More than Counting Beats:

Connecting Music and Mathematics in the Primary Classroom

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Abstract

Connections between music and mathematics have been of interest to scholars as far back as the time of Pythagoras. In Aotearoa-New Zealand, the use of songs and chants as aids for memorising information such as number patterns and names of geometrical shapes is common practice in early childhood centres and primary classrooms. While such practices are beneficial for purposes of recall, the authors of this article share the belief that, if we also examine the thinking processes involved in music and mathematics learning, there are more profound connections between the two domains that could enhance mathematical learning. The combination of music and mathematics and the analogous concept development that may arise equates to more than a sum of the constituent parts. In this article, three educators share their teaching experiences involving mathematics and music. Each narrative is discussed from a theoretical perspective, bringing together the tacit knowledge of experienced teachers and their perceptions of how the two fields are related, supported by, and build on research in their respective fields. The intention of the article is to establish a foundation for further research in the field.

Background

Mathematics and music are part of children's daily lives and yet, as they move through the school system, some children are challenged by mathematical concepts that are considered abstract and difficult to visualise (Tall & Vinner, 1981). As a result, children may experience feelings of anxiety and loss of interest (Nagisetty, 92014). An and

Tillman (2015) point out that, 'traditional' methods of teaching and learning mathematics where mathematics is separated from other learning areas, may be ineffective, which, in part, could be attributed to a lack of connections with students' interests. Engagement, through building on children's natural instincts and interests, particularly in social and co-operative contexts, is considered by Dewey and Jackson (1990), to be central to children's learning. This paper explores the potential of a music–mathematics link to not only engage children, but also to support analogous conceptual development. We build on claims that music may foster mathematical learning. The notion of 'specific content domains' is a construct that young children are unaware of until they enter formal education settings. When categories of learning are determined, it is often the *content* that is the referent, rather than the *process of learning* (Gagne, 1972).

A comparative perspective identifying common threads between music and mathematics is provided in An and Tillman's model (2015). The model identifies two levels of connection – firstly, the combination of the two subjects into an interdisciplinary music–mathematics framework and, secondly, "the overlap between the cognitive psychology and abilities of the individual during musical and mathematical experiences" (p. 45). The term *inter-disciplinary* used by An and Tillman (2015) is sometimes loosely referred to as *integration*, a concept that has been a topic of conversation in education for the last 50 years (Perger & Thomson, 2008). Early integrated experiences tended to focus more on content than process, and have been viewed as somewhat superficial. While there is considerable debate over the definition of integration, as opposed to other inter-disciplinary relationships or partnerships such as collaboration, connection and correlation, the important consideration is 'integration' rather than 'isolation' (Anderson, 2015). We, the authors, feel the need to clarify that the focus of discussion in this article is the use of music as a catalyst or pedagogical resource for mathematics learning. While a collaborative approach offers benefits for music as well as mathematics, we concentrate, unapologetically, on the role of music in fostering mathematics learning. Music serves many purposes in education – as well as 'music for music's sake', Barrett (2001) points out, "a comprehensive music education embraces valid inter-disciplinary studies" (p. 27).

Research indicates that there is a growing body of theory relating to music's contribution to the development of mathematical principles such as spatial reasoning, sequencing, patterning, counting, one-to-one correspondence, and problem solving

