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Aesthetics in embodied task design in mathematics

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STEAM (Science, Technology, Engineering, Arts, and Mathematics) research emphasises interdisciplinary approaches to developing skills needed for the 21st century. In this paper, we explore three aesthetically rich mathematical activities involving dance and bodily performance (e.g., creative body postures) with 6-year-old students. Supported by an embodied perspective of task design and a Deweyan view of aesthetics, we argue that a high degree of bodily engagement and a high degree of task integration allow space for creativity and imagination that may involve aesthetic dimensions. Specifically, we argue that body postures, bodily rotation, rhythm, and fluency in composite sequences of movement may connect art and mathematics in a way that treats the students as active creators of aesthetic experiences, in contrast to other STEAM approaches that do not consider bodily performance as a way of connecting art and mathematics.

Keywords: STEAM, embodied learning, aesthetics, design research, mathematics.

Introduction

Some scholars argue that aesthetics is connected to learning mathematics and that aesthetic experiences may expand learning impacts in mathematics (Parrish, 2009; Sinclair, 2011). Interdisciplinary transformation processes involving mathematics and aesthetic experiences in arts have recently been highlighted through developments in STEAM (Science, Technology, Engineering, Art, and Mathematics) research. Within research focussing on mathematical education through arts, several scholars have paid attention to the aesthetics in mathematical logic, proofs, reasoning, and problem solving (Breitenbach, 2015; Sinclair, 2011; Todd, 2018; Zhanys et al., 2020), and the beauty of symmetry and harmony in visual art or in visual representations of mathematics (Gadanidis et al., 2016; Meier et al., 2018; Treder, 2010). But while the OECD promotes embodied task design for innovation, in a shift towards learning centred pedagogies for the fostering of knowledge, creativity, and imaginative skills needed for the 21st century (Paniagua & Istance, 2018), most of the above-mentioned studies assign the body an inactive role in connecting arts, aesthetics, and mathematics. This aligns with criticism directed at mathematical educational research for having a narrow and elitist view of aesthetic experiences, restricted to mathematicians and visitors in museums (Sinclair, 2008). Instead of exploring the arts from the perspective of the audience, Dewey's writings direct attention to the creator of aesthetic experiences (Dewey, 1958). The student as an active participant in learning is consistent with an embodied view of learning, which connects aesthetic concepts to bodily states and multimodal interaction (Scarlinzi, 2015). Based on these observations, we investigate how aesthetic dimensions can come to the fore in tasks where full-bodily performance is related to mathematical content in a meaningful way. Below, we turn to Dewey's ideas and an embodied view of learning to conceptualise our understanding of aesthetic experiences.

Theoretical framework

Dewey's notions of learning through experiences and experiences through learning are important concepts in the field of education (Dewey, 1998), with the latter serving as the starting point for Dewey's ideas of art and aesthetics (Dewey, 1958). Dewey sees aesthetic experiences as the basis of art, and his writings give insight into how any learning experience can foster enriched experiences (Pugh & Girod, 2007). From a Deweyan perspective, an aesthetic experience has a temporal structure (i.e., it takes time to complete), it is dynamic (i.e., the perception of the material involves changes) as it connects earlier phases to further phases forming a sense of wholeness (Dewey, 1958). In contrast to mechanically performed experiences, aesthetic experiences are felt intensely and directed to fulfilment, and this internal momentum is guided by a sense of rhythm. Aesthetic experiences also involve a sense of resistance that feeds the experience towards fulfilment. In embodied contexts of learning, this resistance may involve efforts in achieving bodily rhythm or coordinated interaction with the environment, and a struggle to compose sequences of bodily action into a holistic experience. However, as noted by Dewey (1958), the ugly and horrifying may also provide aesthetic experiences. This means that representing mathematical content using frightening body postures, wagging duck imitations, or stiff giraffe walk mimics can provide aesthetic responses.

Several scholars argue that a Deweyan view on aesthetics is consistent with an embodied perspective of thinking and learning (Johnson, 2007; Scarinzi, 2015). A main principle of the embodied perspective is that emotions and abstract concepts (e.g., mathematical and aesthetic concepts) are grounded in sensorimotor and perceptual states (Scarinzi, 2015). Accordingly, aesthetic concepts are multimodally represented and perceived through embodied simulations (Barsalou, 2003), which may involve visual, verbal, aural, and kinaesthetic modalities in the sensation of the beautiful or ugly in visual art, dance, bodily performance, and everyday bodily behaviour (Eskine & Kozbelt, 2015). Next, we review STEAM-related literature linking dance and bodily performance to mathematics.

