Embedding embodied cognition and neuroscience in music pedagogy

by Robyn Marie Staveley

Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

under the supervision of
Emerita Professor Rosemary Johnston

University of Technology Sydney
Faculty of Arts and Social Sciences

March 2020

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Robyn Marie Staveley, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in the School of International Studies and Education, Faculty of Arts and Social Sciences at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Production Note:

Signature: Signature removed prior to publication.

Date: 31 March 2020

Acknowledgements

My heartfelt thanks to everyone who has walked this PhD journey with me. I shall start with my supervisor, colleague and dear friend, Emerita Professor Rosemary Johnston. She has always advocated for "my voice" to shine out this work, and even when that voice has been a whisper behind the door, she had faith that the process would unfold and magically appear. I am so grateful for her continuing encouragement and wisdom as this study took shape. Thank you dear Rosemary.

Walking by my side, closer and closer as the years went by, was my other wonderful supervisor, Associate Professor Anne Prescott. It turns out Maths and Music are very closely allied, and Anne has been my ever-present supporter, cheer leader and tireless reader. Having neighbouring offices at work certainly helped me test out ideas, theories, clarify what was important, what was not, and how to wade through this whole process. I greatly value the time she has so generously given, the laughter and tears, and above all, her great friendship.

Thank you to the inspirational participants in this study. All of them I count as dear friends, outstanding teachers and colleagues, and the most clever and innovative practitioners one would ever find. The music teaching profession is in excellent hands with people who give so much energy, time and intellect to improving practice and doing it joyously. Thank you for all the laughs, courses, coffee and chats, and most of all, for encouraging me to continue. Particular thanks go to Linda, Paul, Biddy, Danielle, Deb, Simon, Mary, Ben, Gin, Rachael, Joyce, Kirrabelle, Jo, and David. To my first mentors who sent me off on this path, Susie, Margie, Carol, Lorna, Di and the Orff family, thank you.

Without my wider group of family and friends, who seem to have unfailing faith that this process was worth pursuing, I just don't know how I would have continued without you. To my wonderful parents, who began this journey with me but sadly are not here to enjoy the end, I give my eternal thanks. To my dear and beautiful children, James, Robert, Christopher and Holly, thank you for still shining your loving ways over me during these study years, and for showing your understanding and care when it was sometimes difficult for you also. Kirsten, Anne and Phil, Zoe and Olivia, I am so blessed to have you in our family.

For my dear partner, Peter Williams, I owe you so much. You have lived and stayed by my side every minute of this time with patience and love. The days, weeks and years that we have sat back to back in the study, you have plied me with cups of tea, a listening ear, wise suggestions, shoulder rubs and interesting conversations. I am amazed by your knowledge and so deeply grateful that you are by my side.

Table of Contents

Acknowledgements……………………………………………………….. iii

List of Tables……………………………………………………….. ix

List of Figures………………………………………………………. x

Abstract………………………………………………………………. 1

Chapter 1 – Introduction…………………………………………….. 2

1.1 Overview of methodology.. 3

1.2 Thesis overview.. 3

1.3 Motivations and background……………………………….. 4

Music classrooms that are musical………………………… 6

Many different ways of being musical – multimodality… 8

The quest to improve music pedagogy…………………… 11

1.4 Embodied cognition and neuroscience: a framework linking action to learning…………………………………….. 15

Research topic diagram and description………………… 16

Embodiment, neuroscience and music – an active process…………………………………………………………… 20

Chapter 2 – Literature Review……………………………………… 21

2.1 Placing music pedagogy in an embodied cognition framework, underpinned by cognition neuroscience…………………………………………………… 27

Description of Embodied Cognition – the brain, the body and the world…………………………………………… 27

4E cognition – Embodied, Embedded, Extended, Enacted.. 31

4E cognition and music education……………................... 33

Effects of embodiment on learning – long-term learning gains………………………………………………………………… 34

2.2 **The musical world**……………………………………………… 36
The teacher – a model of musical embodiment……….. 37
Tools, objects and materials – to embody being musical………………………………………………………… 38
Other people………………………………………………… 39
Physical space – constraints and effects on musical embodiment………………………………………………… 42
Summary of the musical world and music pedagogy…. 44
2.3 **The brain and musical embodiment – brain processes that impact embodiment**………………………………….. 45
Complexity – The Brain and learning……………………… 46
Neurons and neural reuse…………………………………. 49
Neuroplasticity……………………………………………..... 52
Enriched environments…………………………………….. 55
The mirror mechanism and musical learning……….…... 59
Peripersonal neurons……………………………………….. 61
The role of the senses in developing music cognition….. 66
Haptic and proprioceptive sensory systems………. 66
Multisensory integration………………………………. 69
Perception……………………………………………….. 72
Sensorimotor integration……………………………… 75
Relationships between sensorimotor integration and multisensory and multimodal integration…….. 78
The brain, embodiment and music pedagogy…………… 79
2.4 **The body and musical embodiment**………………………… 80
Embodying music – the body in action…………………….. 81
Multimodal – multiple modes of musical behaviour.......... 82
Tool use, affordances, extended mind……………………. 86
Joint action and joint attention……………………………… 100
Embodying music through gesture and movement……… 107
Types of gesture……………………………………………..... 108

