which students acquire through learning about grammar meets each of his criteria for cognitive consonance:

- Grammar learning provides an overarching explanatory structure that matches students' everyday language use (*coherence*)
- This structure is able to capture the complexity of language use in all its variety and generativity (*breadth of scope*)
- English grammar is parsimonious and requires knowledge of a relatively small number of building blocks and rules (*simplicity*)
- Grammar knowledge feels familiar and readily forms a new layer of consciousness (*fluency*) due to the tacit knowledge already being place

We therefore speculate that explicit grammar learning evokes a special kind of cognitive consonance, resulting from the mapping of declarative knowledge onto existing procedural knowledge.[2]

Todd (2018) argues that feelings of fittingness have a hybrid aesthetic-epistemic nature. As well as being associated with an epistemic experience of understanding, cognitive consonance is proposed to evoke an aesthetic experience of harmony/fit. In support of the notion of feelings of fittingness having an aesthetic nature, a neuroscientific study by Vessel et al. (2013) found that intense aesthetic responses may occur 'when our brains detect a certain "harmony" between the external world and our internal representation of the self' (p. 7). While Vessel et al.'s study involved participants engaging with artwork, they argue that their findings are likely to be the 'tip of the iceberg' suggesting that 'instances of resonance between external stimuli and our internal representation of the self'

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2 Note that we would not expect the same type of cognitive consonance when learning L2 grammar as this would not involve mapping declarative knowledge onto existing procedural knowledge.

(p. 7) may occur frequently in a range of contexts. In the case of grammar learning, students are not engaging with mathematical proofs or artworks, but rather are having the structure of their native language revealed to them, generating moments of insight. These moments might be likened to those experienced during Gestalt detection (e.g., the sudden detection of a hidden structure within a 'Magic Eye' image). While students have always had access to the underlying structural rules of their native language (indeed, they have been using them to communicate competently for many years), it is only through explicit teaching and/or learning that the rules are revealed.

Research in the field of psychology, has demonstrated the link between such moments of insight and aesthetic experience. For example, Muth and Carbon (2013) showed participants images which contained hidden faces that were barely detectable. They found that the intensity of the moments of insight reported by participants correlated with levels of aesthetic appreciation–in other words, the bigger the sense of 'aha', the more the participants reported liking the image. This and similar studies (Muth et al., 2013) suggest that the experience of suddenly seeing hidden structures within complex stimuli is associated with a pleasurable moment of insight. We suggest that our students experienced a similar 'Aesthetic Aha' (Muth and Carbon, 2013, p. 28) when they began to 'see' the structure of language. For example one student in our previous research, described a satisfying moment of insight as they realized the extent of their (albeit tacit) linguistic expertise:

> It is kind of gratifying when you finally get it and you think, ah! I knew what that was all along, but I didn't know what it's called! (Ainsworth and Bell, 2020, p. 605)

As noted by Reber (2019, p. 457), Aha moments, where information is integrated in a new way, 'combine understanding with the aesthetic' and are signaled by a feeling of pleasure. While the aesthetic dimension comes from the learner's newfound ability to appreciate the coherence of language as a structural system, the epistemic dimension comes from the sense of understanding how all the pieces map onto their existing procedural knowledge. In the words of Fisher (1998), p. 31 'the mind says 'Aha!' in the aesthetic moment when the spirit says 'Ah.''

ii. Of language as an artifact…

When learning about grammar, students' attention is drawn to language as an object of inquiry; they are now encouraged to consciously consider it rather than use it unreflectingly. An important vehicle for making language visible is the use of labels, which act to anchor the previously tacit knowledge onto a visible map of concepts and interrelations between them. At an epistemic level, acquiring knowledge of this map, requires a process of abstraction which provides the students with a virtual model of language, decontextualized from specific examples of language use. In aesthetic terms, the newly acquired metalinguistic labels may be conceptualized as providing beacons, illuminating the structure of language. It is this quasi-visual element of grammar learning which makes it a potential source of aesthetic pleasure, where 'the "sensory" of the "aesthetic"' (Vasalou, 2015, p. 91) comes from a mental appreciation of the analytic structure rather than from actually seeing a physical object.

When considering the aesthetic dimensions involved in admiring language as an artifact, we identified some intriguing parallels between

learning about grammar and engaging with art. In his discussion of an 'evolutionary perspective on aesthetic experience' (2014, p. 37), Consoli emphasizes the central role of concrete tokens in aesthetic experience. For Consoli (2014), concrete tokens (e.g., a painting or temporal performance) are powerful sources of aesthetic experience because of their 'material presence' (p. 41). It is their materiality which grabs and holds the audience's attention and facilitates the development of a virtual model, shared between the artist/performer and the audience. Grammar learning shares with art a reliance on concrete tokens. The ability to see 'language as an artifact' (Myhill, 2012, p. 250) is mediated by metalanguage: grammar terms which allow teachers, students, linguists to think about and talk about language. We view this experience as aesthetic as it shares with more traditionally aesthetic endeavors, the phenomenon of 'pleasure that comes with the perception of order' (Starr, 2023, p. 5). By bringing the structure of language into focus, learning about grammar provides students with an opportunity to make sense of the complexity of language, leading to the kind of 'generalized sense of comprehensibility' (Starr, 2023, p. 5) that often emerges from aesthetic experience.

As well as supporting conscious access to an ordered picture of language, the metalinguistic labels themselves (adverbial, modal verb, subordinate clause, etc.) may also have an intrinsic aesthetic appeal. Consoli (2014) argues that the materiality of concrete tokens 'is attractive and produces pleasure *per se*, and is appreciated and valued for itself' (p. 41). This resonates with our experiences of teaching grammar, where students seemed to derive intrinsic pleasure from learning new technical terms. In our previous work (Ainsworth and Bell, 2020) we described how students talked excitedly about their love of labels and how grammar tapped into their thirst for 'knowledge for knowledge's sake' (p. 602). Such conversations revolved around the pleasure that comes from simply being able to attach a new word to an existing concept, rather than for instrumental reasons. We argue that the process of learning new labels, which is central to opening up language as an artifact to learners, taps into a particular aspect of humans' 'epistemic hunger' (Dennett, 1991), namely our status as logophiles (e.g., see Crystal, 2013). In this way, grammar learning has the potential to evoke intrinsic motivation in students (Deci and Ryan, 2000), tapping into the 'active integrative tendencies in human nature assumed by SDT' (Ryan and Deci, 2020, p. 2), self-determination theory. These tendencies are proposed to 'motivate individuals to assimilate ongoing experience into increasingly elaborated self-structures' (Ryan and Deci, 2004, p. 87). We speculate tentatively that students' seemingly intrinsic drive to acquire new conceptual labels (in this case labels for linguistic structures) might be a manifestation of these broader tendencies.

iii. …and the conscious monitoring and manipulation of language

One of the things that we found most interesting in our data was the fact that students' new declarative knowledge seemed to follow them round outside the sessions, lurking in the background and catching them unawares. Students reported a new tendency to 'see' language through a grammatical lens while going about their day-to-day business:

> 'I'll be like reading a magazine and I'll be like ooh, there's the subject, there's the object!'

> I'll be all weird like, 'Ooh! But should that have a comma, because that's a … whatever' (Ainsworth and Bell 2020, p. 607).

They seemed to have developed a new layer of consciousness with respect to their language use, which 'sees' language as parsed into grammatical elements. As well as providing a scaffold for conscious monitoring and reflection on language (as seen in the quotes above), their recently acquired metalinguistic knowledge also provided a new platform for conscious manipulation of language:

> I was using adverbials pretty much to start every single sentence. You know, like 'however', 'therefore'. But then I was like, you don't always have to do that. […] I didn't even know what an adverbial was six weeks ago. So then I was like, actually I can move that around (Ainsworth and Bell, 2020, p. 607).

Within this last example, the student is now able to imagine/simulate new ways of writing sentences, thanks to the virtual model of language that they have now acquired. By virtual, we refer to a model of language which allows a decoupling of language from its immediate use within specific contexts. This decoupling occurs as a consequence of acquiring knowledge of abstract grammatical categories. In the example above, now that this student understands the abstract 'adverbial' category, it has enabled them to perceive that the adverbial tends to be more mobile than other clause elements–i.e. it can often take a wider range of positions in relation to other parts of the sentence (e.g., Yesterday I went home/I went home yesterday). Consequently, they are now able to imagine different ways to express their ideas through language and to simulate the effect of different possibilities (e.g., by better predicting the effect that the adverbial would have if placed in different parts of the sentence).

This decoupling of specific exemplars of language use (e.g., real sentences) into abstract categories is analogous to the decoupling afforded by aesthetic experience in Consoli's (2014) account of human evolution. According to Consoli (2014), one of the key adaptive features of aesthetic experience (in the context of early art) is that it 'provides modal knowledge of and about possibility' and 'allows the exploration of possibilities in conceptual space on the basis of imagination' (p. 40). Similarly, Marković (2012) notes that the creation of 'virtual reality' is a key characteristic of aesthetic experience. Consoli (2014) and others (e.g., Asma and Gabriel, 2019) argue that decoupling is an important stage in the human evolutionary story. The capacity to generate 'imaginative simulations … that are decoupled from the actual state of the world' (Consoli, 2014, p. 40) evolves first in the form of dreaming (a precursor of aesthetic experience) and is also implicated in play, aesthetic experience and language. Each of these competencies has in common a metarepresentational structure which abstracts regularities or 'isomorphisms' (Asma and Gabriel, 2019, p. 161) from concrete experiences. In the context of art, Consoli (2014) argues that aesthetic experiences allow the artist to depict concepts through concrete tokens in a way that is decoupled from the concept itself (e.g., a cave painting may depict a horse that is not immediately present). This is a powerful tool for communicating ideas. There are of course, strong parallels between art and grammar in this regard, as grammar provides a common metarepresentational structure through which we can make our thoughts intelligible to one another, and through conscious reflection, we can make our own language use intelligible to ourselves.

While linguistic communication is, of course, effective without the need for any declarative knowledge of grammatical structure, this additional metalinguistic map, layered onto the underlying procedural

knowledge, enables what Consoli (2014, p. 45) describes as 'a flexible, de-constrained use of imagination'. In this way, grammar provides a further layer of decoupling (or abstracting out from the particular), providing 'the doorway into a wider aesthetic universe' (Tooby and Cosmides, 2001, p. 19). This decoupling opens up the structure and generativity of language, which not only has instrumental advantages (e.g., by improving one's authorial style) but also creates an aesthetic experience in itself: the experience of being able to 'see' the structure of our own language use as it unfolds in real time.

Consoli (2014) emphasizes the centrality of concrete tokens to the construction and sharing of virtual models by and between humans. We contend that the materiality of metalinguistic terms plays an analogous role, making visible to learners, 'a universalizable virtual model' (Consoli, 2014, p. 44) of language which they can then reflect on and consciously manipulate in a way that was not possible before. Explicit grammar learning may be conceptualized as concrete labels being attached onto the 'nodes' of the learner's existing language structure, anchoring their tacit knowledge into an intelligible, concrete frame. This virtual model supports the development of a conscious awareness of how we use language to construct and share meaning with others. In this way, explicit grammar learning allows you to peer inward to reflect on the way that you as an individual represent and use language. For example, in the quote below a student is reflecting on how following the grammar sessions, they had developed an augmented understanding of the way that they use language:

> This morning I was talking to my son and I was like, 'Go!' And I was like 'Oh! You go' and then I was thinking that was one of the things we'd spoke about in one of the other sessions. So it's like, there's actually a word missing from that sentence [the subject], (Ainsworth and Bell, 2020, p. 603)

In this moment of insight, the student realized that when we issue commands, we do not usually include the subject (We say 'Go!' rather than 'You go!') as the audience (in this case the participant's tardy son) will automatically infer from the context that the command is being directed at them. In response to the student's comment, the first author joined in with a reflection on the consequences of their own recent progress in terms of developing their knowledge about grammar:

> I know what you mean because I often say 'Get me them pens' or 'Get me them cakes', you know like when I'm at home. And now I always think, 'Oh, that's interesting! Because what I'm doing is swapping a determiner for a pronoun' (Ainsworth and Bell, 2020, p. 607).

While the above examples involve reflections on the individuals' own language use may seem trivial, the discussion around them was lively. We speculate that the positive affect which accompanied these reflections may reflect an aesthetic feeling associated with self-understanding. Within both the philosophy and psychology literatures aesthetic experience is often associated with self-relevance experienced as being 'touched from within' (Vessel et al., 2013, p. 1). In that same study, while reporting neuroscientific markers of harmony (see also section i), Vessel and colleagues argued that 'certain artworks can "resonate" with an individual's sense of self' (p. 6). While the research

of Vessel et al. reports on aesthetic responses to artwork that seem to be related to a drive for self-knowledge, we tentatively suggest that the metalinguistic knowledge that students acquire when learning about grammar might also generate aesthetic responses through a similar mechanism. In the latter case, it is the 'picture' of how language works that is provided by grammar learning which 'reaches the self' (*ibid*), fostering a satisfying sense of self-understanding.

   iv. … to create desired meanings grounded in socially shared understandings

Learning about grammar is a socially driven and socially situated enterprise. At the very heart of language use is the desire to construct and share meaning within and between people. At a procedural level, grammar is clearly a tool which people use to make themselves intelligible to one another–a shared system for communication of ideas. But less has been written about the social dimensions of learning *declarative* grammar knowledge. We explore below some of the ways in which 'the social' is implicated in grammar learning, and the aesthetic character of each of these aspects.

Learning about others through learning about grammar. Learning about grammar helps us to develop knowledge of other people. By drawing attention to the way that people use language structures to communicate in different ways, grammar learning provides an additional tool for reflecting on people's thoughts, behaviors and intentions. This particular affordance of learning about grammar lies at the intersection of grammar and pragmatics, which are 'complementary domains within linguistics' (Leech, 1983, p. 4), focusing on the interrelated areas of language structure and language use, respectively.

While the potential for grammar to foster learning about others did not feature in the data from our previous study, we will provide a brief reflection from the first author's own experiences of learning about grammar to suggest a further parallel between grammar learning and more traditional aesthetic experiences. Firstly, to provide some context, it may be useful to note that the first author only acquired declarative knowledge of modal verbs relatively recently as they strived to bring themselves up to speed with the new requirements of the National Curriculum (DfE, 2013) in their role as a teacher educator. The quote below describes the first author's reflections on the way in which becoming more aware of grammar, allowed them to become more aware of the subtle ways we communicate with each other, and of the pragmatic function of our particular authorial choices when constructing a particular communication act (e.g., an apology, request, demand, etc.).

> After the grammar sessions, I was struck not only by the intrinsic satisfaction that I gained from acquiring the new grammar term 'modal verb', but by the way in which my newfound grammar knowledge spontaneously came to mind when I was reading my emails. For example, I could feel myself bristling when reading an overly direct presumptuous email bluntly making demands with no attempt to soften them. This feeling of irritation at receiving this kind of message was not unusual; but what was new was the addition of an another feeling–a combined sense of recognition and interest: recognition that what made the message so jarring was the lack of carefully chosen modal verbs to signal politeness; and interest, as to whether this absence was deliberate or unwitting.

This example illustrates how declarative knowledge about grammar can provide an additional tool for thinking (and talking) about the language choices that people make, allowing for a more concrete pinning down of the nature of those choices (e.g., rather than just a vague sense of knowing that someone 'sounds rude'), which in turn can provide grounds for inferring intention of the language user. In this way, explicit grammar knowledge has the potential to help us to better understand the ways in which people position themselves through their use of language. This ability for grammar knowledge to open up new spaces for making sense of others' behavior is something which is shared with other forms of aesthetic experience such as art and performance.