Studies on bodily performance and dance in mathematics

The use of the body in performative arts and dance in mathematical educational design is an attempt to engage learners while supporting the meaning-making of abstract concepts aesthetically and emotionally through bodily action (Kaufmann & Dehline, 2014). Aesthetic qualities of dance and bodily performance include rhythm, creative body postures, and the beauty in functional and fluent movement, with each dimension edifying both the performing individual and those observing the performance (e.g., Mattsson & Lundvall, 2015). Rosenfeld (2011, 2013) developed the Jump Patterns tool to help students create percussive (using the feet to tap) dance patterns in the learning of mathematics subjects. This approach of integrating dance and mathematics learning was based on a four-beat structure, where the students could experiment by varying foot position, type of movement, and direction. Examples include transformation processes (changing the shape or position of an object) or dancing patterns using different types of symmetry (reflection, rotation, or slide symmetry; Rosenfeld, 2013). An et al. (2019) investigated preservice teachers' development of instructional strategies for dance-themed activities for young students in mathematics. The intervention consisted of variations around a prototype model developed from Rosenfeld's (2011, 2013) square frame for percussive dance. The results showed improvements in the number of new methods and that more

advanced pedagogical strategies for dance-mathematical integration were employed. Activities include assigning a particular dance move to each answer in addition (e.g., to spin around for the answer 10 in $5+5$), verbally counting the number of movements of a choreographed dance, stepping harder on given movements (e.g., third, fourth, or fifth) to facilitate learning of multiplication, and creating dances addressing even-odd or large-small numbers in terms of movements. Additional activities include pair dance involving part-part-whole relations of numbers (e.g., choreographing the part-part-whole relation $5+7=12$). In our final reviewed study, Leandro et al. (2018) showed that 7- and 8-year-olds who had consolidated mathematical knowledge through creative dance and performing art (e.g., body postures and movement representing mathematical concepts such as composition/decomposition of numbers, structures in addition and subtraction) exhibited significantly better learning gains than the control group receiving traditional teaching. A common feature of most of the above studies is their focus on the learning gains of dance and bodily performance integration in mathematics. In contrast, our study focuses on aesthetic qualities in students' dance and body performance in their representations of mathematics content.

Methodology

This paper reports from a design study involving thirteen 6-year-olds, who had just begun their first year at school. Five iterations of testing, evaluation, and refinement (Gravemeijer & Cobb, 2006) resulted in two hours of video from the five 45-minute sessions involving embodied activities aiming to improve the students' number sense. The first author was a facilitator in cooperation with the first-grade teacher. To guide the researcher-teacher planning, evaluation, and redesign, two specific design principles were formulated. Firstly, 'a high degree of bodily engagement' (Skulmowski & Rey, 2018) i.e., that the activity should promote aesthetic full-body movements as part or in combination with the representation of mathematical content (e.g., numbers and number relations). And secondly, 'a high level of task integration' (linking movement and mathematical content; Skulmowski & Rey, 2018). This was obtained through multimodal bundles (two or more connected modalities produced by a learner at a distinct moment in time; Abdu et al., 2021). An example of a multimodal bundle regarding children's number sense is a speech-body-aural-iconic bundle involving stepping on dots on the ground in a four-beat arrangement while verbally counting. Using these two principles as a foundation, we integrated aesthetic dimensions into the activities by asking prompts such as "How can you make the number beautiful/scary?" or "Can you make a rotation in between each 4-step?" Guided by our theoretical framework and previous studies in this area, we looked at the aesthetic dimensions of rhythm, body posture, bodily rotation, and fluency in composite sequences of bodily action. We understand rhythm as the temporal recurrence of bodily action, body posture as the configuration of body parts in a particular moment, rotation as the movement of the body around its axis, and fluency as the ability to integrate distinct motor actions into a coherent whole. Our aim was to understand how these aesthetic dimensions might come to the fore in children's full-body performance while engaging with various aspects of number sense. Three of the developed activities specifically focused on this, and an overview of these is given in Table 1. The activities were situated in arrays of four dots outside a large circle ($d = 5\text{m}$) of 200 dots, all painted on the ground (Figures 1–12). The activities were composed of speech-body-iconic-aural-bundles (Activity 1 and 3) or speech-body-iconic-bundles (Activity 2).

Table 1: Overview of activities, mathematics content, and aesthetic dimensions

Activity	Mathematical content	Aesthetic dimensions
1: Dancing numbers	Counting (up/down); Skip-counting; Parts-whole relations of numbers.	Rhythm; Rotation; Body posture; Fluency.
2: Expressing numbers	Cardinality.	Body posture (Creative configurations of body parts onto dots).
3: Walking numbers	Cardinality; Counting (up/down); Number relations (one/two more/less, doubling/halving).	Rotation; Body posture; Fluency.