	Movement embodies and shapes the musical mind….....	112
2.5	**Summary and conclusions**………………………………….	116
Chapter 3 – Methodology……………………………………..……		119
3.1	**Design Research**……………………………………………..…..	121
	Characteristics of design research…………………………..….	121
3.2	**Use of video in data collection**……………………………..….	124
	Data analysis………………………………………………………..….	126
	Finding the focus in large amounts of data………………..….	126
	Site visits for video recording…………………………………..……	128
3.3	**Participants / Participant-researchers**……………………..…...	129
	Participants – their participation in the study………..……..	130
3.4	**PHASE 1 – Professional development, lesson observations, semi-structured interviews in Reflection meeting**………………………………………………………..….	132
	Phase 1 Reflection – Semi-structured interview questions in reflection meeting…………………………..…………………..	133
3.5	**PHASE 2 – Redesign of professional development, lessons observations, reflection**……………………………….	137
3.6	**PHASE 3 – Application of usable theory in a new setting**…	138
3.7	**Summary**…………………………………………………………	139
Chapter 4 – Settings and Findings…………………………………..		141
4.1	**Phase 1 Semi-structured interview meeting**………………	142
	Overall outcome of the semi-structured interview and meeting………………………………………………………..	150
	Points for redesign of Phase 2………………………………..	151
4.2	**The instrumental setting – multimodal embodiment**…….	153
	The instrumental setting story………………..……………….	154
	The Instrumental classroom and music pedagogy informed by embodied cognition and neuroscience…..	172

4.3 The secondary setting - problem-solving with the body.
Dana's secondary music classroom – Multimodality, embodiment and joint action………………………………
Steve's secondary music classroom – multimodal embodiment and joint action to experience chord progression…………………………………………………….. 174
Summary………………………………………………………..
4.4 The primary setting – Complexity through simplicity…….. 185
Kindergarten classroom – complexity through simplicity.. 187
The primary education classroom – Year 4……………….. 188
The primary classroom and music pedagogy informed 190
by embodied cognition and neuroscience……………… 202
4.5 The special education setting – Joyous, rapturous, exuberant action……………………………………………….. 217
The special education classroom – primary………………
The special education classroom – secondary………….. 219
Conclusion: the impact of embodiment and 222
neuroscience on music pedagogy in the special 240
classroom…………………………………………………………
Summary…………………………………………………………
4.6 The embodied music classroom – Principles for 248
embodied music pedagogy………………………………… 250
The role of the world in embodied musical cognition…...
The role of the body in embodied musical cognition…… 251
The role of the brain in embodiment……………………….. 251
4.7 Principles for embedding embodiment and 261
neuroscience in music pedagogy………………………….. 262

Chapter 5 – Conclusions and future directions…………………… 264
5.1 Summary of results and conclusions………………………..
5.2 Implications of the study for music education settings…. 265

	Instrumental setting – Multimodal embodiment…………..	266
	Implications for instrumental music pedagogy……………	267
	Secondary setting – problem-solving with the body…….	268
	Implications for secondary music pedagogy……………..	272
	Primary setting – complexity through simplicity……………	273
	Implications for primary music pedagogy…………………	275
	Special education setting – joyous, rapturous, exuberant	275
	action…………………………………………………………..	277
	Implications for special education music pedagogy……	
	Embodied music classrooms – principles for embodied	278
	music pedagogy………………………………………………..	280
	Implications for embodied music pedagogy……………..	
5.3	**Principles for the design of embodied music pedagogy**.	281
5.4	**Limitations**…………………………………………………………	282
5.5	**Future research and directions**………………………………..	283
		284
References………………………………………………………………..		289
Glossary……………………………………………………………………….		
Appendices………………………………………………………………..		291
		319
		324

List of Tables

Table 1.1 – Overview of Study Topics

Table 2.1 – Multimodal uses of tools with musical affordances

Table 3.1 – Neuropedagogy Participants

Table 3.1 – Neuropedagogy Participants who came to Reflection meeting

List of Figures

Figure 2.1 - Enriched environments experiment

Figure 2.2 - Extending thinking into objects (blocks)

Figure 3.1 – Research design diagram

Figure 3.2 – Participant settings

Figure 3.3 – Phase 1 of research design

Figure 3.4 – Phase 2 of research design

Figure 3.5 – Phase 3 of research design

Figure 3.6 – Phase 1, 2 & 3 of research design

Figure 4.1 – Front of room

Figure 4.1 - Around perimeter, small upright pianos

Figure 4.2 - Representing rhythm and pitch patterns

Figure 4.4 - Piano hand shapes

Figure 4.5 - Crossing the midline

Figure 4.6 - Carer as part of social aspect of the world

Figure 4.7 - Carers assisting in performance skills

Figure 4.8 - Social collaborations between teacher and students, and students and students

Figure 4.9 - Playing with both hands (1)

Figure 4.10 - Playing with both hands (2)

Figure 4.11 – Setting up pitch chime bars

Figure 4.12. - Preparation of the pitch and rhythm pattern before transfer to instrument

Figure 4.13 - Multimodal, social cognition

Figure 4.14 - Learning to use "Practice Buddy"