Aesthetic experience is often a vehicle for understanding others, including 'helping individuals learn group behaviors and adapt to changes quickly' (Starr, p. 11). Consoli (2014) argues that aesthetic experience co-evolved with 'mind reading'–the capacity to understand 'others' complex mental states as integrated patterns of beliefs, desires, and intentions' (p. 49). In the context of art, the painting, performance etc. acts to convey the artist's intentionality. Language, of course, plays a similar but more direct role, where we use words as mediating signals (or tokens) of our thoughts, feelings and ideas. As described in section (iii), a key affordance of art is its ability to simulate 'imaginings'. Language is also simulative in that it allows us to cultivate a particular imagining in someone else's mind (e.g., I write the words 'fat cat' and you cannot help but picture one) (Asma and Gabriel, 2019). We suggest that the additional layer of tokens which declarative knowledge provides–in the form of a metalinguistic map–allows us to gain a deeper understanding of *how* we and others are using language to signal what we/they are thinking. While art and words are mediating objects that allow us to put ideas into people's heads, explicit grammar knowledge provides a map of how the meaning is being mediated–what we might call a *meta-mediation map*. We argue that this concrete schematic of language provides a 'mediated workspace' analogous to that afforded by art, through which 'subjects can become reflexively conscious of mind reading itself' (Consoli, 2014, p. 48).

Sharing learning about grammar. The collective workspace which grammar opens up is something which learners seem surprisingly keen to share with others. Within our previous research, students talked animatedly about how they had been sharing their newfound knowledge about grammar with family and friends, at home and even in the pub. The quote from one of our students below, provides an example of the level of giddiness that grammar learning can foster along with a compulsion to share the excitement:

> Every time I met somebody, I just had to tell them all about it. I was like, 'Did you know that there is no future tense in the English language?!' And they were like, 'What do you mean?' And then I was totally explaining it […] I was like, 'It's amazing, isn't it?!' […] It's fascinating, because it's something that's so … it's one of the first natural things you do in the first year … and then when you suddenly … it just … when you learn something, about a language that you have spoke for twenty years of your life, and you realize that there's no future tense in your language, it just completely blows your mind. You're like, 'What?!' (Ainsworth and Bell, 2020, p. 608)

We were struck by students' enthusiasm for talking about grammar beyond the sessions (for example, emailing us jokes about grammar and showing up in great numbers to the post-session focus groups to share their experiences of learning about grammar). They also reported trying to recruit new followers to what had unexpectedly become more of a grammar club than a series of lessons: 'We were like, "Are you coming? Honestly, it was really, really good!"'(Ainsworth and Bell, 2020, p. 609).

The fact that students were so keen to talk about grammar resonates with Consoli's observation that aesthetic objects are meant for sharing, as they provide 'a collective workspace dedicated to common, cultural processing' (2014, p. 42). The language of metalanguage allows for shared understandings and a shared vocabulary to talk about how language works, how it is used to create 'desired meanings grounded in socially shared understandings' (Myhill, 2012, p. 250), and to appreciate the wonder of this incredible human capacity. In addition to the specific affordances that might come from sharing knowledge about grammar with others (i.e., opening up the collective workspace to develop shared understandings about language), part of students' compulsion to share may be related to the aesthetic nature of language structure being unveiled:

> 'We care about aesthetics because we care about having aesthetic experiences. And, most of the time, we care about having aesthetic experiences together. Sitting next to each other in the movies, dancing, listening to music together' (Nanay, 2022, p. 29).

The eagerness with which students shared their learning about grammar felt akin to the impulse we have to tell our friends about a book, film or television series that we have just delighted in. This might be understood in relation to Nanay's suggestion that aesthetic phenomena can act as a 'glue for social cohesion', (Mechner, 2018, p. 297) providing a 'medium for sharing perceptions, information and beliefs' (*ibid*, p. 303). Indeed, from our subjective standpoint within our grammar lessons and follow-up focus groups, we experienced a sense of relational affective intensity, or 'transpersonal affects' (Anderson, 2009, p. 608) as students shared their journey into the 'aesthetic universe' (Tooby and Cosmides, 2001, p. 19) of grammar together.

Discussion

Summary of findings

In the preceding analysis we have presented an exploratory framework for considering the potentially aesthetic nature of learning about grammar. We have suggested that the layering of declarative knowledge on top of existing procedural knowledge has the potential to generate cognitive consonance as the new concepts map onto the learners' tacit understanding and experience of language. We speculate that the representational harmony which learners experience as the structure of language suddenly emerges from the shadows might be accompanied by an aesthetic-epistemic feeling of fittingness (Todd, 2018). We have further argued that the 'material presence' (Consoli, 2014, p. 41) of metalanguage may be central to the potential of grammar learning to evoke aesthetic experience. These concrete tokens support the development of a

virtual map, which provides a metacognitive platform for reflection on and manipulation of language. Here there are further parallels with more traditional aesthetic experiences. While art (and also language) involves the construction of virtual realities by decoupling concepts from their immediate referents (e.g., a painting of a cat represents the cat without it actually being there; Consoli, 2014), metalanguage supports decoupling of grammar elements from their immediate use within specific contexts. This decoupling process enables conscious reflection on one's own language use, which supports self-knowledge and may lead to an aesthetic experience of being 'touched from within' (Vessel et al., 2013, p. 1). It also allows 'simulative imaginings' (Consoli, 2014, p. 49), which may support diversification of the language user's grammatical repertoire. We have argued that learning about grammar also has social relevance. Declarative knowledge, when brought together with pragmatics, provides an additional tool for 'mind reading' – a capacity that is implicated in other aesthetic endeavors. And finally, we have suggested that as with other forms of aesthetic experience, grammar knowledge is best shared with others, providing a collective workspace for exploring socially shared understandings.

Significance for disciplinary aesthetics

To the authors' knowledge, this is the first time that the potential of grammar learning to evoke aesthetic experience has been explored in depth. We have identified a number of facets of learning about grammar that make it a potentially rich source of aesthetic pleasure. In this way we contribute to the expanding field of 'disciplinary aesthetics' (Wickman et al., 2022, p. 719), which argues for the importance of considering the aesthetic dimensions of all curriculum areas not just the arts. Our findings contribute to the growing body of evidence which suggests that aesthetic experience plays an important role in learning and meaning-making (Wickman, 2006; Vessel et al., 2013; Lemke, 2015). Aesthetic experience has been argued to serve the epistemic goal of knowing (Csikszentmihalyi and Robinson, 1990; Consoli, 2014), making it particularly advantageous to 'infovores' (Biederman and Vessel, 2006) like humans (Starr, 2023). In fact Starr (2023) argues that aesthetic experience 'emerges as a necessary outcome of the way humans learn and the parameters of human learning' (p. 2). The arguments presented above provide support for the notion that cognition and affect are intertwined and for the impossibility of 'separating affect from the moment of knowing' (Wickman et al., 2022, p. 720). Specifically, we have speculated that aesthetic-epistemic feelings of fittingness (Todd, 2018) may emerge as learners perceive a resonance between their outer (metalinguistic labels being learnt) and inner worlds (existing tacit knowledge of language). In this way we have contributed to thinking in relation to the relationship between perceptual insights (in this case suddenly 'seeing' the structure of language) and aesthetic pleasure (Consoli, 2015). As well as supporting meaning-making at a processual level (e.g., by signaling a state of cognitive consonance), aesthetic experience may also foster meaning in life, which comes in part from being able to make sense of your life and the world around you (De Ruyter and Schinkel, 2022). We have contributed to understandings around the relationship between meaning in life and disciplinary aesthetics by beginning to explore some of the ways in which learning about grammar might foster self-knowledge and knowledge of others.

From a methodological perspective, we have added to the growing body of work in disciplinary aesthetics which adopts a synthetic approach (see Special issue: Wickman et al., 2022). In order to avoid the limitations associated with using pre-defined categories of aesthetics to generate the exploratory framework presented within Table 1, we started from the bottom up, using our data as an initial basis for the development of our arguments. At the point of data collection, neither the students nor the study authors had aesthetics in mind. Rather we were engaged in an open-ended exploration of what happens when students need to develop a substantial body of declarative grammar knowledge quickly (in order to prepare for teaching the National Curriculum). The focus on aesthetics occurred *post hoc*, as we were struck by the affective dimension within the students' narratives. By adopting this 'bottom-up' approach, we were able to focus on the 'emergent interactions' (Wickman et al., 2022, p. 723) that occurred when students engaged with grammar learning, rather than attempting to fit a preconceived aesthetic framework onto their experiences. In addition, by adopting an interdisciplinary lens we have been able to identify resonances between our students' responses to learning grammar and ideas from the fields of evolutionary aesthetics, philosophy, cognitive psychology and neuroscience. These resonances were mobilized to create a speculative framework for understanding the aesthetics of grammar learning, which in turn has significant implications for education.

Towards a comparative disciplinary aesthetics

A central aim of the field of disciplinary aesthetics is to explore the aesthetic potential of learning within specific disciplines (Wickman et al., 2022). One might therefore wonder whether the framework set out within Table 1 is unique to explicit grammar learning or might also be applicable (in part or in full) to other types of learning. As an initial attempt to address this question, we will briefly compare explicit grammar learning (ELG) with two other examples of learning: explicit learning of conceptual metaphors (ELM) and explicit learning of walking (ELW).[3] We will briefly speculate on the extent to which the epistemic and aesthetic dimensions set out within Table 1 might apply to these other types of learning. These tentative comments illustrate that we are not arguing that explicit grammar learning is the only potential source of the kind of aesthetic-affective responses that we observed among out students. Rather, we are suggesting that there are likely to be both commonalities and differences across different subject areas/types of learning in terms of their potentiality for evoking aesthetic experience.

The two other types of learning which we will compare with ELG–ELM and ELW provide useful reference points as they each share with grammar the characteristic of bringing previously tacit knowledge into consciousness. Given that one fundamental aspect of our thesis in this paper is that developing declarative knowledge of grammar from procedural knowledge can give rise to a particular epistemic-affective reaction, one important question is whether explicit learning about grammar is different in kind from other instances of learning where

there is a shift from procedural to declarative knowledge. Beginning with the case of ELM, humans frequently, and largely unwittingly, use metaphor within their everyday language. For example, phrases such as *warm welcome* and *cold stare* are used commonly within speech, usually without the speaker being conscious of their metaphoric nature (Lakoff and Johnson, 1980). If a student develops declarative knowledge of this existing procedural knowledge, e.g., by attending a cognitive semantics lecture on conceptual metaphor, then the structure that motivates such expressions (i.e., AFFECTION IS WARMTH; Lakoff and Johnson, 1980; Grady, 1997) will then be revealed to them. ELM might therefore have the potential to evoke an aesthetic experience as students 'see' the structure of this particular aspect of language appearing from the shadows. In the case of ELW, a student acquiring knowledge *about* the process of walking (e.g., as part of their medical or physical therapy training) is unlikely to have the same kind of aesthetic experience, which we have likened to Gestalt detection, because arguably learning about walking does not involve the unveiling of an overarching structure in the way that it does for ELG and ELM. Learning about walking does, however, share with the other types of learning, its place at the nexus of novelty and familiarity, so it may be that ELW has the potential to generate an aesthetic experience of some kind due to it affording the opportunity for learners to see an aspect of their everyday behavior (walking) in a new light.

ELM is closer to ELG than ELW as it sits within the same broad area of learning about language. This means that we might expect ELG to share, at least to some extent, grammar's potential to evoke aesthetic experience. For example, ELM shares with ELG the potential to encourage students to develop an extra layer of self-knowledge–in the case of ELM, knowledge about conceptual organization and how we use metaphors to map between conceptual domains (Lakoff and Johnson, 1980). In a broader sense, if ELM occurs within the context of a course on cognitive semantics/cognitive linguistics it has the potential to open up to learners the relationship between mind and meaning. In this way, we might wonder if ELM could have the potential to provide a similar aesthetic experience of being 'touched from within' (Vessel et al., 2013, p. 1) to that described above in relation to ELG. ELW on the other hand, also involves knowledge of the self, but this involves acquiring an understanding of motor processes rather than cognition, and while it may well have the potential to give rise to aesthetic-epistemic feelings, this would likely be underpinned by a different (but perhaps partially overlapping) set of epistemic and aesthetic dimensions. Similarly, even though ELM shares many commonalities with ELG in terms of the types of learning invoked, we would not expect the *aesthetic profile* to be identical. For example, we might speculate that ELG and ELM share the potential for fostering 'simulative imaginings' (Consoli, 2014, p. 49), given that they both provide a *meta-mediation map* of the way in which we use language to conjure images in the minds of others. However, arguably, ELM learning does not afford the same opportunities for manipulating and experimenting with language as ELG (or at least not to the same extent), and therefore we might not expect it to harbor the aesthetic potential that comes a new lens through which to 'see' language as a structure of manipulable building blocks. In fact, it is possible that the more distal ELW, may share some overlap with ELG in this regard. When patients who are recovering from stroke re-learn how to walk, declarative knowledge about walking is sometimes used to support them in re-developing their procedural knowledge of walking, e.g., by introducing concepts. One of the approaches used to support stroke

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3   With thanks to an anonymous reviewer for suggesting these examples.

patients' rehabilitation involves engagement with virtual reality environments (e.g., Kim and Kaneko, 2023). Within these programs patients receive explicit feedback on their walking movements, which is presumed to activate explicit learning (Taylor et al., 2014). One might speculate as to whether these virtual reality interventions to support ELW, have the potential to stimulate aesthetic experience due to their simulative nature.

In summary, we have argued that each subject area is likely to have its own aesthetic profile, which will be defined by the particular kinds of learning involved. Given the overlap across subjects in terms of the kinds of learning being promoted and the associated cognitive mechanisms (e.g., connecting procedural and declarative memories), these profiles may contain shared aspects across subjects. We suggest that consideration of the three dimensions shown within Table 1–the key characteristics of the type of learning and the associated epistemic and aesthetic dimensions–might be a useful framework for exploring the aesthetic potential of other subjects. We argue that such a framework might be generated through bringing together learners' first-hand experiences of engaging with the subject with insights from the literature about the kinds of learning processes which they highlight as being most pertinent to how it *feels* to engage with that subject.

Pedagogical implications

Aesthetic experience has been argued to be 'both epistemically motivating and epistemically inventive' (Schellekens, 2022, p. 123). In other words, aesthetic experience has the potential to spur us on towards our overarching aim of knowing, while also fostering creativity. Aesthetic experiences have the potential to promote learning gains by enhancing motivation and guiding learners towards a 'sweet spot' in terms of learning gain (Starr, 2023, p. 10). Aesthetic experiences have also been argued to foster broader flourishing (Lomas, 2016). Yet formal education remains focused on preparing learners to be economically viable citizens (Reber, 2019; De Ruyter and Schinkel, 2022) and the role of aesthetics remains largely unexplored within pedagogical inquiry and practice, especially within the area of language learning (Reber, 2019). Our findings demonstrate that learning about grammar has the potential to generate rich aesthetic experience. Consideration of the aesthetic characteristics of grammar learning (and indeed of other curriculum areas) leads naturally to exploration of how such aesthetic aspects might best be harnessed within the classroom. While a full exploration of what might constitute an aesthetic approach to teaching grammar is beyond the scope of this paper, we will make some tentative preliminary remarks about the potential of the exploratory framework presented in Table 1 to inform pedagogical inquiry and practice.[4]

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4   The students described in this paper have full control of English, yet typically very little metagrammatical knowledge. Students learning English as a second or other language, by contrast, typically do not have full procedural knowledge (they are learners, after all) and yet depending on contextual factors many have some metalinguistic knowledge. In this section, therefore, we limit our discussion to 'monolingual native speakers studying the grammar of their first language'.