(Geist, Geist, & Kuznik, 2012; Gruhn & Rauscher, 2002; Sposet, 2008). Developmental psychologists and constructivist learning theorists claim that music can assist children in the development of flexibility and transferability of their thinking, allowing for meaningful connections and multiple representations of concepts. (Chrysostomou, 2004; Medina, 2002). The use of music as an aid to learning mathematical concepts is a form of "enacted pedagogy," a choice that is influenced by teacher's views of mathematics (Taylor & Bailey, 2011, p. 90). Considering that mathematics learning is a developmental process influenced by the child's physical, social and emotional state, music plays an important and well-recognised role in its contribution to well-being and to a stimulating learning environment (Geist et al., 2012; Paquette & Rieg, 2008). A physiological response to music is a natural phenomenon which provides a foundation for learning based on principles of Dewey (Dewey & Jackson, 1990). Children have the inherent potential to respond to music and its mathematical constructs such as form, pattern, sequence and symmetry (Hasan & Thaut, 2004). Activities that involve both music and mathematics foster "a degree of pleasurable intensity, promote the fun of learning and allow the child to be an active participant" (Geist et al., 2012, p. 76). Consequently, teaching mathematics through music may be viewed as an enjoyable and imaginative way to introduce mathematical topics and vocabulary (Goulder & Lodge, 2008), and to introduce children to visual systems that connect concept and sign (Lynch, 2007).

In light of the second level of An and Tillman's (2015) framework for music–mathematics' connections, engagement in music and mathematics activities stimulates higher-level thinking and increases student involvement and motivation (Cranmore & Tunks, 2015). A number of studies have been undertaken to attempt to measure cognitive function when music and mathematics are combined. One example is the work of Graziano, Peterson, and Shaw (1999), who claimed a causal relationship between music training and improved numerical ability. More recently, in a study in which music was used as a tool for mathematics learning, Goulder and Lodge (2008) found that the more they worked in the area of mathematics and music the more they became aware of music-making as a useful teacher tool for communicating key mathematical ideas.

One contentious theory relating to music's impact on cognition, known as the 'Mozart effect', claims increased brain function when the music of Mozart is played (Campbell, 2001). Similarly, Rauscher and Shaw (1993) advocate for the use of baroque music as a means of stimulating brain activity and maintaining a positive mental attitude. While these theories offer interesting viewpoints, a number of scholars consider that there is little conclusive data to support these assumptions (Harvey, 1997; Holden, 2003), and that music's impact on mood and arousal could simply be attributed to non-musical factors (Schellenberg, 2006). Similarly, Nuhfer (2005) places such contradictory theories in a category he calls "academic snake oil" (p. 11). Perhaps more convincing is Gardner's (1997) theory of multiple intelligences that categorises intelligence, and acknowledges that individual strengths and interests can be addressed through a range of learning disciplines (An & Tilllman, 2015).

As noted, many theorists have identified the benefits of connecting music and mathematics for the development of cognitive function, as well as the identification of commonalities between the two domains. It is common practice in the field of education for research to inform teaching. For the purpose of this article, rather than beginning from existing theories, our starting point comprises three stories from researchers who began their careers as classroom teachers and who have a wealth of tacit knowledge from which to draw. This autobiographical narrative enquiry7 approach enables us to draw theory from practice.

Methodology

This article captures the essence of ongoing conversations amongst a group of four colleagues around the idea of connecting music and mathematics in generalist primary classrooms. The data is drawn from the narratives of educators who reflect on their previous classroom practice, and describes how they drew the two learning areas together to maximise learning opportunities in their classrooms.

Autobiographical narrative is employed to construct an honest and genuine narrative of the scholars' personal and professional experiences (Bullough & Pinnegar, 2001). The personal narratives examine how experiences have shaped and influenced the scholars' beliefs about music as a tool to promote the acquisition of mathematical understanding. The scholars are placed at the centre of the discussion, with autobiographical narrative being used to examine how music, in its many and varied forms, may be used by reflective teachers who are looking for effective practices and pedagogies to support the mathematical learning needs of diverse students.

Autobiographical narrative enables individuals to pay particular attention to their actions, and provides a method by which they can share their stories and articulate how they made sense of a phenomenon (Brunner, 1986; Connelly & Clandinin, 1990). Telling stories involves reflection, and careful presentation of past and present events that have significant personal meaning for the storyteller (Watson, 2006). The authors have looked back on their careers as teachers to share anecdotes that describe how they interpret the influence that music has played in their mathematical classrooms, and to argue that music can contribute significantly to the learning of some mathematical concepts.