Figure 4.15 – mirroring

Figure 4.16 - Exploration with drumsticks

Figure 4.17 - Ostinato and improvisation

Figure 4.18 - Composed ostinato

Figure 4.19 – Sitting in a circle

Figure 4.20 - Walking to the beat anywhere in the room

Figure 4.21 - Class in front of teacher

Figure 4.22 - Groups of students distributed through the space
Figure 4.23 - Saying the rhyme with partner
Figure 4.24 – Four beats to find a new partner
Figure 4.25 - "Saw a ghost"
Figure 4.26 - Pointing for where and which
Figure 4.27 - Move back
Figure 4.28 - Stand up
Figure 4.29 - Which side, which foot
Figure 4.30 – Direction
Figure 4.31- Copying to create a touch memory
Figure 4.32 - Lstep
Figure 4.33 - Rcross
Figure 4.34 - Rclose
Figure 4.35 – Transfer from hands
Figure 4.36 – Transfer to feet
Figure 4.37 - Forward and backward
Figure 4.38 - Representing resting foot and sweeping foot
Figure 4.39 - Kick step
Figure 4.40 - Heel rest
Figure 4.41 - Breath as a metaphoric gesture
Figure 4.42 - Gesture, movement and words
Figure 4.43 - Student using words and gestures
Figure 4.44 - finger snapping on the crossover
Figure 4.45 - Clapping on the closing step
Figure 4.46 - Student suggesting arm movement
Figure 4.47 - Singing melody, performing movements
Figure 4.48 - Playing set up
Figure 4.49 - Xyloglock
Figure 4.50 - Pointing to focus on notes
Figure 4.51 - Already notating before hearing the music
Figure 4.52 - Students notating and pointing while teacher moves structure

Figure 4.53 - Teachers and teacher aides assist in lesson
Figure 4.54 - Joyful learning
Figure 4.55 - Scarf as tool for expressing action
Figure 4.56 - Improvising singing and dancing
Figure 4.57 - Embodying disappointment
Figure 3.58 - Synchronising actions with music
Figure 4.59 - Tool for playing and associating with character
Figure 4.60 - Predicting and anticipating
Figure 4.61 - Complex movement in joint action event
Figure 4.62 - Synchronising movements with music and demonstrating listening skills
Figure 4.63 - Smile and hand on hand
Figure 4.64 - Touching the playing hand
Figure 4.65 - Focus
Figure 4.66 - Joy in the sensory, musical tool
Figure 4.67 - Students inventing new gestures; teacher copying
Figure 4.68 - Touch demonstrating musical understanding
Figure 4.69 - Falling pitch using tools
Figure 4.70 - Shared sensorimotor representation of pitch

Abstract

Embodiment is at the heart of being musical. Music pedagogy that fosters active engagement and interaction between the brain, the body, and the world, creates a living system, primed for developing deep, musical cognition. This thesis investigated how embodied cognition and neuroscience was embedded in music pedagogy in music education settings. A design-based methodology was employed to create research-based practices. Experienced music teachers attended a professional development course on embodied cognition and neuroscience, looking at how embodied practices could be applied in music education settings. A group of the teachers conceptualised and embedded embodiment theory in their music pedagogy. These conceptualisations and practices formed new perspectives and usable theory on how musical embodiment can be practiced. The researcher gathered data, through observations of lessons and reflections with participant-researchers, to identify what embodied practices looked like in their classrooms. The findings revealed that embodied music practices are achieved through enriched environments. Teachers' pedagogy created worlds where the body, including the body of the teacher, students and others, was characterised by high levels of musical action and social interaction. The worlds the teachers created were full of opportunities for musical interaction between people, places and tools with musical affordances. The brain was primed for developing musical cognition through opportunities for personal engagement in complex, authentic environments. This thesis puts forward some key insights for application of pedagogical principles and practices to foster embodied music cognition.

Chapter 1 - introduction

This thesis investigates how the rapidly expanding fields of embodied cognition and neuroscience inform music pedagogy. The study has both a theoretical and practical aspect. Grounded in research, it describes how action develops cognition (Glenberg, 2010, p. 445; Maes & Leman, 2013b), and that this occurs through the interaction between the brain and the body in the world. As part of the research, teachers experimented with how they could embed embodiment and neuroscience in their music pedagogy. Exciting, practical approaches that can be shared with all music practitioners arose from a variety of music education settings, to answer the main research question:

> ***How do music teachers embed embodiment, informed by neuroscience, in music pedagogy?***

And the two associated questions:

> ***What does music pedagogy informed by embodied cognition and neuroscience look like?***
>
> ***What future directions does this research offer to specific music settings and the wider music education field?***

1.1 Overview of methodology

A qualitative approach using Design Research methods was utilised to address the main research question:

How do music teachers embed embodiment, informed by neuroscience, in music pedagogy?

The research was in a three phase process of design, enactment, analysis and redesign (Collins, Joseph, & Bielaczyc, 2004). Collected data was analysed through an interpretive perspective (Thorne, 2016). From a pool of thirteen participants, six were chosen for their rich demonstration of embodied practices and represented a distribution of music education settings. These participant-researchers embedded embodiment and neuroscience in their pedagogy to produce theory-related practices.

1.2 Thesis overview

This thesis is set out in five chapters.

Chapter 1 provides a background and sets the context for the thesis.

Chapter 2 is a review of current national and international literature in embodied cognition, and neuroscience research pertinent to learning in music.

Chapter 3 justifies and outlines the methodological approach undertaken by this thesis to explore the main research question.

Chapter 4 presents the findings from the four music education settings: Instrumental, Secondary, Primary and Special Education. The final section describes the insights gained from each of the settings and how these shape principles for embodied music pedagogy.

Chapter 5 summarises the results and discusses how they address the research questions. It provides implications for specific and overall music education settings, with suggestions for future directions for music teachers who wish to explore embodied practices in their music pedagogy. It concludes with a set of principles for embodied music pedagogy.

1.3 Motivations and background

The overall motivation for this thesis was to ground musical learning in action. Musicality, the inner sense of being musical, is embodied; that is, all knowledge, understanding, skill and musical behaviour is the result of the interaction of the brain, the body and the world. When learning is embodied, meaning unfolds through action in authentic contexts.