Making grammar 'insight-full'. One of the ways that educators can cultivate aesthetic experience is to provide opportunities for students to experience the kind of 'aesthetic aha' (Muth and Carbon, 2013, p. 28) experiences that we reported above. Aha-experiences have been shown to foster positive attitudes in other curriculum areas (e.g., mathematics), sometimes dramatically so (Liljedahl, 2005). The enthusiasm with which our students spoke about grammar and their compulsion to bring others along for the ride, suggests that pedagogies for teaching grammar (and perhaps other subjects) which provide the space for moments of insight to be 'sparked' might foster intrinsic motivation and enjoyment. Liljedahl (2005) identified two categories of aha moments experienced by students learning mathematics: those relating to teaching (where the teacher revealed something to them) and those relating to discovering (where the insight came from working something out themselves). As one might expect, the latter category was found to be far more prevalent, suggesting that students are more likely to experience moments of insight when they are engaged in solving problems themselves. Liljedahl (2005) suggest that when trying to cultivate an environment conducive to moments of insight, it is important to provide students with plenty of time to explore and talk about problems in groups without too much intervention from the teacher (see also Bell and Ainsworth, 2019). More recently, Brady et al. (2022) have also suggested that collaborative work may foster aha experiences, providing evidence that group work can support 'the emergence of tacit knowledge onto the plane of the explicit' (p. 230). While this research was conducted in the context of mathematical modeling, given the parallel emphasis on bringing tacit knowledge to the fore within grammar learning, these findings may be useful in informing thinking around how to foster insightful moments when develop students' metalinguistic understanding. From a methodological perspective, observation of students engaging in group work may be a promising approach for exploring the aesthetic dimensions of grammar learning, as Brady et al. (2022) argue that:

> using the interactional dynamics of groups as a lens into tacit knowledge can provide a means of studying processes that are hidden and inaccessible in individuals, through their manifestation in the social space of interaction (p. 230).

As well as harnessing the potential for group dynamics to foster (and make transparent) conceptual transformation, we suggest that opportunities for moments of insight within grammar learning might be maximized when grammar teaching is grounded in real life examples of language use. In order for students to achieve cognitive consonance with the declarative knowledge being learnt, it needs to be brought into contact explicitly and meaningful with their own language use. This aligns with Myhill's (2013) pedagogical principles for teaching grammar, which include the suggestion that metalanguage 'is always explained through examples and patterns' and that 'links are always made between the feature introduced and how it might enhance the writing being tackled' (2013, p. 105). Interestingly Myhill (2013) also highlight the benefits of collaborative work, 'encouraging critical conversations about language and effects' (p. 105).

Harnessing the materiality of metalanguage. Another promising approach to harnessing aesthetic experience might involve capitalizing on the 'materiality' or concreteness of metalanguage. According to Consoli (2014), concrete tokens (in this case metalinguistic labels) mediate aesthetic experience by guiding and prescribing imagination

in the construction of a virtual model. We suggest that aesthetic experience might be maximized by adopting strategies which are designed to support the learner to 'see' language in terms of abstract chunks/categories. Blair's (2019) treatise of 'the ornament of grammar' provides an interesting experiment into how grammar may be interpreted visually, as a 'means of 'seeing' a voice lending to thought at a detailed level' (p. 137), however, this work has a theoretical rather than a pedagogical focus. At a more practical level, we might take advantage of the materiality (Consoli, 2014, p. 41) of metalanguage by using carefully chosen visual scaffolds to support the process of mapping new grammar terms onto existing tacit knowledge. For example, Myhill (2013) describe a lesson focusing on 'how modal verbs can express different levels of assertiveness or possibility in persuasion' (p. 105). Students first explore modal verbs in famous speeches before they are asked to have a go at writing their own persuasive speeches. When analyzing this task, we might consider the concrete label of 'modal verb' to serve as a potential anchor for students' discussions around authorial choices. Without the term modal verb, it would arguably be harder to pin down and talk about those choices and their effects within the speeches. In this lesson the students are provided with a list of modal verbs to refer back to, providing a visual scaffold which makes the category of modal verbs (which the students may still be acquiring at an explicit level) visible to the students. While Myhill (2013) do not refer to aesthetics explicitly, it is striking how many words there are within the article that are associated with the domain of aesthetics e.g., 'to *see* how language works' (p. 105); '*making visible* and explicit the authorial choices' (p. 105); 'makes the process of writing more *visible*'(p. 108); 'to *see* the process of writing as a process of *design*' (p. 108). While Myhill (2013) argue that the grammar terms should not be the key focus of a lesson, they suggest that the explicitness that they bring is useful as a vehicle for 'see[ing] through language in a systematic way' (Carter, 1990, in Myhill, 2013, p. 109). Similarly, in their pedagogical guidebook for teachers, Corbett and Strong (2014, p. 101) recommend using visual strategies for teaching grammar with the following advice: 'to draw attention to specific structures or words, use color to make the features stand out'. While our findings lend support to the rationale for such approaches, which draw attention to abstract grammar categories in very explicit ways, further research is needed into how the aesthetic affordances of concrete labels for categories might best be harnessed within the grammar classroom.

Encouraging 'simulative imaginings'. A related approach to maximizing the aesthetic potential of grammar might focus on the use of metalanguage to guide 'simulative imaginings' (Consoli, 2014, p. 49)–in other words using metalinguistic knowledge to support conscious reflection on and manipulation of language. Both Myhill (2013) and Corbett and Strong (2014) suggest practical activities for how this aesthetic dimension of grammar learning might be utilized within lessons. For example, Corbett and Strong (2014, p. 101) argue for a multisensory approach to grammar learning, underpinned by the principle 'hear it, say it, see it, move it, make it!' Many of the activities suggested by Corbett and Strong (2014) can be conceptualized as involving simulative imaginings as they involve students physically manipulating and playing with language structures in order to 'see' what is possible. For example, one activity involves students reading a passage where all the adjectives have been replaced with names of sweets (liquorice, jelly baby etc; Corbett and Strong, 2014). The children then imagine what the adjectives might have been. This

activity is simulative because the students need to try out possibilities and get an aesthetic sense of if it 'feels' right. Experimenting and analyzing the effects is an important part of 'beginning to understand the writer's craft and the possibilities open to a writer' (Myhill, 2013, p. 106); we argue that it is also an inherently aesthetic endeavor.

When considering what an aesthetically informed grammar pedagogy might look like, it might be fruitful to explore ideas from the burgeoning field of embodied education (Shapiro and Stolz, 2019). This relatively new area, seeks to apply insights from embodied cognition within the classroom, developing teaching approaches which foreground the complex interplay between mind, body and environment. Such approaches emphasize the importance of integrating firsthand knowledge (direct bodily experience) with secondhand knowledge (learnt through language, e.g., written texts or verbal explanations; Schwartz et al., 2005). For example, Goldberg (2008) describes an embodied approach to the teaching of reading, which involves children being trained to physically manipulate toys in a way that reflects what is happening in the story, before then learning how to perform an 'imagined manipulation' of what is happening in their heads. This approach, which supports the child in 'creating mental models from the text' (p. 307) was found to promote better attainment than a traditional approach involving re-reading the story. Goldberg's (2008) findings were interpreted as evidence in support of an embodied account of language comprehension where words, phrases and grammatical constructions are indexed (mapped) to concrete objects and events, 'thereby grounding the symbols and imbuing them with meaning' (p. 305). While the above example focuses on the process of learning to read, the process of learning about grammar also involves a mapping between firsthand and secondhand knowledge, and is widely conceived to be embodied. This leads us to speculate as to whether pedagogies analogous to those used by Goldberg (2008), where students are encouraged to engage in physical manipulation of grammatical elements in real sentences–see for example, Corbett and Strong's 'human sentence' activity (2014, p. 109)–before moving on to simulating the effects of different grammar constructions in their heads might be helpful in supporting learners to apply the simulative potential of grammar knowledge in an embodied way.

While on the surface, grammar may appear to be archetypically abstract, 'even syntax is shaped and given meaning by the contours of our bodily experience' (Johnson, 2017, p. 27). It therefore, stands to reason that pedagogies to promote grammar learning, should provide opportunities for embodied learning. A number of studies in the area of second language learning have explored the pedagogical implications of the embodied nature of grammar (e.g., Evans and Tyler, 2005; Suñer et al., 2023). In a recent study, Boieblan (2022) found that an embodied approach to teaching spatial prepositions (in, on, at, etc.), which foregrounded 'the geometric and functional properties of figure and ground and how these intersect in space' (p. 1391), led to learning gains for Spanish learners relative to the control group. To the authors' knowledge, there are no studies which have explored the pedagogical implications of 'the embodiment of language' (Johnson, 2018, p. 623) for teaching explicit grammar knowledge to native speakers. The potential transferability of embodied L2 approaches to explicit L1 grammar learning represents an interesting line of inquiry for future research.

Making room for mind reading. Finally, educators might consider emphasizing in their teaching the potential of metalinguistic understanding to support an understanding of authorial intentions–a

form of 'mind reading' (Consoli, 2014, p. 48). Such an approach might involve framing grammar as a collective workspace for understanding how different language structures are used to generate 'desired meanings grounded in socially shared understandings' (Myhill, 2012, p. 250). A simple example could involve asking learners to rank an assortment of emails or commands in relation to how polite they 'feel' or in terms of where you would place the author on a scale of how angry you think they are, using consideration of their language choices to explain their reasoning. As well as incorporating the aesthetic endeavor of mind-reading, these activities also tap into children's procedural knowledge (sense of what's right). This is advantageous in the sense that learners would be able to do these activities relatively easily, providing reinforcement for them that they are already 'experts' on language. This kind of approach to teaching grammar, which highlights what students already know, is in opposition to the common negative perception of grammar as a difficult subject likely to leave learners feeling 'defeated by the operations of their own words' (Kennedy, 2016, 00:07:50). We therefore tentatively suggest that in order to maximize the full aesthetic potential of grammar learning it might be beneficial to support learners in understanding the relationship between grammar and pragmatics with activities that draw upon their existing (but tacit) knowledge of how language is used to convey particular effects and intentions. Notably, while grammar is currently a very visible strand within the National Curriculum (DfE, 2013), pragmatics is not explicitly mentioned.

Concluding remarks

In summary this paper has taken an initial step towards conceptualizing the aesthetic dimension of learning about grammar, an area which has hitherto been overlooked. We have also begun, albeit briefly, to make some preliminary suggestions about what 'metalinguistically aware teaching' (Myhill, 2013, p. 110) might look like when viewed through an aesthetic lens. We hope that the speculative framework presented in Table 1 opens up a broader conversation around the aesthetics of grammar as a discipline and motivates further research in this area. Gaining a deeper understanding of the potential role of aesthetic experience within the grammar classroom (and education more generally) is crucial, not just because an aesthetically oriented approach might optimize learning, but because it can foster authentic engagement (Ainsworth and Bell, 2020) and human flourishing (Reber, 2019; De Ruyter and Schinkel, 2022).

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by MMU Faculty of Education Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SA: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. HB: Conceptualization, Data curation, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Aesthetic experience in technology education – the role of aesthetics for learning in lower secondary school robotic programming

Maria Andrée[1,2]*, Per Anderhag[1,2,3], Sebastian Björnhammer[1,2,4] and Niklas Salomonsson[2,3]

[1]Department of Teaching and Learning, Stockholm University, Stockholm, Sweden, [2]Stockholm Teaching and Learning Studies, Stockholm, Sweden, [3]City of Stockholm, Stockholm, Sweden, [4]Kunskapsskolan, Stockholm, Sweden

Introduction: Within the technology education research field, aesthetics has primarily been treated as either related to artifacts, design processes and innovation, or as related to students' enjoyment, appreciation, and participation in technology and technology education. This study focuses on the role of aesthetics in technology learning more specifically the learning of programming. Previous research has pointed to aesthetics as important for the learning of programming, e.g., that programming activities in higher education typically involve experiences of frustration. While previous research is primarily based on student reports, there is a need for further exploration of processes of learning to program. The aim of this study is to explore the role of aesthetics for student learning to program in and what these processes may mean in relation to a disciplinary aesthetics of the technology subject.

Methods: The study was part of a design-based study with the overall purpose to develop the teaching of programming in lower secondary school. Data was collected from a programming task designed and implemented in school-year 9 (the students were aged 15–16) in Technology in two lower secondary classes. In total, three teachers participated in the implementation. The students pair-programmed Lego robots that should perform specific movements, such as following a curved line. Each group recorded their coding process along with audio, resulting in videos that documented the gradual evolution of their programs. These videos, capturing the real-time programming and associated student and teacher conversations, serve as the data for this study. In order to analyze the role of aesthetics in classroom conversations a Practical Epistemology Analysis was applied.

Results: The results show that aesthetic judgments were important for orienting learning toward (1) the movement of the robot and (2) the ways to be in the programming activity. During the programming activity, the students expressed feelings of frustration but also joy and humor.

Discussion: The findings concur with previous research and contribute to further understanding the role of negative and positive aesthetic experiences in the teaching and learning of programming. The importance of the objects of aesthetic experience found in this study are discussed as part of a disciplinary aesthetic of programming.

KEYWORDS

aesthetic experience, programming, technology education, robot programming, disciplinary aesthetics

Introduction

This study delves into the significance of aesthetic experiences within the realm of technology education, building upon a line of research on disciplinary aesthetics in education. In this context, disciplinary aesthetics is conceptualized as connected to and emerging in specific school subject practices (Wickman et al., 2021). We draw inspiration from the investigations of aesthetic experiences in science and science learning by Wickman (2006), who demonstrated that aesthetic experiences play an important role in the learning of science (see also, e.g., Jakobson and Wickman, 2008). By examining how people talk about what they do in technology education practices – what they express as interesting-uninteresting, nice-disgusting, cute-ugly and so on – we seek to gain insights into what characterizes a school-subject-specific aesthetics of technology and what role a disciplinary aesthetics may have for teaching and learning technology.

Aesthetics and technology education

Typically two different but interrelated denotations of aesthetics are discerned; aesthetics as (I) a set of design and art practices, and (II) aesthetics as expressions of affect, emotion and taste (Wickman, 2006; see also Prain, 2020). In the realm of technology education, aesthetics has been discussed in relation to both denotations: that is, both as a foundational element in design practices, and as cultivation of appreciation of aesthetical qualities in technological artifacts and technology education, which are in turn intertwined with personal identity and lifestyle (DeVries, 2016).

In previous research on aesthetics in technology education related to practices of design and innovation of technical solutions there are some main lines of reasoning. First, aesthetics is seen as related to the quality of design and disciplinary content knowledge required for analyzing and constructing designs. For example, Haupt and Blignaut (2008) have investigated what aspects of aesthetic design theory that can be taught in technology education, such as visual language and design principles. In this line of reasoning aesthetics is considered a domain-specific construct that students need to develop through explicit teaching. However, aesthetics has also been framed as a critical curricular dimension that goes beyond design and innovation in that it may provide opportunities for students to "step outside of conventional reasoning processes imposed by the rest of the curriculum" Lewis (2005, p. 36). In this line of reasoning aesthetics is framed as complementary to design in engineering processes and as a means to expand the notion of design and problem solving in technology education to encompass the creative potential of design teaching (Lewis, 2009).