The narratives told are not the products of research, but rather a basis for further research. It is not the intention of this paper to make grandiose allegations about connections between music and mathematics. Rather, the purpose is to relate real stories from educators who share common beliefs based on experience, supported by relevant literature.

The Narratives And Responses

Karen

Teaching music for me invoked feelings of anxiety that I imagine some people feel about teaching mathematics. And yet it didn't occur to me how much I used music in my teaching, for example, playing music in my classroom while children were working and using chanting and clapping rhymes to develop number patterns.

It was A.O.s [Achievement Objectives in the New Zealand Curriculum] *that helped me see how I could teach music to my year one class of children even though I didn't consider myself musical in any way. When I first started teaching music it was about singing, exploring sounds on percussion instruments and playing simple tunes on the recorder. That was the sum of the musical learning experiences in my classroom. Not easy for someone who is tone deaf!*

When the Arts curriculum was developed I went to the published document to plan a music unit. Reading the achievement objectives, I realised that I could teach music in a different way, different to my 'traditional' view of teaching music and my personal experiences. There had been a terrible storm the week before and the children had *witnessed thunder, lighting, hail and heavy rain whilst at school. We had written about the storm as a class and they had written individually about their experiences. Using the class story, we talked about the sounds we had heard and how we might make similar sounds using our bodies or objects around us. The children came up with symbols for the sounds we created; they suggested I drew large symbols when the sound was really loud and smaller versions of the symbol when the sound grew quieter. They also came up with a symbol for a quiet time (a rest). I wrote the symbols on a large sheet of paper and we 'played' the music to check that it sounded like the storm. The children then wrote their own music for their individual storm stories, which we published and displayed.*

A couple of days after our music-writing experiences, I was teaching addition and subtraction using words when writing the equations. It occurred to me that as the children had worked with symbols in music that we could talk about symbols we could use in maths instead of writing the words in our number stories. The children came up with non-mathematical symbols for addition, subtraction and equals. We 'read' the mathematical equations in a similar way to the way we had read the music symbols. I was explicit about making the connections about the use and purpose of symbols in music and maths. The children were very excited about 'reading' their symbols in the maths stories. This led to discussion about all the different symbols the children came up with and eventually let to a discussion about the need for a common symbol that everyone would recognise (e.g., '+' for adding). The music learning experience had provided an opportunity for the children to develop an understanding of the use of symbols that supported their learning about symbols in mathematics.

Discussion

A key theme that emerges from Karen's narrative is the importance of symbols for mathematical learning (Vlassis, 2008). Although the content of the music and the mathematics differed, the children recognised the benefits and importance of visual symbols in helping them learn. Visual symbols aid children in building bridges from perception to conceptual understanding in both music and in mathematics contexts. Symbols play an important role in the creating, representing and interpreting of meaning using "different semiotic, or sign, systems, which learners naturally employ as they make sense of the world" (Lynch, 2007, p. 34).

Mathematics involves manipulation and recognition of symbols, often in abstract settings, adding to the challenges encountered when learning mathematics (Ashcraft & Krause, 2007). The New Zealand curriculum (Ministry of Education, 2007) is geared towards children's use of cultural signs and symbols as psychological tools used in intellectual operations, suggesting that mastery of such tools supports the development of more complex thinking. Mindful of "Vygotsky's work in mathematics education, socio-cultural approaches are revealing a close relationship between the use of symbols and the formation of concepts" (Vlassis, 2008, p. 568). For example, in Karen's class, symbols were used to represent concepts of dynamics, such as a large symbol for a loud sound, and a smaller version of that symbol for a quieter sound. This notion of representation was then applied to the recording of number stories, where words were replaced with mathematical symbols.