When the brain-body-world coupling is hindered by learning practices that downplay action and personal engagement, learning, meaning and mental life are downplayed. The connections that would enable concepts to link to authentic knowledge are absent. The learner misses out on all the joy and excitement of making first-hand, personal discoveries. This is the case in passive learning, where facts are provided to students, with no link to how the knowledge was derived. This is what Dewey would call, "the abnormality of the situation in which the bodily activity is divorced from the perception of meaning" (Dewey, 2015, p. 223). John Dewey (1859-1951) was a philosopher, psychologist and education reformer. He emphasised the importance of being active in learning, and that learning through experience makes a backward and forward connection between the world and the consequences of our actions in it (Dewey, 1916). He also stressed that there had to be an intentionality about this "doing", that some part of the process involved active response and shaping so that understanding would ensue.

Performing music with no meaning, in an expressionless and detached way, is comparable to Dewey's description of reading language with no meaning. He described that the "isolation of an act from a purpose … makes it mechanical" (Dewey, 2015, p. 225). The purpose of performing is to bring meaning to music through the way it is expressed. Mechanical instrumental performance is often the result of learning to match an action (playing) to a symbol (reading notation), with no understanding of the musicality of what the symbol represents. However, learning to perform musically through authentic structures, such as speech rhymes and simple songs, allows age-appropriate and musical ways of developing understanding through active, personal engagement.

Making music is both an individual and social activity; we create meaning together as we participate in musical, joint activities, and in doing so, develop skilful engagement and music cognition. We use many tools to develop musicality, such as the voice, the body or playing instruments; or the tools might include the choir, a ceremony or problem-solving activity. Musicality arises in the joy of song and singing in a choir; the inspiration of playing in an ensemble, where we become as one in interpretation of repertoire; the yearning to express what cannot be captured in words but emerges in the body's expression through movement and performance.

Learning about being musical cannot be just seen or read. Language cannot fully explain what it really *feels* like to be musical. One must experience being musical through doing it, and therefore, learning to be musical involves movement and action to develop embodied, music cognition. "The abstract cognitive process and the physiological bodily process are intertwined and inseparable" (Gulliksen, 2016a, p. 2).

As a long-standing music practitioner and having observed the results of embodied musical learning in my own classrooms, it was my personal conviction that embodied learning results in deep understanding about music. Embodied learning is when all knowledge is developed through the body of the learner. In music, concepts and skills are explored, manipulated and played with through personal interaction through musical tools such as repertoire. Embodied learning drove the three main motivations for doing this study. The first was to find music classrooms where there is lots of musical activity happening. The second was to see many different ways of behaving musically occurring in music classrooms, and the third was to improve my own music pedagogy as part of the constant quest for knowledge. As a passionate music teacher, it is my greatest desire to offer my profession research-based approaches that have been co-developed and tested by music colleagues and practitioners. These practices form the basis for a set of principles to guide teachers in developing embodied music pedagogy.

When teachers understand the theory and have a guide to what it looks like in practice, they can apply the research-based practice to their own music settings. They can explain to their students, parents and education community why they teach the way they do and discuss the research that supports it.

Music classrooms that are musical

The first motivation for this thesis was the desire to see musical classrooms where everything about the classroom suggests “music”. The musical world in the classroom is created by the music teacher’s pedagogy. The focus in this thesis is how to inform pedagogy so that music classrooms engender musical behaviour.

Teachers and students look musical by what they are doing. The whole environment is musical through what is in the space; how it is being used, the sounds, the objects, artefacts, tools and people. Everyone is interacting musically, through collaborating, exploring, experimenting, playing, performing, actively listening and contributing, symbolising and notating.

The music classroom should look different to other classrooms. To accommodate this and to encourage musical behaviour such as playing instruments together, the space needs to be flexibly arranged. If students are to fully understand the effect of sound, how it resonates with the body, there needs to be a variety of musical tools and sound sources to practise developing this understanding.

Music cognition unfolds over a lifetime of interacting with musical ideas and experiences. Fundamental to this is movement. Whole body interaction with music provides rich and multilayered memories. Dance and movement to repertoire provide wonderful opportunities for immersion in the patterns, sounds, tonal systems and traditions of different cultures. Dance and movement require unimpeded space, so flexible use of space in the music classroom ensures the opportunity to develop this whole-body interaction.

Being musical has many different modes of behaviour, and they all involve action. These include singing, playing, moving, notating and symbolising, improvising and composing, conducting, directing, reading, and actively listening. These can all occur in many different musical ways, such as when using:

- **Physical tools** – musical instruments, other sound sources, materials and objects, movement, gesture, games, technology;

- **Conceptual tools** – songs, symbols, language, solfa[1];
- **Cultural tools** such as ensembles, choirs, dances and events;
- **Social tools** – the interplay and constructing of knowledge between individuals and group.

(Note: these tools can be interchangeable, for example, a song can be a cultural tool as well as a social or physical tool)

It is not uncommon to see music classrooms where neither the teacher nor the students look musical. There is no sound, no movement, no interaction; nothing that would suggest that it is a music classroom. This thesis looks at the research that shows why the world of the music classroom is important for priming the brain to be musical.

Many different ways of being musical - multimodality

Embodied cognition emphasises the role of action in learning. Using tools with musical affordances[2] increases skilful musical behaviour and capacities for being musical. As mentioned in the previous section, there are many different ways of being musical, such as singing and vocalising, playing, moving, dancing and moving, improvising, notating, problem-solving, experimenting, and so on. When all the musical modes of behaviour are explored, students develop skills and understandings in one mode that can inform knowledge in another mode of musical behaviour. However, some teachers limit the development of this cross-referential process by favouring one or only a few ways of being musical, such as just listening to music or only singing. This does not provide the full scope of musical behaviour, and is not developing the depth that cross-modal learning creates (Martin-Martin & Brock, 2017).