DeVries (2016) argues that aesthetics in the sense of appreciation of technological artifacts and qualities, is connected to personal identity and the ways we experience the artifacts surrounding us. Moreover, DeVries (2016) argues that aesthetics plays various roles in different technological domains. Notably, the field of architecture is related to different logic or visions of aesthetics such as modernism, art deco, or brutalism. These aesthetics follow the same rules of logic as for other types of reasoning making it possible to discuss qualities in the architecture related to different aesthetic visions. Likewise, in industrial design, appearance of a product is intertwined with functionality – shapes, colors and so on connected with what the

design is supposed to achieve. Consequently, this form of aesthetical reasoning aims at conclusions regarding appreciations of experiences (e.g., Haupt and Blignaut, 2008). There is also previous research on appreciation of (or taste for, cf. Anderhag et al., 2015) technology and technology education which is mainly motivated by a recognition of the significant relationship between student interest and learning outcomes (Witherspoon et al., 2018; del Olmo-Muñoz et al., 2022; cf., Potvin and Hasni, 2014). Gender differences in attitudes toward technology have also been a subject of investigation (e.g., Virtanen et al., 2015; Witherspoon et al., 2016; Svenningsson et al., 2018), as well as the implications of these attitudes related to the need of a qualified workforce, and societies need of technological literate citizens (Ardies et al., 2013, 2015; Witherspoon et al., 2016). Most of this research on student attitudes and motivation toward different aspects of technology builds on Likert-type questionnaires (Potvin and Hasni, 2014). An implication of this is that the knowledge to date on the role of aesthetics experiences for student learning technology is largely based on students' recollections of their experiences of technology class rather than of investigations into classroom practices.

Technology education and programming in school

In this study, we zoom into the role of aesthetic experiences in teaching programming as part of technology education and the ways in which aesthetic experiences contribute to student learning.

In contrast to other areas of technology education, such as construction work (building of bridges, towers, cars etc.), the aesthetics is not so much related to design features or artistic expressions of a produced artifact but more with the processes of designing programming solutions. During such processes different disciplinary aesthetics may be constituted, potentially orienting student learning in unexpected or unwanted directions. For example, in a study of programming activities for novice learners in primary education, Sparf et al. (2022) caution against prioritizing aesthetics in the form of artistic expressions in programming as it may overshadow the technical aspects. Sparf et al. (2022) analyzed students' informal conversations during programming lessons at three Swedish science centers. They identified five different student approaches to programming: mathematical, trial and error, step-by-step, routine and aesthetic. Sparf et al. (2022) argue that when students approached programming aesthetically, they tended not to focus on the functional solutions to the assignment and, thus, the students missed out on opportunities to discuss and reflect upon the main purpose of the programming. They argued that although aesthetics may be an important part of programming, a focus on aesthetics as artistic expressions of the product may result in the technical task of programming becoming subordinate. It has thus been demonstrated that student engagement in programming education is both personal and situational including dimensions of cognitive, behavioral and emotional engagement (Sparf, 2021). The findings presented by Sparf et al. (2022) diverge from the insights in a seminal paper on programming education authored by Turkle and Papert (1990). In their work, Turkle and Papert (1990) challenge prevailing assumptions and expectations associated with programming as primarily a rational pursuit. Their study, which was based on observations and interviews with students in primary school and university, reveals diverse student

approaches to programming intricately linked to who the students are, think, and how they act as individuals. When observing these students in action, Turkle and Papert (1990) observed a spectrum of approaches, including formal and abstract methods. However, they also noted that the interactions of highly successful programmers with their material "more reminiscent of a painter than a logician" (p. 128). Students who did not conform to the conventional view of programming as a rational-logical process expressed a sense of pressure to transform themselves in order to align with the prevailing programming culture they were a part of.

In von Hausswolff and Weurlander's (2020) study on an introductory programming course in a five- year engineering program at a Swedish university, the students described the process of programming as an emotional roller-coaster. The students experienced both frustration and inadequacy when encountering obstacles, as well as joy and relief when making progress. In particular, the results of the study show how frustration was widely recognized as part of programming practices among the students. Based on the results, von Hausswolff and Weurlander (2020) emphasize the significance of considering the social and emotional dimensions in programming education. A similar argument is put forward by Ford and Parnin (2015) based on an analysis of professional programming practices where they identified situations of frustration when software developers are programming (e.g., in the process of identifying what portion of a code was causing problems). In the analyses of the social dimensions of programming education von Hausswolff and Weurlander (2020) also noticed that aesthetic values were frequently expressed by the students. These results indicate that aesthetics can play a role in students' engagement with technology and that aesthetics form a vital part of programming education in tertiary education. Interestingly, the aesthetic quality of the code was not necessarily consistent with its functionality. Instead, the students primarily emphasized readability and abstraction.

In a systematic literature review on introductory programming Luxton-Reilly et al. (2018) conclude that several studies have explored student engagement in introductory programming encompassing papers focused on time on task, encouragement of self-regulated learning, and the issues surrounding disengagement. Much research focuses on internal characteristics of students and issues of self-regulated learning. Luxton-Reilly et al. (2018) also conclude that affect and emotion is a topic which has received attention (*cf.* a systematic literature review on the role of anxiety when learning to program by Nolan and Bergin, 2016). For example, there are a few studies that have analyzed students' emotional experiences when students work with introductory programming tasks. Based on an interpretative phenomenological analysis of student interviews, Huff and Clement (2017) concluded that experiences of frustration were connected to identity formation, experiences of shame, and maladaptive help. In addition, Kinnunen and Simon (2010) show that the way students talk about their experiences with programming assignments was dominated by emotional expressions. Based on a survey of 388 undergraduate introductory programming students' emotional reactions, Lishinski et al. (2017) also concluded that frustration is the most important emotional reaction and that there is a correlation between students' emotional reactions and their performance on programming projects (*cf.* Martin et al., 2017). Robins et al. (2003) discuss the strains and challenges with learning programming as associated with the abstract nature of programming concepts, the

difficulty in understanding algorithms and problem-solving strategies, and the need for students to develop programming skills along with their understanding of programming principles.

In summary, previous research on programming education have emphasized the importance of designing educational programming environments that enhance student engagement, motivation and learning (*cf.* Martin et al., 2017). Existing literature, primarily focused on tertiary-level programming education, indicates that programming activities encompass a spectrum of emotions, ranging from frustration to joy. Students in these contexts frequently express aesthetic values. Notably, at the tertiary level, there seems to be a distinct disciplinary aesthetics of programming education. However, when it comes to programming within compulsory technology education, the knowledge about the role of aesthetic experiences and the ways in which they mediate learning in classroom practices is more limited. Additionally, numerous studies rely on students' self-reported experiences of strains and frustrations. It is not unlikely that aesthetic experiences in compulsory technology classrooms may manifest differently where the students have not chosen programming as a professional career. More generally, the research on aesthetics in technology education points to the importance of fostering appreciation of technology and technology education. An exploration into how such appreciation is cultivated in classroom practices would provide a more nuanced understanding of the role of aesthetics in and in what ways the aesthetics of programming and technology education may be understood as a disciplinary aesthetics of programming.

Aim and research questions

The aim of the study is to explore the role of aesthetics in programming activities as part of technology education. The research questions asked are:

- What are the objects and phenomena aesthetically evaluated when students are programming in technology class?
- What role do aesthetic evaluations have for student learning in programming?

Theoretical framework

As mentioned in the introduction, two types of meanings are usually associated with aesthetics, where one specifically deals with art and design processes, and the other concerns what people experience. The latter meaning, which since Kant (1790/1987) is linked to people's feelings of pleasure and displeasure, and what they find beautiful or ugly, is the focus of the current paper. The study takes a pragmatic perspective on learning, drawing on previous empirical studies grounded in John Dewey's works on aesthetics. We primarily take our starting point in the tradition that stems from Dewey's problematization of aesthetics solely linked to the realm of art, and that emotion, practice, and facts usually has been treated as separated when people learn. Instead, aesthetic experiences are viewed as connected to learning in general and thus having significance for how people understand and act in the world. To Dewey (1997), aesthetic experience goes beyond mere sensory pleasure or the recognition of

artistic value. Rather, it entails an emotional engagement with an object, event, or circumstance, resulting in an awareness of perception, response, and intellectual engagement, in which anticipation is consistently present regarding what lies ahead. Therefore, within the process of learning, individuals continually form connections toward completion and closure. According to Dewey, who saw human conduct as a result of an evolutionary process of adapting to the world, aesthetic, and cognition is intertwined and so constituting processes that by necessity, as we in some way or another always are "in the world", is continuous with previous experiences. These processes entail a rhythm of anticipation and potential fulfillment, and the interplay is shaped by actions in which aesthetics both impact and facilitate the rhythm's continuity (Dewey, 1997).

Continuity is closely related to purposes and to Dewey, individuals naturally engage in activities driven by a purpose, objective, or a goal. Through these purposeful activities, people develop habits of coping with the world, so constructing their understanding and learning new things and skills (Rorty, 1991). Purpose and continuity thus intertwine as purpose connects different experiences and activities and when an individual engages in an activity with a purpose, it becomes a part of the broader scope of their experiences (Dewey, 1997). Therefore, interpreting and comprehending aesthetic expressions within a classroom necessitates an understanding of what is going on in the situation where a certain object is aesthetically evaluated (Wickman and Östman, 2002). For example, when students describe worms as "cute" during practical work in science class, it does not necessarily imply a desire to keep worms as pets at home (Jakobson and Wickman, 2008). In this context, the aesthetic object pertains to worms within the science classroom and the purposes transacted by the students (such as daring to hold the worm when examining it), rather than worms in general.

Aesthetic experience and student learning

The role of aesthetic experiences for student learning and especially regarding what may characterize a specific disciplinary aesthetics have recently been studied within the field of science education (e.g., Caiman and Jakobson, 2022; Ferguson et al., 2022; Hannigan et al., 2022). Common to these studies are their interest in the specific purposes, processes, and objects that students and teachers discern as interesting, beautiful, ugly, disgusting, etc., and the significance these distinctions have for the meanings about the subject (and themselves) that are constituted in the classroom. A person's aesthetic experience is evident through the verbal aesthetic judgments s/he makes, and such judgments have been shown to orient student talk and action toward (or away from) the purposes of the classroom activity (Wickman, 2006). Aesthetic judgments thus have a key role for what route learning take in the classroom, irrespectively whether it is students learning about marine animals and insects at the university level (Wickman, 2006), electrical circuits in secondary school (Anderhag et al., 2015), earthworms (Jakobson and Wickman, 2008), or ecology (Caiman and Jakobson, 2022) in primary school.

Being expressions of preferences of like/dislike, or perceptions of beauty/ugliness, aesthetic judgments are directed toward something, such as for example that a code is described as 'nice' by students in the technology classroom. In so doing they simultaneously express something about their feelings while labeling the subjective qualities

of the object (Wickman, 2006). These qualities, however, are continuously negotiated as part of the social situation in which they are transacted, potentially leading to agreement among participants ("yes, it is a nice code"). In this way, the participants may (or may not) jointly construct a shared understanding of what and how objects are aesthetically valued in the technology classroom. For example, a nice code may be easy to read, short, or having certain functional segments. Besides being closely connected with the learning of the procedures and facts of a specific school subject (such as what characterizes a nice code and how to produce such a code), aesthetic experience is however also closely connected to different ways-of-being in the classroom. For example, who is smart or nice or who can distinguish what is smart or nice (such as a nice code). Such distinction of taste is central to how people navigate socially, distinguishing themselves and others as belonging or not. Developing an understanding of the disciplinary aesthetic is thus important for students' opportunity to learn cognitively about the subject but also to successfully participate in settings where the subject is at stake (Anderhag et al., 2015). As the disciplinary aesthetic can hinder or enable students' socialization and identification as participants, teaching is of great importance for supporting students in negotiating aesthetic objects within the classroom culture. The immediacy of communication is facilitated by aesthetic judgment, especially when a student lacks familiarity with certain cultural concepts (Wickman, 2006). This sometimes leads to the use of more practice-specific content of communication and sometimes functioning as a natural part of the practice (*cf.* Knorr-Cetina, 1999).

In this study we focus on the students' verbal aesthetic judgments during a programming lesson in technology class, with an awareness that this constitutes a specific aspect of the broader communication taking place within the classroom. We analyze these judgments in relation to the aesthetic objects to which they are directed, with the intention of gaining a deeper understanding of the role of aesthetics in students' learning of programming within the technology classroom.

Study design

The present study is part of a collaborative project between teachers and researchers with the overarching aim of developing teaching in programming within the context of the Swedish primary school's technology subject.

Programming in Swedish compulsory school technology education

In Swedish compulsory school, technology education is taught throughout compulsory school as a subject aiming to foster technological literacy. The Swedish school subject Technology (*Teknik*) aims at providing students with opportunities to develop an understanding of the role of technology in society; to develop technical awareness and vocabulary. As a school subject Teknik represents technical knowledge traditions, which are different from the knowledge traditions of science, and related to the specific contexts and practices in which the technical and technology knowledge becomes meaningful (Björkholm et al., 2016). In particular, reflection, analysis and construction of technical solutions is emphasized

(Swedish National Agency of Education, 2022). In the Swedish technology syllabus, programming is part of the core content *methods for developing technological solutions* and in years 1–3 (age 7–9) the students are supposed to learn to control objects, such as a robot, using programming. In years 4–6 (age 10–12) the students should learn to control their own constructions or other objects by using programming, and in years 7–9 (age 13–15), the students are supposed to use programming for controlling and regulating their own constructions. Programming is thus primarily a tool for controlling objects and a progression in terms of knowing how to program is not formulated in the technology syllabus.

Programming was a relatively new content in the technology curriculum for Swedish compulsory school when the project started, and there was generally a lack of experience both among teachers and educational researchers in Sweden regarding what characterizes programming education within the scope of the technology subject (Vinnervik, 2022). What content, concepts, procedures should be emphasized, and how can it be connected to the broader objectives of the technology subject? Within the project, there was, therefore, a shared interest in developing teaching in programming.

Study setting

The study was conducted within the research environment Stockholm Teaching & Learning Studies (STLS) (Andrée and Eriksson, 2019). Within STLS, researchers and teachers collaborate in designing and conducting small research and development projects that address challenges and questions that have been identified in the teaching of different school subjects. The teachers' participation (10% of full-time-employment) is funded by their respective school authorities and the activities, lessons, and series of lessons that are jointly developed are tested in the participating teachers' classrooms. As part of participating in STLS the teachers implemented lesson designs, which had collectively been developed, with their students in their respective classrooms. The sample of the participating students in the study thus depends on the teachers' participation in STLS.

The collected data comes from two lower secondary technology classrooms (School A and B) in Stockholm, Sweden. Niklasson was the teacher of one of the student groups participating. The students (year 9, ages 15–16) were working with a task of programming Lego robots that should perform specified movements, such as following a curved line. The lessons were designed so that students were given the opportunity to develop skills and understanding specified in the curriculum of the technology subject. In school A this task was part of a broader unit that we had jointly designed that centered around sustainability and technology. During this unit, both the teacher and students collaborated to discuss and create a model of an automated recycling station. Conversely, in School B, students solely focused on the curved line task. Throughout the lessons, the teachers actively moved around the student groups, assessing their programming progress. They interacted with the students by posing and answering questions, and also encouraged discussions that allowed students to articulate their programming intentions. The students utilized the Lego Spike package on their iPads while engaging in pair programming their robots.