The children's excitement in transferring their learning across domains was evident. The experience of recording music through creating meaningful symbols was used as a resource to engage the children in mathematics, and allowed the teacher to present mathematical problems in non-routine ways (An, Capraro, & Tillan, 2013). The use of music symbols introduced Karen's children to new ways of recording mathematical ideas. When given the opportunity to demonstrate learning, the children in Karen's class used multiple sign systems, an important consideration when giving learners opportunities to extend their repertoire of communication (Lynch, 2007).

Gail

As a beginning teacher I was initially extremely anxious and hesitant about the teaching of music. I did not believe that I had the skills or experience needed to teach music effectively. Looking back, I realise that these feelings of low self-efficacy were, in part, due to the requirement of having to complete a musical solo during my teacher training. This traumatic experience (that had reduced me to tears), had obviously made me question my teaching ability. Fortunately, it wasn't too long before I recognised just how important music was in the children's lives. Without any formal planning or instruction, my class of 32 five and six year olds would often start singing, play clapping games, or use the making table to create their own musical instruments. As a result I took advantage of these impromptu developments and began incorporating music into my reading programme. We would regularly use the class kit of musical instruments to accompany poems or shared books. Sadly, it took me longer to *develop the confidence to use music in my maths programme.*

This increased confidence enabled me to use music as a tool to support children to retain and recall early mathematical concepts like number words, number sequence, days of the week and the names of shapes. I began to use music regularly as a tool to help the children develop automaticity. One of the things I did was to use tried and true singing rhymes. As we learnt the 'Tahi is one, rua is two….[1] *rhyme we used the Beginning School Mathematics*[2] *digit and picture cards. As the children sang the number word, they would tap the matching card with a pointer. I also used auditory stimuli to help the children commit the correct counting sequence to memory. While the children sat with their eyes closed I would beat a drum or strike a tambourine, and the children would count out loud the number of beats. Another experience that promoted auditory patterning was a movement activity like musical statues. As I played a piece of music the children would dance around the room. When I stopped the music they had to stop like statues while I created a musical pattern such as, clapping my hands four times, or blowing a whistle three times. When my pattern was finished, the children had to find the closest piece of paper (that I had previously distributed around the class), and record the digit, or word, or stylised pattern that matched the count I had created. Without doubt, I believe these musical experiences enabled the children to commit early mathematics concepts to their long-term memory. These experiences encouraged me to add the use of music as a tool to my repertoire of engaging and successful teaching strategies, which I continue to use four decades later.*

Discussion

The underlying theme in Gail's narrative is 'recall versus conceptual thinking' based on the use of music as a mnemonic device, as evident in chants and songs. In the examples Gail shared, music played an important role. She utilised song to engage children in mathematical learning, promoting a positive attitude towards mathematics, while developing mathematical recall. Gail's narrative describes how music can enrich the mathematical learning environment for children by encouraging participation in the learning process. Integration of music into teaching and learning programmes are able to be used by all teachers, even those with no formal musical training (Edelson

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[1] A popular rhyme used to learn Māori counting words.

[2] A Ministry of Education resource supplied free to all New Zealand junior schools.

& Johnson, 2003).

It could be argued that the use of music to promote recall may not aid the necessary conception of mathematical constructs and there is a need for children to attain a deep structural and functional understanding of mathematical concepts (Hiebert, 2013). However, memory plays a vital role in mathematical cognition and there is potential value in developing procedural memory to draw on fundamental tools and information (Medina, 2002). When using music as a tool for teaching mathematics, teachers must ensure that children are aware of the mathematical learning if genuine understanding is to be achieved (Kassell, 1998).

The positive impact of music on memory and recall is well documented. Music, particularly song, helps to store and release information when needed, a phenomenon that may serve as a useful pedagogical tool when teaching mathematics (Medina, 2002; Mora, 2000). Research on cognition has identified that storage of information in the long-term memory relies on the proper encoding of items, and that the encoding may be supported by the use of multiple senses and meaningful associations. Sustained practice over time is the key to retention, and rehearsal or practice can help to consolidate new learning into long-term memory (Hunter, 2004). Through singing, children can make meaningful associations and rehearse or practise mathematical concepts, increasing the chance for new learning to be anchored and strengthened.