---

[1] Solfa – a system that ascribes syllables and handsigns to degrees of the diatonic scale. The tonal centre, designated as "doh" is movable, so all other notes of the scale are related to where the "doh" is situated. It is used as a teaching tool for sight-singing and reading.
[2] Musical affordances – interactions in musical contexts between musical tools and the user that give rise to musical cognition (Menin & Schiavio, 2012).

Teachers may offer a limited variety of musical modes due to:

- a lack of experience in a variety of ways of being musical;
- a lack of support in terms of:
    - resources, equipment, school, community and educational authority leadership;
    - training and professional development;
- and a lack of pedagogical understanding.

The Australian "National Review of School Music Education: Augmenting the Diminished" (Pascoe et al., 2005) reported that only some schools have music programs. Around 40% of schools perceive that their community does not value music education and therefore provision of a music teacher is not of importance (p. xii). If music is taught in those schools, it is taught by a range of teachers, some without qualifications in music or education. Additionally, spaces for teaching music are variable, with little equipment or resources. If teachers have little experience or qualifications in teaching music, they presumably have limited ways of being musical themselves. "A high proportion of music in schools appears to be listening to or responding to music" (p. xii), and of that, the nature and quality of either the music or activities was not known. The report strongly recommended that professional development support was necessary if meaningful music education was to exist.

Music education approaches

Two music education movements have made positive impacts on the quality of music teaching and learning in Australia; Orff Schulwerk and Kodaly music education. Zoltan Kodaly was a composer and educator from Hungary. His philosophy was based upon the belief that children "should learn to read and write music just as they learn to read and write the language of their mother tongue" (Rozmajzl & Boyer-Alexander, 2000, p. 214). Central to this approach is singing to develop music literacy.

Carl Orff was a German composer and educator. His approach to learning in music was that it should be elemental, "belonging to the roots or first causes of artistic development"(Shamrock, 1997, p. 8). In children, this arose from their speech and songs, rhymes, dances and play of their culture. His programs made music *for* children and *with* children. A distinctive feature of Orff's approach are the instruments that encourage students to create accompaniments and melodies. Xylophones and metallophones, recorders and wood, metal and skinned percussion instruments are easily played and provide a full variety of tone colours

An Orff approach assumes active participation by both students and teachers. The overall aim is the development of everyone's inherent musicality, through creating, listening and performing (Frazee, 1987, p. 7). At the core of these activities is movement and engagement with authentic musical materials and tools.

The Orff Schulwerk and Kodaly movements provide structured professional development[3] through workshops, conferences, symposia and post-teacher training. They are both strong advocates for movement and action in all musical learning and are supportive of research insights that can strengthen a focus on this.

Engagement in every mode of musical behaviour should be the aim of all music teachers in every music setting. Being musical in a variety of ways ensures that all students acquire a wide variety of musical skills, gain rich understanding of musical concepts, and develop meaningful music cognition.

---

[3] E.g. Orff Schulwerk Teacher Training courses (Levels); Australian Kodaly Certificate.

The quest to improve music pedagogy

Another motivation for this thesis was to investigate whether research in embodied cognition and neuroscience could explain *how* action contributes to learning in music. A number of music education studies had appeared in this field (Nijs & Bremmer, 2019; Schiavio, Biasutti, van der Schyff, & Parncutt, 2018; van der Schyff, Schiavio, & Elliott, 2016), but these were not intended to provide research-based practices to embed in pedagogy.

For educators, the strength and value of research is in how it can be applied in the classroom. Translating those findings into language that makes the knowledge clear and demonstrates relevance, is a key role for researchers. Dissemination of this research then needs active engagement with the teaching community through appropriate publications, professional development and engagement of proactive professionals in the field (Koner & Eros, 2019).

This thesis seeks to achieve this through:

- Identifying research and literature in the fields of embodied cognition and neuroscience that applies to how humans learn and the related neural mechanisms and processes;
- Examining the impact of this knowledge to music pedagogy;
- Translating this pedagogical understanding into practical strategies;
- Presenting professional development on this background theoretical research and exploring how it could be applied in classroom practice;
- Inviting teachers to participate in the research through identifying ways of applying the research-informed pedagogy in their own classrooms;

- Collating participant-researchers' experiences and applications and demonstrating how they applied the research in their own pedagogy;
- Presenting findings that link the research to practice in music education pedagogy.

This type of collaborative research, between researchers and practitioners, helps to create researcher-informed and practitioner-informed contributions to professional practice. This link between research and practice has been a drive in music education research since the mid-1960s, with the establishment of the Australian Society of Music Education.