Synchronic and diachronic analysis

We used synchronic and diachronic analysis as complementary tools for analysing the video-recorded material (Arzarello et al., 2009). The synchronic analysis allowed us to examine how distinct multimodal bundles, or events at a specific point in time, reflected the intersection of mathematical content and aesthetic dimensions. The diachronic analysis allowed us to examine the movement of the whole activity by considering the connection between multimodal bundles over time, revealing a more comprehensive and coherent depiction of aesthetic qualities (cf. Dewey, 1998). By using these analytical tools in combination, we were able to explore how aesthetic dimensions can be integrated into activities where dance and bodily performance were related to mathematics in a meaningful way.

Results

We will start by giving an account of the three activities and the aesthetical dimensions observed. Following this description, an account of the synchronic and diachronic analysis will be given.



Figure 1: Four-step pattern



Figure 2: Rotation in “four” as a part of ten



Figure 3: Body posture in parts-whole relation



Figure 4: Rotation in the final step “ten”



Figure 5: 2·360° and 3·360°, respectively, in “seven”



Figure 6: Four-beat rhythm with high and low steps



Figure 7: Scary leopards counting



Figure 8: How many four steps in 10 seconds?

Activity 1: The four dots were used to structure the cyclic movement pattern “Right leg forward, left leg forward, right leg backward, left leg backward” in conjunction with verbal counting up/down, or skip-counting (Figure 1). To emphasise the sensation of rhythm, the students were encouraged to keep the balance or perform bodily rotations in between completed four-step cycles and in the final step (the cardinal value). For example, targeting the additive relation $4+4+2 = 10$, the students could include bodily rotations (Figures 2 and 4) and elegant body postures (Figure 3) in expressing the parts and the whole. Variations in the auditory, verbal, and kinaesthetic modalities were achieved through

prompts such as “Can you mimic a slow and angry elephant/a fast and nice mouse in stepping to eight?” Depending on what animal and emotional mode they simulated, the students could tramp hard/slow, soft/fast, in conjunction with shouting/whispering the number words, evoking emotions of reflecting anger/happiness (Figure 6). To foreground the ugly and horrifying, the students were asked to perform scary body postures as part of the number dance (Figure 7). To support the consolidation of rhythm and counting of parts, the students worked in pairs, counting the number of completed cycles in 10 seconds (Figure 8).



Figure 9: Body posture of the number 4



Figure 10: Creative bodily configuration



Figure 11: Body posture and cardinality



Figure 12: Run, count, and rotate

Activity 2: The circle with 200 dots challenged the students’ imagination in exploring creative ways of using body parts in one-to-one correspondence with dots in the representation of numbers. Figures 9 and 10 show creative bodily configurations onto dots in the representation of the number 4.

Activity 3: The students were guided in the joint embodiment of numbers and numerical relations. The facilitator could ask; “We just walked to four. What is one/two more/less/the double/the half of four?” Based on students’ responses, the next challenge was enacted three times in mutual rhythmic counting, and with aesthetic body postures in the final tagging (Figure 11). The integration of multiple aesthetic dimensions was highlighted in the students running and performing body rotations in the final tagging (e.g., “One, two, ..., eight” [Rotate]; Figure 12).

The synchronic analysis revealed how multimodal bundles observed at specific points in time reflected aesthetics in mathematics. In Activity 2, for example, the way the body was frozen while saying the word "four" was coded as the intersection between creative configuration of body parts (i.e., body posture) and speech-body-ionic-bundles representing cardinality (Figures 9 and 10). In Activity 1, aesthetic elements included static body postures involving arm gestures and facial expressions mimicking the horrifying (Figure 7). Similarly, in Activity 3, the one-legged body posture assigned the last step in a count an aesthetic dimension (Figure 11). The diachronic analysis showed how connected multimodal bundles were assembled into the aesthetic dimensions of rhythm, rotation, and fluency in composite sequences of action. We use the aesthetic dimension rhythm to demonstrate the diachronic coding. In Activity 1, assemblages of speech-body-ionic-aural-bundles created a four-step pattern, and the temporal recurrence of speech-coordinated stepping on dots was coded as the intersection of counting and rhythm (Figure 1). Similarly, the dynamic and interconnected movements in representing parts-whole relations illustrate how the aesthetic themes of rotation and body posture can be part of a holistic experience (Figures 2–4). In Activity 3, the aesthetic dimension fluency in composite sequences of action was illustrated in speech-coordinated stepping onto dots in counting, the final step integrating a bodily rotation (Figure 12). Similarly, in Activity 1, the complex movements in tagging the cardinal value “seven” show how the aesthetic dimensions rhythm and

rotation are connected into a fluent holistic experience (Figure 5). In summary, the analysis shows that students can have aesthetic experiences when learning mathematical content.