The use of music as a mnemonic device is evident in many contexts, ranging from the passing down of tribal histories through traditional songs and chants (Levitin, 2008; Van Gunten, 2006). The powerful medium of advertising jingles that get 'stuck in our heads' is well recognised. The associations made between particular songs and memories and images suggests that songs work on both long and short-term memory and leave a deep trace when associated with the affective aspects of music (Mora, 2000; Tomaino, 2010). Gail used the number songs and rhymes the children knew to support their learning of numeral recognition. The powerful connection between music and memory is also associated with the claim that songs are not only catchy and repetitive but are also stored in memory as both speech codes and musical codes (Lake, 2002; Samson & Zatorre, 1991).

Instant knowledge, and recall of mathematical concepts can take longer for some children than others. Research on children with cognitive learning delays has found that some of these children may experience difficulty when it comes to automatic mastery of basic concepts such as the correct sequence of counting words (Kroesbergen & Van Luit, 2005; Porter, 1999). It is important that the learning is carefully observed to avoid errors being over-learned. Improving access to memory is extremely important if students are to experience success and continued access to mathematics (Conners, Rosenquist, & Taylor, 2001). Using teaching strategies that make rehearsal and practice more meaningful can result in increased automaticity (Laws, MacDonald, & Buckley, 1996; Porter, 1999), and music is suggested as a vehicle to help students commit foundational mathematical knowledge to long-term memory (Horstmeier, 2004).

Robyn

I began my teaching career in the late 1970s, a time when 'integration' was the 'buzz word' in education. As an accomplished musician, I saw great potential for music to be interwoven throughout the curriculum. With little theoretical understanding to support my actions, I instinctively used songs, chants and rhythm patterns to aid children in recall, and to visualise patterns.

I have always been intrigued by patterns – visual, musical, numerical (and) linguistic. Patterns provide structures and frameworks, aid logic and prediction, and enable transferability. This was particularly evident in a mathematics context. For example, when working with number, I would encourage children to recognise groups and name numbers without counting. I would throw dice where dots represented the numbers and the children would call out the number that matched the dot pattern. I would also apply this concept when listening to music, and children would identify whether a musical excerpt was grouped in three or four beats, which gave the music a particular 'feel'. The children would also listen for repeated patterns in recorded music from a range of genres. They would identify instruments that played particular patterns, and when the patterns, stopped, started or changed. We then added another dimension by visually representing the patterns using colour and shape.

My music expertise enabled me to see music possibilities in mathematics and vice-versa. Many of the activities I used were musically sophisticated, and not transferable to other teachers who are less confident with music, but I capitalised on my own interest and strengths in my teaching role. With increasing demands for assessment and other *aspects of compliance in today's classrooms, I believe there is a tendency for educators to be less creative in their approach to teaching and learning. Consequently, opportunities to maximise learning opportunities are missed.*

Discussion

A strong theme evident in Robyn's narrative is 'patterning', a key concept of mathematics. There are patterns in both music and mathematics that could be regarded as building blocks for future learning. While patterns and associated materials are often visual, music is predominantly made up of aural patterns, such as rhythmic, melodic, harmonic and structural patterns, which may be presented visually. Geist et al. (2012) identify three types of patterns, each of which is found in both music and mathematics: repeating patterns, growing patterns and relationship patterns. For examples of mathematical and musical patterns that relate to Geist et al.'s (2012) categories see Figure 1.