Value of research contributions to music education

In 1978, Doreen Bridges, Australia's first music education PhD recipient, called for researchers to inform and progress music education by bringing forward the latest knowledge to "find solutions to the problems confronting teachers…" (p. 25). In 1994, Barbara van Ernst emphasised that an area that needed extensive focus was the music learning process (van Ernst, 1994). While she focussed on appropriate learning experiences, curriculum, evaluation, assessment and student learning strategies, she also mentioned "multiple intelligences" (Gardner, 1985), a topic of current interest at the time (1994, p. 47). Gardner proposed that intelligence was wider than just an overarching capacity for understanding the world. He suggested that humans have the capacity for a number of interacting intelligences and that these provided a "better understanding of the variety and scope of human cognitive feats" (Gardner & Moran, 2006, p. 227). One of these intelligences he proposed was musical intelligence, suggesting that this intelligence had unique ways of thinking and behaving. The interest in such topics indicates that researchers were looking to other fields, such as the beginnings of neuroscience research, for what it could offer music education. Overall, her comment on research and practice stated that, “It is the responsibility of active researchers to demystify research, and to develop an expectation on the part of practitioners and teachers to research as part of their routine” (van Ernst, 1994, p. 48). My experience with teachers involved in music and general education is that they care deeply about improving their practice. They thirst for knowledge about learning and how it can be applied to their practice.

Translating Neuroscience to education

Teachers are eager to see if information about learning, that is being revealed in neuroscience research, can provide insights into making teaching and learning stronger, more relevant, easier, deeper and wider. However, the problem is in finding knowledgeable, verified information that can reliably cross the boundaries between the two fields of education and neuroscience. This information needs to be clearly described and understood.

Embodied cognition and neuroscience reveal many aspects that are valuable for music educators. However, there are a number of issues that often prevent important knowledge from crossing the divide between neuroscience and education. These issues include:

- the language used to deliver this information
- the way and where it is communicated
- clarity of description
- complexity of information
- access to information
- oversimplification
- neuromyths
- lack of evidence
- motivations
- expertise in translating information between neuroscience and education.

These issues have resulted in educators not having enough expertise or confidence to understand, digest and apply these important findings.

Neuroscientists present scientific information in academic language that does not translate to classroom practices and pedagogy. This information is usually presented at academic conferences of fellow scientific researchers, where the application to education practice is not clearly described.

Additionally, while research in neuroscience is now informed by technology that can monitor real-time activity in the brain, this information does not necessarily lead to understanding of behaviour or the learning experience (Ansari & Coch, 2006; Ansari, De Smedt, & Grabner, 2012; Goswami, 2008; Varma, McCandliss, & Schwartz, 2008). This is why some teachers are hesitant to translate findings into practice. However, others believe "that neuroscience has already reached a sufficient body of knowledge as to substantially improve" and inform educational practices (Martín-Loeches, 2015, p. 67).

Teachers usually do not have access to research that is written in language that translates to practice. Some reports on research are misconstrued or misleading. This can be because the research that becomes noteworthy is that which justifies the concerns of varying parties. In the retelling by non-scientific writers and presenters, the facts become "watered down" and so far from the facts that misinformation proliferates.

Oversimplification and over-generalisations of research findings have resulted in "neuromyths" (Clement & Lovat, 2012; Dekker, Lee, Howard-Jones, & Jolles, 2012; Düvel, Wolf, & Kopiez, 2017; Flohr, 2010; Geake, 2008; Pasquinelli, 2012; Purdy & Morrison, 2009; Tardif, Doudin, & Meylan, 2015). These are popularly relayed neuroscientific ideas that lack evidence in research. Such neuromyths include left-brain and right-brain learning, VAK learning styles and intelligence theory, all stemming from valid research, but incorrectly interpreted (Düvel et al., 2017; Odendaal, Levänen, & Westerlund, 2019).

There have been many cautionary articles, written by neuroscientists, warning about applying neuroscience to education. Some warn about basic differences in use of language, methods and motivations (Palghat, Horvath, & Lodge, 2017; Willingham, 2009), others about unrealistic expectations for what neuroscience can offer education (Ansari et al., 2012). All this confusion with neuromyths, how neuroscience is translated and communicated, and how to avoid over-simplification has left teachers wary of applying neuroscience to education.

However, evidence from neuroscience is developing exponentially and has made clear findings that impact educational practice. For example, research has shown that there are critical periods in music development (Penhune, 2011; Trainor & Hannon, 2013) and that music training changes auditory development (Banai & Ahissar, 2013; Gingras, Honing, Peretz, Trainor, & Fisher, 2015). There are critical periods for the processing of rhythms (Hannon & Trehub, 2005), metre (Kalender, Trehub, & Schellenberg, 2013), and pitch (Kraus, Skoe, Parbery-Clark, & Ashley, 2009). This is very significant for music educators, and especially that the earlier that musical training occurs, the greater the structural and neural changes develop that enable enhanced musical behaviour (Gooding & Standley, 2011; Phillips-Silver & Keller, 2012; Schiavio, van der Schyff, Kruse-Weber, & Timmers, 2017). This neuroscientific research demonstrates to teachers, educators and educational organisations that there are already important findings that can be translated from neuroscience to education.

Teachers need easy-to-understand, clear guidelines if new knowledge is to be applied to their pedagogy. It can be too tempting to adopt practices that look appropriate, sound easy, seem appealing, are commercially available, can be captured in technology, and overall, appear simple to explain and assess. Unfortunately, any human endeavour and behaviour is not simple, and brain processes that underlie these are complex. For these reasons, educators need practice-based research so that they can gain deep knowledge, make informed judgements, and practise applying these to their pedagogy.

1.4 Embodied cognition and neuroscience: a framework linking action to learning

Embodied cognition theory conceives that cognitive processes arise out of the bodily interaction in the world (Anderson, 2003; Chemero, 2013; Glenberg, 2015; Lakoff & Johnson, 1999; Wilson, 2002). A central characteristic of this theory involves a recognition of the deep interactivity between the body, the brain, and the world as a unified system, and, accordingly, the grounding of cognition in action (Wilson, 2002). The aspects of neuroscience considered in this thesis are those that directly relate to musical behaviour and can help explain what happens in the brain when we act in the world.