Discussion

Our study focuses on the integration of aesthetic experiences in movement-based task design in mathematics. The aesthetic dimensions examined are informed by a Deweyan and embodied view on aesthetics and STEAM-related literature on math-dance connections. They include the partly overlapping themes of rhythm, body posture, bodily rotation, and fluency in composite sequences of bodily action. As shown in ‘Dancing numbers’ (Figure 1), the four-step corresponds to mathematical representations of feet tapping the ground in spatial patterns of numbers. Like a musician creating a rhythm in the spacing between notes, the insertion of time spacing between completed cycles makes a rhythm. To Radford (2015), rhythm produced by gestures and hand-material-action has a structuring feature of mathematical thinking. We argue that the four-step attributes rhythm to a double function – to represent beauty and to structure mathematical thinking. In the example $4+4+2=10$ (Figures 1–4), the rhythmic four-step modelled a parts-whole relation, while core aesthetic qualities in performative art and dance (e.g., rhythm, rotation, body postures) were reflected in the patterns of beats produced by the moving body. As noted by Rosenfeld (2011), the aesthetics in percussive dance provide the foundation for creativity and improvisation. The intervals between completed four-step cycles open space for unique and expressive body postures and hand gestures (Figures 3 and 4). The performance by two girls of two and three 360 degrees body rotations in stepping the cardinal value “seven” (Figure 5), illustrates the interplay of improvisation and resistance, which as (Dewey, 1958) suggests, adds depth to the aesthetic experience. Additional aesthetic aspects include shifts between hard, soft, high, and low steps, revealing the potential to be a source of delight for both the student and those observing the movement (Figures 6–8).

According to Dewey (1998), aesthetic experiences are heightened, immersive, infused with meaning, and felt coherent and complete. The diachronic analyses revealed how distinct multimodal bundles were connected and formed such holistic and coherent experiences. For example, the embodied representation of the parts-whole relation $4+4+2$ involved two and a half rhythmic cycles of four steps, multiple rotations, and elegant body postures (Figures 1–4). The link between flow in mathematical and aesthetic performance (Figures 11 and 12) finds support in Reber et al. (2004), who noted that the more fluently a student can process a learning objective, the more positive their aesthetic response will be. Building on ideas from STEAM-related literature on dance-mathematical connections (e.g., Leandro et al., 2018; Rosenfeld, 2011) and embodied design research (Skulmowski & Rey, 2018), our study revealed the potential of how aesthetic dimensions of students’ performative movement and bodily action may open a window of beauty, creativity and imagination to their mathematical experiences. This means encouraging students to explore how they can represent mathematical contents in rhythmic/beautiful/ugly/forceful/funny/frightening ways. This highlights the potential of integrating aesthetic-related prompts into teacher instruction.

Concluding remarks

Although the aesthetic subjects (dance, music, theatre, and visual arts) are devalued in national curriculums in OECD countries, there is a growing interest in integrating aesthetic methods that allow

students to use their STEAM knowledge in new and creative ways. In this study, we have shown how aesthetic qualities can be integrated into embodied task design that involves a high degree of bodily movement and a high degree of consistency with mathematical content. Our study shows that the aesthetics in dance and bodily performance can be used as a resource in the design of activities in mathematics. As noted by Paniagua and Istance (2018), embodied activities based on the primacy of creativity, imagination, self-expression, and aesthetics are more likely to foster student engagement than academic activities. We argue that bodily movement contributes to an active role in sensing aesthetic qualities in mathematical learning, thus fostering experiences with lasting resonance. In contrast to previous STEAM-related research that highlights the beauty in mathematical reasoning (e.g., Todd, 2018), symmetry in visual art (e.g., Meier et al., 2018), or the instrumentalist aspects of mathematics-dance/bodily performance connections (e.g., Leandro et al., 2018; Rosenfeld, 2011, 2013), our study reveals how aesthetic dimensions coexist with mathematical representations in students' dance and performative bodily action. In conclusion, our study contributes to the field of STEAM research by proposing innovative embodied task design in mathematics that highlights the acting body in the creation of meaningful and aesthetically coherent experiences (cf. Dewey, 1998).

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