The study adheres to the ethical guidelines of the Swedish Research Council (2017). The students and their guardians of the participating classes were provided information about the purpose and the design of the project. The participating students and their guardians all signed a letter of consent. The collected data of the study is handled according to the General Data Protection Regulation (GDPR).

Data collection

The lesson was part of the regular teaching and aimed to support the students' understanding of programming. The organization of the lesson followed the teachers' usual approach when programming with the students. The teachers divided the students into groups of two or three, where each group had access to an iPad and a robot. The teachers explained the aim of the lesson and asked them to start screen recording when they started with the tasks.

Each student group screen recorded their coding process along with audio, resulting in videos on their Ipads that documented the gradual evolution of their programs. A total of 7 screen-recorded videos, with 4 from School A and 3 from School B, were transcribed verbatim. The length of these videos varied from 30 to 60 min. These videos, capturing the real-time programming and associated student conversations, serve as the data for this study.

The data was initially analyzed in order to explore what strategies the students use when they were programming a robot to perform a specific movement, which we have reported in a previous study (Anderhag et al., 2023). During this process we noted that the students recurrently used aesthetic judgments while they were programming. The presence of aesthetic judgments were not something we had expected or planned for when we designed the lessons together with the teachers, nor was it something that the teachers consciously acted upon or considered when they were teaching the students. Thus, the focus on aesthetics of the present study emerged through the processes of designing, implementing and reflecting upon programming classroom practice rather than as a consequence of planning for it. In the current study, we use the same data as in the previous study but with the analytical focus on aesthetic judgments used by the participants.

Data analysis

The transcribed films were initially analyzed to identify aesthetic situations, primarily evident when students verbally made aesthetic judgments while they were programming. Aesthetic judgments are evident as the students and teachers make judgments of inclusion and exclusion on language use (language in a multi-representational sense), procedures (ways-to-act), and ways to be. We then conducted a categorization of the types of objects and phenomena toward which students directed their aesthetic evaluations. The categories were developed, integrated and reorganized until agreement was achieved between the co-authors (*cf.* Glaser and Strauss, 1967). Potentially, objects and phenomena could be physical items, such as a robot, iPad, or a piece of (digital) code, but they can also encompass actions (e.g., ways of programming) and concepts (e.g., loops). We deliberately chose to use this rather inclusive heuristic to encompass a wide range of situations. These situations were then analyzed using Practical Epistemology Analysis (PEA) (Wickman and Östman, 2002). PEA is

grounded in a pragmatic perspective where learning is operationalized as discourse changes as part of an activity (Kelly et al., 2012). We primarily used three of the analytical concepts of PEA, *stand fast*, *gap* and *relation*, to identify the role of aesthetics for student learning. What stands fast in a situation are things, phenomena, actions, words that the interlocutors do not question in talk or action. As an activity proceeds, such as when students are programming, gaps emerge as a result of encounters between persons and artifacts (*what does this code do?*) or phenomena (*why did the robot stop moving?*). In order for the activity to proceed, the gap needs to be filled with a relation to what stands fast, that is things that are intelligible in the situation.

The following transcript exemplifies the concepts further. The students had programmed their robot to stop at a red line after it had followed a curved line. They had debugged their code and in turn 1 they decided to run the program to see if adjustments worked as intended. In turns 3–5 a gap is noticed, that is, the robot did not stop when it reached the red line. In order to proceed with the activity, the gap "how should we stop the robot at red?" needed to be filled with a relation to what stands fast. Several things in this situation stand fast, such as for example they do not question or discuss that the robot should stop at red, or that something is wrong with the code. The gap is filled in turns 6–7 as S2 noted that they had forgotten to insert a stop command after the sensor command (wait until sensor B registered red). A relation is established "how should we stop the robot at red – by inserting a stop command."

1. S1: We can try just first.
2. [testing the new code].
3. S2: Oops! [The robot crosses the red line]
4. S1/S2: [laughter].
5. S2: It's supposed to stop?
6. S2: When B. When the color is B. Damn, we need to stop there, we forgot [giggle]. Damn. It's fighting! [the robot keeps moving].
7. S1: Yes, stop.
8. S2: Should I try now?
9. [testing].
10. S1: Now it might be good
11. E2: Yes.
12. S1: Here it comes [the robot moving along the line].
13. S2: Damn [giggles], what, what movements it makes!
14. S1: Perfect movement.
15. S2: Check it out! Check it out! Stop then! Like that! Yeeeees.
16. S1: Yeeeees.
17. S2: Yeeeees.
18. S1: And then, then we must have, then we make a new one like this. Sensor A.

The transcript exemplifies the flow between anticipation and fulfillment of an aesthetic experience. After the students had inserted the stop command and executed the program again, the changes were aesthetically evaluated as potentially good, so anticipating that the robot would now move as intended. While observing they made positive consummatory judgments on its movement and the situation is summed up in turns 16–17, as they happily concluded that the changes to the code had resulted in a stop at red preceded by *perfect* movements. In turn 18, they started with the next task. In this example, hence, the 'movement of the robot' was an *object* of students' aesthetic evaluations.

In summary, the first step of the analysis aimed to generate results to answer research question 1. That is, what is evaluated aesthetically when students are programming. We were thus interested in what objects and phenomena the students distinguished. In the next step, PEA was used to gain a deeper understanding of what was extracted in step 1, potentially producing results on what identified objects and phenomena may mean in relation to learning to program. In other words, what consequences do these aesthetic objects and phenomena have for the meanings students construct while programming. This step aimed to address research question two.

Results

Throughout the programming activities aesthetic judgments were used by the students and their teachers for evaluating actions conducive to the purposes of the activity, that is, programming the robot to move in a specific way. Such actions were primarily dealing with the emerging code and how it could be altered. Although rarely articulated explicitly by the participants, the students were thus engaged in an activity where they were developing, testing, and evaluating a technical system where the construction (the code) was adjusted to improve its functionality (movement). In the programming activity, primarily two kinds of aesthetic objects were evaluated: *The robot movement* and *Ways to be a programmer*.

In what follows, we will present our findings in relation to the two research questions of the study, we will do so by presenting the two aesthetic objects identified under separate headings. The second research question, what role aesthetic evaluations had for student learning, will be handled throughout the paper and summarized at the end of the section.

The robot movement as an aesthetic object

Disgust and frustration when the robot takes an unwanted direction

Although the students understood the task to program the robot to make it follow a curved line, they were not sure how to use the example code to make the robot move in alignment with the purpose. The uncertainty about how to proceed resulted in frustration among the students and the analysis revealed several instances where they were using negative aesthetic judgments while they were programming their robots. These judgments were directed toward different aspects of the programming activity, primarily toward the unexpected and unwanted ways the robots moved but also for example the losing of Bluetooth connection between the Ipads and the robots or the depletion of the batteries of the robots. Negative aesthetic judgments were thus used in situations where the activity stopped or took an unwanted direction. In Example 1 a student expresses frustration as the wheels of the robot did not move as expected.

Example 1: *This was incredibly disgusting*
1. Student: This was incredibly disgusting. Because, you see, the problem before was that they were driving backwards, and now they are driving forward. When you turn. When you turn them

around, then it starts moving forward. But then, they do not go at the same time. Which is quite strange. I mean.

The student felt disgusted by the fact that the wheels moved in unexpected ways and the irregularity of the movement of the robot was judged as quite strange. In the example the situation was evaluated as disgusting; sometimes the students' frustration was directed explicitly toward the robot– the performer of the unexpected movement. The next example illustrates a similar situation: the students had been working with their program for 40 min when the robot unexpectedly no longer stopped at the red line.

Example 2: *I could easily kill you*
19. S1: What happened now?
20. S2: I'm going to start crying soon.
21. S1: It missed the red one?
22. S2: I'm going to start crying soon. I'm going to start crying soon.
23. S1: [Laughs].
24. S2: Do you [the robot] want to die? Because I can easily kill you.
25. S1: Are you threatening it [giggles]?
26. S2: It's just a matter of breaking you apart. Do you know how easy that is? I have the power here, not you.

In turn 1 S1 noticed a gap, the robot did not stop at red. The students did not expect this to happen as they had inserted, tested, and debugged a code that previously had made the robot stop at the red line. S2, being frustrated, said that she is about to start crying (turn 2, 4). Later S2, still frustrated, humorously asked the robot if it wanted to die and that she could easily kill it and take it apart (turns 7, 9). The joke was well perceived by S1 who giggled as she questioned S2 threatening the robot (turn 8). The two examples above showed how students were engaged in the programming activity and express frustration but also humor as their actions did not result in the anticipated outcomes. If the students did not establish relations that filled the respective gaps (they did) the only possible scenario would be that the activity ended. That is, they could not continue with the task. Although jokingly, S2 seemed to consider the possibility of putting an end to the activity by simply breaking the robot.

Celebrating desired robot movements

Examples 1 and 2 showed instances where students evaluated situations and artifacts that did not comply with their expectations of what route the activity should take. The teachers were attentive to situations where students faced challenges, and provided support and guidance to help students navigate their way forward. The next example showed such a situation. The students had been working for some time coding and debugging but still not yet been able to program the robot to perform the task. In turn 1, the teacher asked how things were going:

Example 3: *I feel like I do not want to continue, honestly*
1. Teacher: How are things going for you?
2. S1: Well, uh… It's not going well at all. It's going insanely bad today. I feel like I do not want to continue [in Swedish *tappar lusten*], honestly.

3. Teacher: Well, we… we'll spice it up [in Swedish *lustar upp det*]. We'll fix it.
4. Teacher: Okay, press that… uh…um. No, let us do it this way. I'll give you some stuff.
5. Teacher: Um… [introduces a new variable "lowPower" and sets it to 20].
6. Teacher: Then it stops all the other blocks, this one and also stops the wheels.
7. S1: Yeah, that's awesome.
8. Teacher: So, now you have that, and then you can start figuring out how to make it drive around in here.
9. S1: Yeah. That's great. So now this should work elegantly.

Things were going "insanely bad" and the student was about to lose his will to continue. In turn 3, the teacher told the students that they together would "spice it up" and that they would "fix it." He then made some changes to the code and inserted a new variable, while doing that he described what the changes would do for the movement of the robot. These changes, and the anticipated outcome of these procedural alterations, were distinguished and aesthetically evaluated by student 1: "Yeah, that's *awesome*" (turn 7), "Yes. That's *great*. So now this should work quite *elegantly*" (turn 9). In the example, positive anticipatory aesthetic judgments were thus used for evaluating procedural distinctions of inclusion that the student felt would lead the activity toward the preferred outcome. Such examples were of course not only connected to previous situations of frustration, as shown in Examples 1–3, but were used throughout the activity for evaluating how procedures were conducive to anticipated outcome. Examples 4 and 5 exemplifies such instances. In Example 4, the students had tested the code and wanted to fine tune the movement of the robot.

Example 4: *It's kind of nicest*
1. S3: No.
2. S2: Yes!
3. S2: It's kind of the nicest.
4. S3: [laughter].
5. S2: Wait, let us try exactly like that so it ends up like that again…
6. S3: If we manage to get it like that again…
7. S1: But, I mean, fifty-five cents, it goes fifty-five centimeters, that's maybe a little bit too little, a lot.
8. S2: No, so, now we go again.

In turns 1–2 students S2 and S3 commented on the robot after they had made some small changes to the code. S2 then made a distinction, "It's kind of *nicest*," making a consummatory evaluation of the movement they just had observed. As evident from the following turns, "nicest" stands fast in the situation and the students were eager to have the robot repeat the (nice) movement and discussed the possibility of making some minor adjustments to the code (turns 5–8). In example 5, below S2 describes to the teacher what he wants to accomplish with the code he is working with, namely having the robot make a continuous turn without stopping first.

Example 5: *No, you want a neat turn*
1. S2: So that's what I need help with. How can it turn like that? Because right now, it just stops and then turns sixty degrees immediately.

2. Teacher: Exactly. In that case, you need to rotate both wheels, maybe like this. Either you rotate sixty degrees, and what you are actually saying is that one wheel rotates while the other stays still.

3. S2: Yes. But actually, I do not want it to drive straight and then turn.

4. Teacher: No, you want a neat turn.

5. S2: Yes.

6. Teacher: Yes, and that's the thing with wheels, it's this...

7. S2: ...needs to move slower.

8. Teacher: Needs to roll further than the other.

9. S2: Yes.

10. Teacher: Exactly. So that it continues rolling forward but also starts to turn slightly.

11. S2: Yes.

12. Teacher: So you need to divide it.

13. S2: Does it have to do with power again?

14. Teacher: Yes, exactly. And then, you simply assign different percentage values to them.

15. S2: I see.

16. Teacher: So that one goes a little faster than the other. If you think about different radii, then one must be much faster than the other.

17. S2: Yes.

18. Teacher: To make a neat turn.

19. S2: Yes.

In turn 1 a gap was addressed by S2: how do I make the robot make a turn without stopping? A relation was put forward as the teacher suggested that the student should alter the movement of the wheels for making the turn. These suggestions did not address what the student wanted the robot to do and in turn 3 he clarified that he does not want the robot to move straight and then make a turn (describing a L-shaped movement). The teacher responded by saying "No, you want a *neat* turn" so making a distinction of exclusion regarding a sharp robot movement. In the situation "neat" stood fast and in the following turns the teacher and the student discussed how the wheels should move in order to perform an arch-shaped, and so neat, turn without stopping first.

Also, the code, rather than the robot or its movements, could be evaluated aesthetically. Usually, it was the teachers who made such judgments. In one instance the teacher asked a student group "Could you make this [a part of the program controlling the wheels] *nice* by adding another variable?". The teacher thus addressed a normative aspect of the code; it could be more or less nice and there were ways to produce a nicer looking code. In this particular situation, the students created a new variable controlling the power of the wheels that they named "Hjulben." The choice of name was a sort of playful joke, in Swedish "Hjulben" (literally translating to wheel legs) means bow-legs.

Finally, consummatory aesthetic judgments were also used in situations of fulfillment when processes came to an end. The next example illustrates how the teacher evaluated how one student group had accomplished the task of programming the robot to perform a specific movement. This is the same group that were joking about killing the robot and before Example 6 they had tried and had made several changes to the code in order to have the robot move as intended. The robot was following a curved line by using light sensors, stopped at a red line where it picked up a Lego-brick, and finally

backed up and stopped when its sensor registered a green line. In turns 1–5 the teacher and the two students were observing and commenting on the movement of the robot.

Example 6: *It's so beautiful. It's so beautiful. Fantastic!*
1. S1: Ah!
2. Teacher: Ah! Now! There!
3. S1: Nooo!
4. Teacher: Well, well, but still...
5. S1: But now it will not find... (inaudible)... green.
6. Teacher: Fantastic. No, exactly, let us redo it.
7. S1/S2: Mm.
8. Teacher: Maybe we should film it because that was brilliant.
9. [They run the program].
10. Teacher: It's so beautiful. It's so beautiful. Fantastic.
11. S1: But then, it does not touch the green.
12. S2: No, that's it. We need a different command then.
13. S1: Yes.
14. S2: Otherwise, it works.
15. Teacher: But that was it, now it's adjusted, now it will work.
16. S2: Yes.