The following diagram, *Table 1.1 – Overview of* thesis *topics*, is a framework based on embodied cognition and neuroscience, how they relate and their common grounding in ACTION. The diagram shows the topics that were investigated in this thesis and specifies aspects of musical embodiment, and the related neural mechanisms. Nothing can represent fully the complexity of how the brain works, and the overlap and interaction that occurs in neural function. The diagram provides focus to containing what was possible to investigate in the scope of this thesis.

Research topic diagram and description

The embodied cognition column (left column) represents behaviour and the neuroscience column (right) represents the neural mechanisms of the behaviour. The adjacent titles in the columns are related, though neural mechanisms are so complex, there is much overlap not represented in this diagram. In chapter 2, the ideas in the columns will be discussed more fully.

In the middle column is the word ACTION, because every behaviour and all functions in the brain are based on ACTION. Conceptual development is grounded in the actions of experiences, and is stored in the sensory and motor brain regions used in concept acquisition (Markus & Pulvermuller, 2012). These mental representations of concepts contribute to our ability to make sense, explore and gather meaning from the world. For example, when we say, "cup", the conceptual meaning about "cup" has been gathered through all our experiences in the world to do with "cup", where maybe a carer has said the word, "cup" to a baby while introducing the idea of a vessel that holds liquid, from which we can drink, pour, carry liquid, splash and so on. The word "cup" therefore is a metaphor for all the meaning attributed to the actions, utilities, meanings and places associated with "cup".

Thinking is action, the movement of neuro-electrical messages from one neuron to another (Hawkins & Ahmad, 2016; Spruston, 2008). All of the ideas require ACTION to make them occur. In neuroscience literature, interaction, connectivity and networks constantly appear to describe the action and function of how the brain works (Bassett & Sporns, 2017; Bressler & Kelso, 2001; Bressler & Menon, 2010; Haller et al., 2013; Mišić & Sporns, 2016; Park & Friston, 2013). In music, we literally hear music through action centres in the brain (Maes, Leman, Palmer, & Wanderley, 2014; Merchant, Grahn, Trainor, Rohrmeier, & Fitch, 2015; Zatorre, Chen,

& Penhune, 2007) and action shapes perception of music (Godoy, 2018; Maes, Leman, Palmer, & Wanderley, 2014; Maes, Van Dyck, Lesaffre, Leman, & Kroonenberg, 2014).

Table 1.1 - Overview of thesis topics[4]

Embodied Cognition Interaction between the brain, the body and the world (Wilson, 2002).	A	**Neuroscience** "Cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks" (Bressler & Menon, 2010, p. 277).
Multimodal integration Many interacting ways of behaving musically (Martin-Martin & Brock, 2017) **Sensorimotor integration** Perceptually-guided behaviour, synchronising of motor and sensory behaviour (Spencer et al., 2006).	C T I	**Multisensory integration** Peripheral, haptic + proprioceptive senses provide the feeling of being musical (Dionne-Dostie, Paquette, Lassonde, & Gallagher, 2015) **Sensorimotor integration** – mirror neurons, perception/action, sensory and motor areas of the brain (also throughout the brain)
Tools and Affordances Develops capacity and skilful interaction (Mooney, 2010). **Extended cognition** Extend thinking into tools to lighten the cognitive load (Clark, 2005). **Joint action** Social cognition and understanding actions of self and others (Pacherie & Dokic, 2006)	O N	**Peripersonal neurons** Manage tool use and incorporate tools into body schema (Graziano & Cooke, 2006). **Mirror Neurons** Learn through imitation. Implicated in perception of tools and understanding behaviour (Rizzolatti & Sinigaglia, 2016).
Enriched environments Attention, goal, challenge, novelty, reward (van Praag, Kempermann, & Gage, 2000).		**Neuroplasticity** Neural change in response to experience (Merzenich, 2013).

[4] Some topics overlap and therefore appear with a number of topics e,g, mirror neurons are implicated in sensorimotor integration as well as extended cognition and joint action. Many regions of the brain interact In processing action and experiences so this table considers alignments with neural processes.

Embodiment, neuroscience and music – an active process

Learning that is grounded in bodily action results in deep knowledge structures in the brain (Johnson-Glenberg, Birchfield, Tolentino, & Koziupa, 2014). Learning and cognitive processes are deeply rooted in sensorimotor activities that engage the body with the world (Wilson, 2002). Neuroscientist, Roldolfo Llinas, who has shaped much of current understanding about the evolution of the brain and its functioning, discusses "mindness" as our cognitive state, and says that,

> The central generation of movement and the generation of mindness are deeply related; they are in fact different parts of the same process…from its evolutionary inception mindness is the internalization of movement.
>
> (Llinas, 2001, p. 5)

Together, these ideas frame how movement and action[5] underpin all the aspects that will be discussed in this thesis and will form the basis for music pedagogy where the teacher and student actively construct musical cognition.

[5] "movement" and "action" are used interchangeably in this thesis.

Chapter 2: Literature Review

Chapter 2 locates music pedagogy in an embodied cognition framework, where the focus is on how the brain, the body and world interact to develop cognition. Central to embodiment, and being musical, is movement and action, and action is embedded in all cognitive processes (Thelen, Schöner, Scheier, & Smith, 2001).