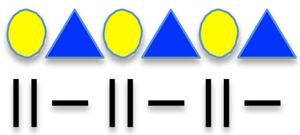
Types of Patterns	Mathematics examples	Music examples
Repeating patterns	 A B C A B C A B C	□ Repetitive rhythm patterns (ostinati) □ Metre (groupings of beats) □ Repeated sections (chorus) □ Repeated melody in verses of songs
Growing patterns	2, 4, 6, 8, 10, 12, 14 ...... 0, 1, 1, 2, 3, 5, 8, 13	□ Extended rhythm patterns □ Layers of sound (texture)
Relationship patterns	(1, 4) (2, 8) (3, 12) 3:6 6:12 12:24	□ Loud/soft, fast/slow, long/short, high/low sounds □ Note-values

Figure 1. *Practical Examples of Mathematical and Music Patterns*

Another form of patterning that is evident in Robyn's narrative involves the concept of *subitising*, when children show recognition of a set without counting. Robyn described how the children in her class identified the grouping of beats in the music they listened to. In mathematics she talked about the children naming the dot patterns on the dice, recognising that a dot in each corner and one in the middle represented five. Subitisation begins non-verbally as a language-independent skill moving from perception to conceptual thinking (McDonel, 2014), and is considered a critical foundation for learning number (Clements & Sarama, 2008). In a similar vein, musical *audiation*, or ‘inner-hearing,’ without the presence of physical sound, involves perception of sounds long before conception (McDonel, 2014). McDonel (2014) aligned the development of young children’s musical thought (from subjective audiation to objective audiation) with the processes in their mathematical development. For example, children respond to the grouping of beats in a bar a long time before they develop a conceptual understanding of musical metre. This knowledge may be transferred to an understanding of fractions – note length into ratio, and symmetry into texture and harmony (Goulder & Lodge, 2008).

Conclusion

The three narratives describe quite different scenarios, but each of them illustrates a number of key points relating to music-mathematics partnerships in primary classrooms. Two of the narratives expressed the teacher’s lack of confidence with music, an issue that is a reality for many generalist teachers. However, this did not put either of them off pursuing an approach that they felt was valuable for students’ learning.

The idea that music and mathematics are connected and that children who are musically inclined are also mathematically competent is not a new idea (Hallam, 2010). Considering that musical rhythm is based on mathematical relationships, we can assume that an understanding of music requires some understanding of ratios and repeating patterns (Geist et al., 2012). If an understanding of music requires an understanding of mathematical principles, then it could be construed that it is possible for the teaching of music to support an improved understanding of some areas in mathematics.

While this article has identified some benefits of using music to foster mathematics learning such as semiotics, recall and patterning, it is not the intention of this article to suggest that music and mathematics should always work together. Both domains are valued for their unique contributions to children’s overall learning, and any form of integration is not intended to compromise the integrity of either learning area. When teaching mathematical ideas through music or vice-versa, teachers need to be mindful of both curriculum areas if learning and assessment across both subjects is to be authentic (Perger & Thomson, 2008). However, in light of growing concerns about children's conceptualisation of mathematical concepts, we encourage teachers at all levels to look for, and to embrace, new and different modes of learning.

There is clearly a need for better understanding about how young children learn in order to provide the necessary groundwork for domain-specific learning later in life (McDonel, 2014). Further research into comparisons between music and mathematics learning may highlight shared and unique features as well as relatively unexplored assumptions in current research. With advances in brain-mapping technology and increasing understanding of how the brain works, it is possible to explore such connections (Cranmore & Tunks, 2015). While there are numerous studies that focus on how music might contribute to mathematics learning, there are few studies that look at how mathematics influences music learning (Cranmore & Tunks, 2015) and this is also an area where there is a need for further research.

As educators, we are concerned about improving teaching and learning, and the need to consider ways to add new layers of meaning and multiple perspectives. If teachers recognise the opportunities music offers in providing an authentic and engaging context in which children can learn mathematics, music has the possibility to bridge the gap between the "intended and enacted curriculum" (Taylor & Bailey, 2011, p. 96). We need to continue our conversations to enable us to form a framework for future research and to help us "turn the key a different way so that we unlock people's potential" (Robinson, 2000, p. 6). More of the same is not necessarily the answer.

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