The teacher and students discussed the movements of the robot and evaluated how well it performed what it was supposed to do. Due to a slight deviation of the movement of the robot, its sensor missed to register the green line, which the students noted (turns 5 and 11). At the same time the teacher summarized their work as they had managed to program the robot to perform the first, rather complex, steps of the task. The movement, and indirectly the code, was evaluated as *fantastic*, *brilliant*, and *beautiful*.

Ways to be a programmer as an aesthetic object

Celebrating oneself as a programmer

The students did not only distinguish and aesthetically evaluate conducive or preferred procedures when programming their robots, they also made distinctions on ways to be in the classroom. For example, they referred to each other as "smart" or as being "Mr technician", thus distinguishing themselves and/or their classmates as persons who know how to solve a programming problem. The following example showed a situation where the students succeeded in programming the robot to perform the wanted movement. The students had worked for a long time altering and debugging their code when they in turn 2 ran the program.

Example 7: *What a freaking genius!*
1. S1: Go. Try it.
2. [the students test their program].
3. Both: Aaaaaah!
4. S2: Who's as smart as me!
5. S1: It works! Oh my god! [clapping her hands].
6. S2: Who's as smart as me!
7. S1: [Name of S2], what a freaking genius!

As with the previous examples, the aesthetic judgments are expressed in evaluating a situation that came to fulfillment – the robot

did as anticipated. Here, however, it was not only the movement of the robot that was evaluated but also the person who programmed the robot. In turn the students screamed in joy as they saw the robot do as expected, in turns 20 and 22 Student 2 made a distinction on herself, saying *Who's smart as me?* That Student 2 is smart was also supported by Student 1, saying in turn *What a freaking genius!.*

It's okay to feel that programming is difficult

As described earlier, the teachers were very careful in supporting student reasoning on how the problems, i.e., the movement of the robots, could be addressed through changes in the code. In such instances they regularly acknowledged the student contributions and clarified how it tallied with what they wanted to accomplish. That the tasks were complex and that potential problems were connected to this complexity, rather than the students' understanding or competence, were made explicit by the teachers throughout the activity. In example 8, the teacher and the student, who had been debugging her code for some time, cheerfully agreed that programming was tough and it was okay to hate it.

> Example 8: *I hate programming, but it's fun.*
> 1. S1: It's not working, I hate programming [laughter].
> 2. Teacher: Me too, but it's still fun [laughter], it's really tough.
> 3. S1: I hate programming, but it's fun.
> 4. Teacher: It's fantastic when it works.
> 5. S1: Yes.
> 6. Teacher: But it's really tough when it does not work.
> 7. S1: Yes [happily]!

Programming could thus be a tough activity and several aspects of it could be difficult to grasp, which the teachers continuously acknowledged. During the lesson, the teacher had explained to the whole class how variables worked and how they could be used. In Example 9 below, the teacher made the students in one of the groups aware of the variable "Power" after having discussed how they could program the robot to follow a curved line by using its light sensors.

> Example 9: *Did it feel completely intuitive or was it very strange to understand it?*
> 1. Teacher: Do you see that there's something called "Power" here? What is it?
> 2. S1: Yes, then it can copy the actual speed to the next one.
> 3. Teacher: Ah, well said. This is called a variable. Did you feel like it was completely intuitive or did you find it very strange to grasp?
> 4. S1: No, I understood it quite quickly.
> 5. Teacher: Great. It's just like X or Y in math.

Learning to program and potentially also to develop a sense of belonging in the practice of programming, thus entails using certain procedures and objects, such as variables. In this process, the function of parts of the code could seem strange or difficult to understand and that was okay. Making students aware of how their doings comply with purposes are likely to be important for how they perceive themselves as participants in the programming activity. For example, as exemplified in the previous example of the teacher making a distinction of inclusion on the student explanation of the variable

Power. Another example of how the teachers made students aware of how their doings adhered to the practice of programming was when a student with the support of the teacher reasoned her way to how they should proceed. In Example 10 a student describes her problem out loud to herself and then found the solution on her own, which, according to the teacher, is something that programmers often do.

> Example 10: *This is a well-known phenomenon in programming, it's called rubber ducking*
> 1. S1: I understood, thank you very much.
> 2. Teacher: Do you know what you just did? This is a well-known phenomenon in programming, it's called rubber ducking. Let me explain. Many programmers have a small plastic duck on their programming desk.
> 3. S1: Okay.
> 4. Teacher: And when they have a problem that they do not understand how to solve.
> 5. S1: Mm.
> 6. Teacher: They explain the problem to their plastic duck, and just by explaining the problem, they often find the solution.
> 7. S2: Exactly. Okay, but then you'll [S1] have to explain it to me.

In the data, there were few situations when the students explicitly made distinctions on ways to be in terms of exclusion, that is, saying that they could not program or that they are not a programming or technology person. However, there were instances where they joked or used irony in humorous ways to distinguish themselves or their classmates as not being great in what they were doing. For example, by jokingly saying that they would get an A in technology when they got stuck or executed a code that did not result in the movement they had expected.

Summary of results

Both students and teachers used aesthetic judgments to assess (1) the movement of the robot and (2) ways to be in the programming activity. In such situations, the interlocutors evaluated whether anticipated or observed procedures tallied with the purpose of the activities, that is, having the robot perform specific movements. Even if judgments only rarely explicitly distinguished aspects of the code, such as being a nice or ugly code, the observed and evaluated function oriented the students' exploration and adjustment of the evolving code. For example, in the case of having the robot perform a neat turn, the teacher and the student first discussed what parts of the robot that should be altered for making a neat turn (different power on the wheels), and after that they discussed what such an alteration amounted to in code. Aesthetics was thus shown to have an important role in orienting student learning, with some exceptions all student groups succeeded in producing code that made the robot perform the wanted movement. Moreover, the analysis showed that students expressed feelings of frustration during the programming activity. If students recurrently experience technology class or programming as a practice where their actions rarely or in arbitrary ways lead to the expected outcome and feelings of fulfillment, it is likely that they will develop negative attitudes toward the subject. As with distinctions in procedures, distinctions on ways to be are likely to be of importance

for how the individual views him/herself as competent in the technology classroom. It is thus likely that a student who continuously is distinguished as not belonging, either by her/himself or others, is likely to turn away from the subject. However, the teachers were very attentive to situations where the students got stuck and, in such instances, they (1) acknowledged the difficulties of the tasks, (2) scaffolded them in reasoning how to proceed, and (3) made them aware of how specific code segments could be used to solve encountered problems.

Discussion

Within the technology education research field, aesthetics has primarily been treated as either related to artifacts, design processes, and innovation (e.g., Haupt and Blignaut, 2008; DeVries, 2016), or as related to students' enjoyment, appreciation, and participation in technology and technology education (e.g., Potvin and Hasni, 2014). Within the research specifically investigating the learning of programming, affect and emotion are generally noted as important for student learning (Kinnunen and Simon, 2010; Luxton-Reilly et al., 2018). Our study can be said to traverse these three areas as it has sought to explore what objects and phenomena the participants appreciate (or not) and what consequences such aesthetic experiences have for learning to program in technology class. In line with previous studies on disciplinary aesthetics and taste in various school subjects, learning technology does not solely mean to learn what is the case in terms of concepts, facts, and phenomena but also to learn what is and what is not valued, enjoyed, and appreciated in the technology classroom. Consequently, learning a disciplinary aesthetic or a taste also means learning who you are or could be in relation to the subject.

Aesthetic judgments as a means to orient student learning in the context of technology education practice

So, how are our findings related to previous research on aesthetics and learning technology and especially learning to program in technology class? The study contributes to the notion of aesthetics being a central element in the understanding, design, and evaluation of technological artifacts in that it presents empirical evidence on how such processes may unfold in classroom action. In line with the work of Wickman (2006) and Jakobson and Wickman (2008), this study has demonstrated the role of aesthetic judgments for orienting learning processes toward the purposes of the activities. In these processes, especially the movement of the robot and the student as programmer were seen to be the focus of the distinctions made, possibly constituting important aspects of what Hannigan et al. (2022) refer to as experiential, subject-based aesthetics which "entails participants' feelings in engaging with the purposes, objects, instruments and inquiry strategies of a subject" (p. 798).

The aesthetics did thus not primarily revolve around the technological artifact that the students were designing (cf. DeVries, 2016), namely the code, but rather its functionality as it was expressed through the movement of the robot. Even if it is not

surprising that the students aesthetically evaluated the outcome of the code rather than the code itself, the finding is nevertheless interesting in relation to learning disciplinary aesthetics as it may exemplify an everyday taste of the novice programmer and that there may be different aesthetics at stake in the activity (cf. Hannigan et al., 2022). There are ample examples from other subject disciplines demonstrating what the experienced connoisseur finds aesthetically pleasing (or not), such as; what is nice in an experimental setup in science (Wickman, 2006), what is interesting in a certain way of presenting data in math class (Ferguson et al., 2022), or what beauty there is in mathematical inquiry (Sinclair, 2006). We can only speculate, and more research is needed, but it is likely that the more experienced programmer successively develops an appreciation of certain aesthetic qualities of the code that to the novice may seem elusive (as in this study). In the study of von Hausswolff and Weurlander (2020) at the university level, for example, a good-looking code amounted to a shared, although implicit, understanding of readability and level of abstraction. Also, the teachers in our study occasionally made distinctions on the code, making the students aware of aesthetically pleasing ways of adjusting their program that would better accomplish what it was supposed to do. The findings thus imply possible instances where positive (or negative) aesthetic experiences may be made continuous between on the one hand the outcome of the program (movement/function), and on the other hand the program itself (code/construction). Again, these aspects need to be studied further but it is likely that such scaffolding is important for students' opportunity to develop a disciplinary aesthetics that is current and recognized also in other programming settings.

Frustrations as opportunities for productive struggle

The programming tasks in this study were a kind of semi-open inquiry in that it had a clear goal - programming the robot to perform a specific movement - while at the same time allowing for various alternative ways of reaching this goal. It turned out that some of these open tasks were difficult for many of the students, and they dedicated a lot of time to writing, testing, and modifying the code required to accomplish the specific movement. This process resulted in a great deal of frustration, a well-known and widely recognized feeling within the field of programming (Lishinski et al., 2017).

If students repeatedly perceive programming as an activity where their efforts seldom result in the intended outcome and feelings of fulfillment, it is probable that they will develop negative attitudes toward the subject. Negative aesthetic experiences do however not necessarily have to be problematic; the important thing is that the students want to take part in the activity and that negative aesthetic experiences are handled and transformed in the long run (Wickman, 2006). The study of Björnhammer et al. (2023) demonstrated how aesthetic experience shifted between positive peaks and negative lows during an inquiry activity in science, where one student group commenced with resignation but ultimately solidified their commitment, while another group, by way of comparison, embarked with excitement but eventually

found themselves mired in frustration. One might posit that tasks, such as the programming activity in this study, could be structured to minimize the occurrence of negative turns, however, Björnhammer et al. (2023) cogently argue that even though reducing the degree of freedom within an activity might limit the risk of failure, it would also inevitably transform an open inquiry into a more constrained activity. Hence a precarious balance exists, determining when modifications would render an entirely different activity. However, our conclusion is not to exclude or protect the students from negative aesthetic experiences.

The teachers in our study were very attentive to situations when the students got stuck and, in those situations, the teachers acknowledged the difficulty of the tasks, and affirmed that it was okay to lose motivation and not know what to do. Through scaffolding student reasoning, they usually conclude together how to proceed purposefully with the activity and with some exception all student groups succeeded in bringing processes to closure. These strategies, to acknowledge difficulties of tasks and encouraging and support students' reasoning on productive ways of moving through difficulties and toward purposes have previously been suggested to be important characteristics of practices where taste may develop (Anderhag et al., 2015). We may see this as means to creating spaces and opportunities for students to engage in a 'productive struggle' (*cf.* Warshauer et al., 2021) with programming.

Distinguishing oneself as a competent participant

In addition, the students also aesthetically evaluated themselves as participants in the programming activity. As with distinctions on procedures, also distinctions on ways to be are important for how the students view themselves as competent in the technology classroom and it has been argued that feelings of frustration while programming is intimately connected to identity formation (Huff and Clement, 2017). Although not specifically exploring emotions or aesthetics, Turkle and Papert (1990) demonstrated that students who approach programming in 'artistic' and unconventional ways, may perceive that their ways of being do not comply with the norms and values reproduced in the programming courses. Turkle and Papert (1990) therefore argue for 'epistemological pluralism', allowing for different ways of being as a programming student. It is thus likely that a student who is continuously distinguished as not belonging, either by her/himself or by others, is likely to turn away from the subject. This was however not the case in the programming activity studied here, besides playful jokes that were well-perceived, the students did not make negative aesthetic judgments regarding themselves or their classmates. Although this is likely to be of importance for how the students perceive themselves in relation to the technology subject and the disciplinary aesthetic emerging, we cannot say whether this was a result of the activity, the teaching, or reflecting a generally positive classroom environment. Whatever the cause was for the good-humored persistence of the participants, we can conclude that becoming a programmer can be a hard and frustrating journey where moments of challenge and adversity may, eventually, provide an important contrast that magnifies the sense of consummation and joy when students finally overcome obstacles. In such situations of fulfillment where normative and cognitive relationship are summed up into aesthetical wholes, the novice programmer may actually turn out to be "a freaking genius!"

Data availability statement

The datasets presented in this article are not readily available although the principle of public access to information applies since, for the processing of personal data in research, there are special requirements. Requests to access the datasets should be directed to dso@su.se.

Ethics statement

Ethical approval was not required for the study involving human samples in accordance with the local legislation and institutional requirements because the collected data do not include sensitive personal data. Written informed consent for participation in this study was provided by the students' legal guardians. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MA: Writing – original draft, Writing – review & editing. PA: Writing – original draft, Writing – review & editing. SB: Writing – original draft, Writing – review & editing. NS: Investigation, Resources, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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How to make a bridal bouquet: sensory knowing in action

Camilla Gåfvels*

Department of Visual Arts and Sloyd Education, Konstfack, University College of Arts, Crafts and Design, Stockholm, Sweden

This study explored the planning and making of a bridal bouquet in classroom interaction between a teacher and a student in a Swedish upper-secondary adult floristry education school. The purpose was to empirically reveal floristry disciplinary aesthetics. Aesthetics can be said to involve the exploration of sensory perception in general, entailing a focus on tacit sensory knowing. Methodologically, this study drew on the principles of ethnomethodology and (multimodal) conversation analysis to investigate video-recorded empirical data. The analysis included three separate sequences of interaction after the student requested the teacher's attention. In the sequences, the student repeatedly provided answers to her own known-answer questions, and it remained her privilege to define what should be done and why as a consequence of the teacher's authoritative guiding and gentle support. The results include examples of floristry disciplinary aesthetics in action when making a bridal bouquet, such as airiness and the role of outer shape. Moreover, *in situ* aesthetic judgement as part of sensory knowing is shown to be ample in the form of embodied actions, such as showing with the hands and communicating with facial expressions.

KEYWORDS

disciplinary aesthetics, floristry, craft, sensory knowing, authoritative guiding

1 Introduction

This study explored the classroom interaction between a teacher and an upper-secondary student in Sweden, as displayed in the planning and making of a bridal bouquet, to reveal, in action, (floristry) disciplinary aesthetics – that is, the aesthetics bound to the specific school subject (Wickman et al., 2022). The starting point was an interest in the so-called "practical traditions of knowing" (Molander, 1996; Carlgren, 2015), combined with multimodal interaction analysis (Mondada, 2019, 2021b; Broth and Keevallik, 2020) of video-recorded empirical data. The data drew attention to *in situ* aesthetic judgement as part of sensory knowing (Emt, 2003), sensorium (Goodwin, 2018) and sensoriality (Mondada, 2021b). The latter (referring to sensory traits, regardless of chosen term or framework) contributes to the formation of any potentially stable (over time) specific aesthetic characteristics of the floristry school subject (and/or the education or craft).

Overall, aesthetics can be said to involve the exploration of sensory perception in general (Danius et al., 2012). In other words, the senses are at the core of aesthetics, and the ability to make aesthetic judgements is a consequence of the functioning of the same senses. These judgements entail an embodied sensation (Wallenstein, 2008) that, in floristry education, is related to becoming socialised into experiencing specific values and norms related to material and composition, through embodied practices of looking, touching and smelling (Biesta, 2021; Mondada, 2021b).

To varying degrees, every vocation has its own occupational aesthetic (Fine, 1992), acquired through the aforementioned process of socialisation (Wallenstein, 2008). In this way,

the ability to make aesthetic judgements is also a form of vocational knowing applied in daily practice (Chan, 2015; Klope et al., 2022). This is the case in floristry (Gåfvels, 2016) and other traditional craft vocations, such as hairdressing (Andersson Gustafsson, 2002; Öhman, 2018; Klope, 2020), bookbinding (Tyson, 2014), textile craft (Ekström 2012), fashion design (Caruso et al., 2019) and goldsmithing (Musaeus, 2005). Since the means through which we perceive aesthetics are highly socialised (Grasseni, 2009), we must note that the content of aesthetics (in the form of more or less stable norms) is always subject to change over time, place and other factors (Bourriaud, 2002; Wallenstein, 2008), parallel to subject matter development in the wake of political reform (Todd, 2023). Todd (2023) emphasised that in an educational context, aesthetics is fundamentally about *encountering*, for example through pointing at something, with shifting borders:

> The aesthetic dimension of educational encounters thus [does] not only pertain to whether or not they are creating some kind of art form, but rather[,] *how* the encounters can be seen as (artistic) formations of sensory experience (p. 8).

Again, simply put, the sensing part is the core. Likewise, the learning of a craft is both an emotional and embodied process (Dormer, 1994; Ekström, 2012; Groth, 2022). Furthermore, Dormer (1994) pointed out that expertise is acquired by "seeing mistakes [and] gaining the ability to discriminate" (p. 45) – in other words, by making use of sensory knowing. Mondada (2021b) described how "sensoriality" holds "a crucial role in decisive moments in the encounter" (p. 7), and Goodwin (2018) explained how sensorium in use can belong to – and be shared by – a community through co-operative action between individuals despite the sensorium being lodged in their separate bodies.

In this article, the implicit theoretical underpinning of the analysis is that the work process – depicted in the video recordings – is, in itself, a form of meaning-making process that contributes to the constitution of a social order (Insulander et al., 2021), which simultaneously forms the participants' views of floristry knowing and process, including of disciplinary aesthetics. To convey the mechanism behind this form of social ordering, the concept of *authoritative guiding* (Meek, 2005) is used to explain how teaching and learning go hand in hand in the (current) classroom setting:

> A knower can sense and grow in her ability to sense an authority candidate's connectedness both to [the] known and to [the] knower. In other words, we build our authority-sensing skill. We sense in-touchness, […] care and expertise (p. 44).

Furthermore, Meek (2005) compared *authoritative guiding* to a global positioning system, emphasising that the person being guided might be wrong about many things but still be able to learn due to the set-up. Meek made frequent and direct reference to Polanyi, who wrote, among other things, that it is through *indwelling* that a novice apprehends the master's skills: "Chess players enter into a master's thought by repeating the games he played" (Polanyi, 1966, p. 14). In line with this view of (tacit) sensory knowing, this article focuses on sensorial practices (Mondada, 2021b). These practices are understood to be revealed through the social organisation of the senses in classroom interaction (Gåfvels, 2016; Öhman, 2018). Considering the above points, the following

research question was developed to guide the investigation reported in this article:

> What aspects of disciplinary aesthetics are discernible in the interaction between teacher and student when making a bridal bouquet?

2 Materials and methods

The analysed data – 4 min and 51 s of video-recorded classroom activity – stemmed from a larger corpus of approximately 50 h recorded during two semesters in a Swedish upper-secondary adult floristry education school. The transcripts that are reported in the Results section are for three separate sequences from within a total time frame of less than 30 min. The bridal bouquet was a one-day (5 h) assignment.

At an overarching level, the data show common features in floristry education regarding how teaching is organised as a regular, ordinary and ongoing classroom activity, such as talk-in-interaction. This includes, but is not limited to, the teacher's verbal suggestions regarding potential choices and *how* the student responds and continues the work on the bouquet, notably, in the form of action formation (Schegloff, 2007) and co-operative actions (Goodwin, 2018). However, the analysis starts by answering the following questions: *What's next?* and *Why that now?* (Schegloff, 2007). These questions draw attention to moment-by-moment interaction. Moreover, we explore *sensoriality in interaction* (Mondada, 2021b) by asking how participants engage in sensorial experiences intersubjectively, collectively and socially. Another core aspect of the analysis is the extent to which *adjacency pairs* (Schegloff, 2007) reveal how the student *accepts* the teacher's *offer*, along with what else is discernible in the (multimodal) interaction.

Furthermore, the above reasoning implies that this study draws on the principles of ethnomethodology and (multimodal) conversation analysis (EMCA; Garfinkel, 1967; Goodwin, 2001, 2018; Schegloff, 2007; Streeck et al., 2011; Broth and Keevallik, 2020; Mondada, 2021b). In this process (EMCA), non-language phenomena – such as flowers, the bouquet and gestures – have been deemed "worthy of analysis on their own terms" (Murphy, 2023, p. 455). Streeck (2009) defines *gestures* as communicative actions that are performed by the hands, emphasising how gestural understanding results from "coordinated embodied actions of people and their perspectives upon the material, real-world setting within which they interact" (p. 5).

When making transcripts, there are always "underlying theoretical assumptions" (Ochs, 1979, p. 45). In this article, these assumptions include an explicit interest in sensory and embodied knowing (Streeck et al., 2011; Mondada, 2021a). Moreover, it should be noted that the video recordings are the data, and the transcripts stand no chance of capturing all aspects of the interaction (Cekaite and Goodwin, 2021). The omission of the (original) Swedish language is motivated by an ambition to promote readability and hence, intelligibility. When it comes to the analytical process, it began with a selection of situations wherein the teacher and the student assessed the bridal bouquet, guided by the EMCA criterion of explicit participant orientation (towards the bridal bouquet, meaning the two participants were discussing ongoing work during the work process). Three separate sequences, when the teacher went to the student's table, were chosen and analysed more deeply, and revealed sensoriality in action. The three separate sequences started from the student addressing a

problem and went on to capture the ensuing dialogue and the (multimodal) exchange about the visual outcome.

Line drawings based on frame grabs, which are presented in the Results section, form part of the analysis, in line with the (multimodal) EMCA emphasis on non-language phenomena, in order to identify and convey what is not easily said in words. That is, the drawings included in this article are not mere illustrations. Rather, in the eye of the researcher, they pinpoint specific details seen in the frame grabs.
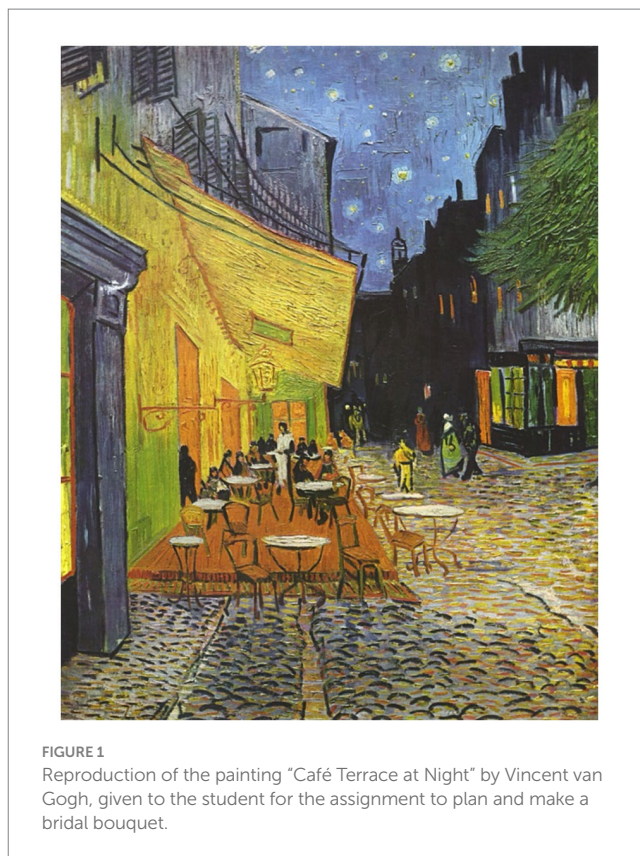
> Video recordings of sensorial engagements as they happen make it possible to analyze these movements in detail, in the way they precisely unfold in time, and coordinate with other bodies, sensing together or accompanying, watching, and guiding sensing bodies [...]. In this way, sensing moments acquire their intersubjective shared intelligibility for the participants to social interaction (Mondada, 2021b, p. 6).

As always, general ethical guidelines (Vetenskapsrådet, 2017) apply to research, wherein some issues deserve extra attention when there is an ethnographical starting point. In relation to the transcripts and line drawings that will be presented in the next section, efforts were made to ensure that recognition and/or identification of the participants would not be possible. These efforts included altering the physical appearance of the participants and slightly modifying their spoken language.

3 Results

The assignment given to the seven students in the class was to make a bridal bouquet. Their starting point was to choose a theme based on a famous work of art. The teacher distributed pictures of different paintings to the students, one picture for each student. In the case of the student in focus in this article, the work of art was the painting "Café Terrace at Night" (*Terrasse du café le soir*) of Vincent van Gogh, which he completed in 1888. The paper print size was approximately 30 × 40 cm. The formal instruction – printed on a single sheet of paper handed out to each student – was to plan one's work according to (1) the "assignment", (2) the "design process", and (3) CLAS (colour, line, area and shape). This type of learning trajectory involves a high degree of uncertainty for the learner. It can be tackled with authoritative guiding (Meek, 2005).

The teacher explained that the work of art would hopefully inspire and give the student an idea as to what to base the student's choice of

FIGURE 1
Reproduction of the painting "Café Terrace at Night" by Vincent van Gogh, given to the student for the assignment to plan and make a bridal bouquet.

material and technique on, as well as provide something against which the student can evaluate or measure the final floristic product. To explain the choice of method, the teacher added that a bride-to-be could say she wants the floral arrangement to convey the same feeling or atmosphere as a specific work of art (Figure 1).

3.1 Airiness and sprawling in Excerpt 1

The student has worked for 1 h on the bouquet and started placing flowers in the holder. She has already made choices regarding the material. The flowers to be used are standing in a bucket on the table. Then, the teacher comes by the student's table for the first time and asks how her work is going.

EXCERPT 1 (2 min, 34 s)

#1

```
01 TEA: ^How is it going for you?
02      ^Looks at the student.
03 STU: ^I do not really know (.) I want to do one (.) that is round (.)
04      but a bit pointed.
05      ^Looks at the bouquet, cuts a branch and meets the teacher's gaze.
06 TEA: Mmm=
07 STU: =but I do not know; I must have more air]#1
08 TEA:                                       ]Mmm^ (3 sec) that could be
09      an idea.
10      ^Nods and looks at the bouquet, student and choice of flowers in
11      the bucket
12      (3 sec)
13 STU: Mmm
14 TEA: Mmm
15      (3 sec)
16 STU: Because I want^ still have some]
17              ^Points at a yellow rose in the middle of the bouquet
18      (3 sec)
19 TEA:         ]Mmm^ that´s great
20                  ^Looks at the bouquet from
21      different angles
22 STU: Ye:s. (2 sec) What had you done then?
23 TEA: But I had probably done so that I would not have had (.) eh, that
24      tight, because then, it is, you know: (.) otherwise, it will be (.)
25      you know, tight with a sprawl]
26 STU:                            ]Mmm
```


#2

```
27 TEA: And then, the humidity (.) then, so (.) but it depends on what you
28      want to have as profile #2 (.) You want to have it round in this
29      shape]^
30          ^Shows a round form with the hands
31 STU:  ]like a mushroom
32 TEA:  Or do you think it should be flatter, kind of (.) and in
33       that case, you get, you kno::w^
34                              ^Shows a flatter sloping line with the
35       hands and meets the student's gaze
36 STU:  Extend the flowers here ^(.) at, but I want to still that it
37       should be °a bit firm° (2 sec). It was kind of how I thought from
38       the start
39                      ^Points at the bouquet.
40 TEA:  Yes=
41 STU:  =You should see that it is ^round-shaped (.) but then, I want to
42       still that it gets a bit sprawling=
```

```
43                              ^Touches the flowers in the bouquet and
44        looks at the teacher; their gazes meet
45 TEA: =with volume^
46                    ^nods
47 STU: =Ah yeah, well, exactly.
48 TEA: But what is it that should create the volume then?
49 STU: It is the foliage
50 TEA: Yes
51 STU: I have^ eucalyptus, pistage (.) these, I thought, but
52        materials, I do not know if they are too pointed that they do not
53        have so much volume but
54            ^Points at the different materials in the bucket and turns at
55        the same time as she holds the foliage in her hand
56 TEA: Mmm^=
57            ^Looks at the bouquet.
58 STU: =it becomes kind of (.) but I thought I should try not really
59        sprawling #3
```


#3

```
60 TEA: ^Mm, exactly () but if you cut, then, you have well nearly do maybe
61        do it #4 there so that you get this little nice top (#5)
62        ^Holds up a branch and takes away a bit of Thalaspi Green Bell
63        from the stem; makes eye contact
```


#4   #5

#6   #7

```
64 STU: =Ah, yeah, exactly.
65 TEA: Mmm, it can, you know, be ^nice to go down so here #6 you must look
66      so that you do not get that shape and go down instead this here lies
67      in the base (.) furthest down, and then you work upwards #7
68                              ^Shows the placement of the Thalaspi Green
69      Bell in the bouquet; shows it with the hands at different angles
70 STU: Should I (.) must I (.) I do not want it to be really big
71 TEA: No
72 STU: I want to () I will try to come out^ with more foliage or
73                                          ^Shows with the hands how
74      foliage can be placed underneath the bouquet
75 TEA: Yes, because if you do not come out with more foliage here^(.) then
76      it will be ball-shaped, kind of
77                                                              ^Shows
78      with the hands a movement up and down in a half-circle.
80 STU: No, but I do not want that, you know ^
81 TEA:                                      ^ Turns the gaze and body and
82      asks the closest other pupil,"How is it going for you?"
```

Floristry disciplinary aesthetics in action are revealed in explicit (verbal) wording starting when the student says she wants her arrangement – when seen from above – to be "round" (line 3) but still "a bit pointed" (line 4), where "a bit pointed" indicates that she has not yet attained the desired aesthetic quality, while also providing an example of situated communication (Streeck, 2009). The teacher and student relatively quickly establish a "shared visual attention" (Goodwin, 2001, p. 157) as displayed in their pointing and gestures when talking about the bouquet's airiness, as well as how the outer shape affects the visual expression regarding the same airiness (lines 23–25), in relation to the desired visual outcome "tight with a sprawl" (line 25) when seen either from above or in profile.

The overall visual expression the student (and teacher) are aiming for (in line with floristry disciplinary aesthetics) is an arrangement of a professional handicraft quality in which material and shape are harmonious insofar as the material chosen supports the desired expression. For example, a round-from-above bouquet consisting of only red roses has a calm expression and is very predictable from a florist's perspective. Simply put, it is supposed to look a certain way. However, in the student's bouquet, the round shape is supposed to be full of life in the form of material expressing airiness – in line with the perceived overall visual expression of the Van Gogh painting. Professional handicraft quality entails not only the *choice* of material but also the placement (not least technically). In this way, the available aesthetic options are interlinked, as displayed both regarding how the airiness is related to the outer shape (both from above and in profile) and how the tightness – or density – defines how sprawling (in terms of volume) the arrangement will be perceived.

When the teacher asks and gestures about whether the form of the bouquet should be flat or round (lines 29–30), it is a question of profile: "it depends on what you want to have as a profile" (line 27–28). The teacher is in favour of a *sloping* form, that is, a relatively flat form in relation to "round" (line 28). The student then responds by describing the later form "as a mushroom" (line 31). Meanwhile, the

teacher displays the sloping form – in gestures – thereafter gazes meet and convey joint understanding and agreement.

The teacher then turns the conversation again, asking how the student will obtain volume (line 48) in the bouquet, thereby implicitly asking which material will be used. In other words, the choice of volume is directly linked to the choice of material (to be used), for example, "eucalyptus and pistage" (line 51), which is the student's choice. When the student describes the chosen material, there is – again – an insecurity related to the talk about what overall visual expression the bouquet will have: on the one hand, airy and sprawling, but on the other hand, not too sprawling (lines 58–59, #3). When the student makes these remarks, gestures stress her "moments of understanding" (Streeck, 2009, p. 209).

In the final part of the excerpt, the teacher provides a solution for how the student can attain the desired visual expression "tight with a

sprawl" (line 25) by working with the qualities of a specific type of foliage – Thalaspi Green Bell – to attain the desired airiness and volume. The gestures seen in (#5) together with "this little nice top" (line 61) communicate beauty and its "situated success" (Streeck, 2009, p. 204).

3.2 Theoretical concepts help in Excerpt 2

After working for 8 min with the bouquet – by adding flowers following the interaction in Excerpt 1 – the student calls the teacher to obtain further advice regarding how to group the flowers, without making the visual impression "too compact".

EXCERPT 2 (1 min 5 s)

```
01 STU: If I will now group these without making them too compact (.)
02      how should I think then?
03      (3 sec)
04 TEA: You make sure not to put them so (.) tight^=
05                                    ^Looks at the student
06      and makes eye contact
07 STU: =^Should I still have some green in between but still yellow
08      groups groups yellow groups purple groups
09      ^Points with the hand where the different groups should be placed
10 TEA: Yes (.) exactly, and so you can, you know, think bigger, smaller,
11      smallest
12 STU: Yes
13 TEA: Mm^
14         ^Looks at the bouquet, then, at the student's actions
15 STU: I have^, you know, some white twig roses. Where did that darned
16      thing go?
17             ^Looks at the bucket of flowers standing on the bench
18 TEA: And then, if you (.) want to avoid making it ^look
        tight, then
19                                          ^Shows with the
20      hands a movement where the fingers meet
21 STU: Mmm
Omitted lines
25 TEA: If it is some area that is different=
26 STU: =Mmm, CLAS ((colour, line, area, shape))
27 TEA: Mmm (.) exactly. You need a ^#8 direction against this passive (.)
28      because here, there is no chance that it will be compact because
29      you have, you know, volume in between
30      ^Shows and points at the bouquet
31      about what is intended with the direction and where there is
32      volume with open hands
```

#8

After working for 8 min with the bouquet – by adding flowers following the interaction in Excerpt 1 – the student calls the teacher to obtain further advice regarding how to group the flowers, this time without making the visual impression "too compact".

The excerpt starts with a question about the placement of material in the bouquet, again revealing the student's uncertainty about how to make the visual impression airy and not "too compact" (line 1). The wording "too compact" relates to the visual expression as well as to technical solutions used in the placement of material. The teacher emphasises "not to put them so […] tight" (line 4), thereby slightly correcting the student. The student becomes more precise in her suggestions, referring to specific groups of flowers by pointing (line 9). In turn, the teacher confirms the student's overall idea, adding general advice regarding how to think about placing flowers in any bouquet: "bigger, smaller, smallest" (lines 10–11) to ensure harmonious transitions between materials, shapes, colours and textures.

Nonetheless, it should be noted that the teacher does not explicitly state *what* the student should do; rather, she reminds the student of a way of thinking (bigger, smaller, smallest) when grouping flowers – a disciplinary-aesthetic tool for decision making entailing achievement of a visual impression that is not "too compact" (line 1). The student's ensuing description of her composition and how to go on, suggesting "twig roses" (line 15), signals her understanding of the instructions being given. Twig roses, as material, have the potential to enable a transition between different sizes of flowers, since the (twig) roses represent a contrast in size (of the capitulum) in relation to the already placed or grouped larger roses. Shortly afterwards, the teacher – again – returns to the student's previously stated idea that the bouquet should not be "too compact" (line 1) by saying, "avoid (making) it

(look) tight" (line 18), thereby repeating her previous (slight) correction (line 4) while demonstrating what she means with her fingertips, very precisely emphasising what she is aiming for (#8), as shown in the line drawing. With the help of clues provided in the teacher's questions, the student says, "Mmm, CLAS" (line 26). This stands for Colour, Line, Area and Shape, and is a theoretical (disciplinary aesthetic) floristry tool when arranging flowers. In this context, it provides an answer to what the student needs to do to create more air in relation to the "passive" (line 27). In particular, the wording "this passive" (line 27) conveys how compactness removes the dynamic of the arrangement, with no room for sprawling volume.

The key takeaways from Excerpt 2 include how the dialogue shifts to a more theoretical (disciplinary aesthetic) level, seemingly allowing the student to use her learned repertoire of theoretical concepts, which is unveiled as she poses known-answer questions (Schegloff, 2007). In other words, the teacher guides (Meek, 2005) the student to rely more – over time – on her own assessments and judgement, aided by the pre-established knowing of these theoretical concepts; notably "passive" (line 27) and "CLAS" (line 26).

3.3 Solving the equation in Excerpt 3

Following the interaction in the previous excerpts, the student adds more material to the bouquet. About 20 min after the end of Excerpt 2, she again calls for the teacher's attention. This time, the student has placed groups of different sizes, worked with foliage and created a round form. Still, something does not seem to add up, which she brings to the attention of the teacher by asking, "How should I solve the equation?" (line 1).

EXCERPT 3 (1 min 12 s)

```
01 STU: ^How should I solve (.) the equation?#9
02      ^Turns around the bouquet, looks at the bouquet, touches the
03      bottom side of the bouquet #9
```

#9

```
04 TEA: How do you think ^now? (.) Do you think that (.) What is the
05      problem?
06                       ^Looks at the student; the student lifts the
07      base and looks at the bouquet
08 STU: It is a bit sprawling^ (.) It should be sprawling (.) That was the
09      thought, but I became a bit stressed because of it.
10                       ^Continues to turn the bouquet
11 TEA: What is it^ that you need to calm down then?
12              ^Looks at the student
13 STU: Ye:s (.) I need, you know, because it is sprawling with fuzzy
14      material, so I need something shiny perhaps^ (.) darker
15                                        ^Touches a leaf of
16       eucalyptus
17 TEA: Yes. Do you have any suggestion?=
18 STU: =But I think first of the form(.) How shall I (.) because now it
19      is quite heavy.^=
20              ^Holds up the base of the bouquet. --->
21 TEA: =Yes
22 STU: I do not know if I can (2 sec) do some kind of arrangement
23      ->+
24 TEA: Yes (.) What you can do there is, you know (.) There, you have a
25       rose that you have inserted underneath that you are not allowed to
26      have^
27  ^Both look underneath the bouquet; the teacher points to where
28   the rose should not be placed #11-12
```


#10   #11

```
29 STU: Oh ()^
30          ^Looks underneath.
31 TEA: Here, you ^should, you know, lift=
32              ^Puts her hand underneath the bouquet
```

```
33 STU: =Mmm.
34 TEA: You see (.) If what you can do there is (1 sek) you know (.) If, for
35      example, you take (.) yes, some material and so that you tread it
36      and bend it up on the base so that you have the metal that lifts
37      so you can do that on the base^
38                           ^Shows with her hands how the
39      technical solution gives an angle for lifting the bouquet
40 STU: Mmm
```

Following the interaction in the previous excerpts, the student adds more material, flowers and foliage to the bouquet. About 20 min after the end of Excerpt 2, she again calls the teacher's attention. This time, the student has placed groups of different sizes and worked to create a feeling of airiness. Still, from her perspective, something does not seem to add up, which she brings to the attention of the teacher by asking, "How should I solve the equation?" (line 1).

While the student asks the teacher how "the equation" should be solved (line 1), she lifts the base of the bouquet (#9) and, through that movement, communicates that she is not happy. When the teacher asks, "What is the problem?" (lines 4–5), the student does not give a direct answer but, instead, alters the construction of the bouquet once more, by holding her hand beneath it, as shown in the first line drawing (#9). While holding the base of the bouquet, the student states that the bouquet is sprawling, but at the same time, she emphasises that it "should be sprawling" (line 8), adding that she is "a bit stressed because of it" (line 9). Then, the teacher asks what the student can do to "calm down" (line 11) the bouquet. The student suggests adding other materials to the composition, something "shiny" (line 14) and "darker" (line 14) to compensate for the "fuzzy" (line 13), thereby calming the visual expression. While the student provides these suggestions regarding her own work, she touches (lines 15–16) eucalyptus (a dusty pale grey foliage). The teacher asks for a more precise answer by asking for "suggestion" (line 17). At this point in time, the student's attention changes back to the outer shape of the bouquet. She changes focus from the material in the bouquet to seeing the (overall) composition as "heavy" (line 19).

While saying so, she once again lifts the base of the bouquet to communicate a perceived lack of form. The student suggests – in an embedded question – that she can make "some kind of arrangement" (line 22) to alter the *heavy* expression in the outer shape of the bouquet. Then, to show or advise the student about *how to go on*, the teacher touches the base of the bouquet and lifts the outer shape, quickly looking underneath it and – as if in passing – verbally pointing out to the student that a rose is placed technically incorrectly (line 25). This occurs along with an active (multimodal) interplay in which the teacher and the student seem to reach an agreement about what the problem is. Both the teacher and the student change their (body) positions (lines 27–28) and look underneath the bouquet (#11) to get a change of scenery and a somewhat alternative sensorial experience of the bouquet. In the process, they attain a shared view of how the material is placed. The teacher shows, with her hand on the flowers, where the material needs to be lifted, thereby giving the bouquet a different closing angle and stabilising its form. Thus, the equation appears to be solved.

4 Discussion

It should be mentioned that the excerpts represent a complete lack of verbal reference to the interpretation of Van Gogh's painting. Although the painting was the starting point of the assignment, it is not evident that the picture continues to be held in mind by the student or the teacher.

A review of the research question of this article – *What aspects of disciplinary aesthetics are discernible in the interaction between teacher and student when making a bridal bouquet?* – shows that, in addition to what they consist of, the excerpts provided clues regarding what occurs in the classroom when an upper-secondary student learns the craft. In the excerpts, flowers' visuality is, in part, enacted as verbalisations, gestures and haptic corrections. The excerpts show how teaching floristry encompasses a variety of resources. How different units are arranged and how the teacher and students interact express the appropriate way forward regarding the specific composition at hand. This is based on how to speak during teaching about floristry and formal aesthetic content, such as volume, lines, colours, textures and forms, applied to different cut flowers. What surfaces is, to some extent, how there are specific aesthetic considerations in relation to different forms of cut flowers and foliage, essentially motivated by the (financial/visual) potential of the material, which is transformed in a process (in turn motivated by) generating (financial/visual) profit. In this context, there should ideally be maximum benefits and minimum waste. From this perspective, the concept of airiness is also of special interest. Working successfully with a high degree of airiness entails a high degree of craftsmanship, but ultimately also a higher degree of (financial/visual) profit since far less material is consumed in the process.

In this way, the excerpts also show how floristry knowledge entails knowing how to work with specific material compositions. Both how to place them and what works together – somewhat the most basic of floristry knowledge – is highly situated and not clearly easy to access without making floral arrangements in ongoing teaching activities. Although the sampled data concerns only 4 minutes, the excerpts can be said to be representative for the floristry educational process, both in terms of form and content of teaching.

Furthermore, throughout the excerpts, the teacher makes use of gestures (Streeck, 2009) to stress different aesthetic qualities, both in small parts, such as showing a piece of foliage, and when talking about the entire floral arrangement. Thus, primarily by using her hands, the teacher provides the student with access to a coordinated embodied understanding of the activity taking place. In this way – through interaction – the student is allowed to enter the sensorial experience of the teacher, very much like how Polanyi

describes the indwelling through which a novice can gain access to the master's skills. As stated at the outset of the introduction, what is at the core is sensorial practices, in line with how our senses are at the core of aesthetics, and the ability to make aesthetic judgements. Thus, regardless of the chosen term or framework, whether sensory knowing (Emt, 2003), sensorium (Goodwin, 2018) or sensoriality (Mondada, 2021b), *in situ* aesthetic judgement comes into focus in the moment-by-moment interactions in the three excerpts. The tacit and multimodal character of this *in situ* aesthetic judgement could also mean that the excerpts actually include references to the interpretation of Van Gogh's painting, albeit not verbal and not easily discerned. In other words, the method used has potential and limitations; notably being limited by the fact that only 4 minutes of data is used to convey a learning trajectory. It should be emphasised that this all occurs in the interaction between student and teacher, which is the very reason some aspects might appear elusive, as the brief meeting of gazes can be a decisive final moment in a mutual exchange. Through this process, the student(s) is(are) socialised into an inner experience of the outer world in parallel to the teacher's experiences. Over time, this leads to making aesthetic judgements that have much – or even everything – in common.

Finally, from the excerpts, the angle of the flowers in the holder was identified as both the problem and the solution. The sprawling or not of the bouquet was no longer an issue when it turned out that altering the form – the outer shape – remedied the situation and solved the so-called equation. At any given moment, there were multiple possible solutions for any given bouquet. As previously mentioned, available choices were interlinked, and any change made had an impact in more than one dimension. Against this backdrop, it is notable that the student continuously chose to add material to the bouquet. From the onset, removing material would have been a viable option. Working this other way around would have been a more complicated procedure for the relatively inexperienced floristry student in question. However, her choice to move forward and add material all the way limited the potential airiness that could be achieved. It should also be noted that this procedure of adding material limits the potential (financial/visual) profit of the material used, compared to what would have been the case if the bouquet was arranged by an experienced florist. In this way, the aesthetics conveyed in the excerpts of this article are also typical disciplinary aesthetics insofar as they are bound to the specific school subject (Wickman et al., 2022). In a high street florist setting, there would have been more air.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CG: Writing – original draft.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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