The many ways of being musical involve action, whether it be to sing, play, dance, compose, notate, conduct or even talk about music. Being musical involves interacting with tools such as musical instruments. Using tools with musical affordances increases capacities for expressing musicality and extends the ability to think about music. Being musical involves others. When we interact musically with others, we develop a musical social cognition that allows us to understand how to behave musically together, such as in an ensemble or choir, what it feels like to be musical, what it looks like and the joy of growing and learning through improvising and composing together. Teachers' pedagogy fosters this through implementing strategies that build social interaction into the learning process.

Neuroscience research reveals much information about learning and action, and therefore, is very important for teachers. The aspects in neuroscience that this thesis focusses on are those pertinent to learning in music. These will include explanations about the senses and multisensory integration; how perception and action are integrated in sensorimotor integration; the peripersonal and mirror mechanism that are so important in understanding how humans learn and how they learn through using tools; and neuroplasticity, the way the brain changes in response to experiences.

When music teachers are making decisions about **what** to teach, the next decision is about **how** to teach it (which are the first two standards in the Australian Educational Standards (NESA, 2018)). This thesis is to do with the next step in the pedagogical process; **why** a teacher teaches **how** they teach. This thesis proposes to examine the how and why of music pedagogy in a framework of embodied cognition and neuroscience.

Making music pedagogy meaningful, strong and relevant to learners is the constant quest of music teachers. There has been some interest in an embodied approach to facilitating meaningful music pedagogy, but little to tell teachers exactly what it looks like or how it can be enacted. An embodied cognition approach emphasises the role of the body and the brain embedded in the world, with cognition emerging through lived experiences with people and things in the world. Understanding this process requires teachers to consider "the different ways bodily, social and material resources scaffold access to new forms of thought and experience" (Krueger, 2019, p. 2).

This review of literature brings into focus how the brain, the body and the world interact. Though the brain, the body and the world are discussed separately, they enfold seamlessly together to develop cognition, so fluidly, that we are unaware of how naturally we are attracted to engage with the world to make meaning from it. Consider walking into a room full of drums of different sizes, shapes, colours and origins. It would be a rare person who did not feel impelled to touch and explore what would happen if they hit the skin to make a sound. Children naturally are attracted to embodied experiences with musical tools such as drums. It seems obvious that if a teacher created an environment such as this, a room full of drums, the natural result would be a joyful explosion of activity in sound making. That is the beginning of understanding how the world and the body interact to develop music cognition. Teachers, through their pedagogy, can guide, reveal, play and uncover delights of learning music through engaging natural curiosity, affective and empathetic sense-making in their students, rather than disembodied, detached symbols that relate little to understanding music.

Making explicit how embodiment can be practised in music pedagogy will build this field in music education research (Hermans & Bremmer, 2015; Nijs & Bremmer, 2019; Schiavio et al., 2018; van der Schyff et al., 2016).

The following reviews why embodied cognition is a suitable framework for locating musical learning. It discusses aspects that come into consideration when discussing the world, the brain and the body, why they are important and the implications for music pedagogy.

Embodied cognition *– why?*

The primary purpose of investigating embodied cognition in this thesis is to explore how the body interacts with the world when being musical, and how teachers can use this information in their pedagogy. This paradigm will assist teachers in designing lessons and programs that are built upon a foundation of physical embodiment of music.

Embodiment is at the heart of being musical. Music pedagogy that is framed by embodiment sees the student as an active generator of their own musicality through interaction in a rich world (Glenberg, 2010; Kiefer & Trumpp, 2012). An embodied musical world builds complex and ever-developing relationships between the student, sound, other people and the world. The environment invites meaning-making interactions that go deeper than external, technical, theoretical knowledge (van der Schyff et al., 2016). The student uses the environment to make meaning about music through interacting with things, tools, other people and sound. The teacher models musical behaviour through embodying her musicality, encourages, leads, guides, affirms and gives recognition to what it is to be musical. The teacher creates rich environments with challenges, problem-solving and creative opportunities, options, choice, skills, all developed through authentic repertoire of sound, literature, dance, movement and art. In this way, the teacher has guided the student to embody musical behaviour, musical understanding, and musical communication.

Embodied musical cognition is a deep sense of *knowing* through every action of being musical. When people are singing, playing instruments, dancing, moving to express musicality, performing in an ensemble, improvising and composing and many more musical activities, this is "the enactment of knowledge and concepts through the activity of the body" (Lindgren & Johnson-Glenberg, 2013). Music itself is not in the world until it is actualised by a music *maker* through embodiment (Gulliksen, 2016b; Høffding & Schiavio, 2019). Body cannot be separated from the making of sound, and sound, as a sonic artefact, is material and part of the world. Sound is sensed and in responding by acting, changes the brain, to make meaning and form cognitive structures. Even when listening to music, the motor response, externally and internally, is as if the listener is making the sound (J. L. Chen, Zatorre, & Penhune, 2006). As being musical is an embodied process, an appropriate framework to discuss the field is through Embodied Cognition.

A key feature of embodiment is action. In traditional approaches to music cognition, the focus is just on perception, especially hearing. In an embodied approach, the focus is on the "tight coupling between perception and action in meaning formation" (Noorden and Leman in Davis et al., 2012, p. 791). Humans are designed to move and act and in fact, every living thing that has a brain, moves (Llinas, 2001). In an embodied cognition view, sensorimotor (perception/action) interactions with people, objects and the world shape cognition (Glenberg, 2010, p. 445; Maes & Leman, 2013b). It is in the act of moving that we learn, and cognition is deeply grounded in the physical interaction with the world (Gallagher, 2019; Lindgren & Johnson-Glenberg, 2013; Wilson, 2002). It would therefore follow that in the music classroom, learning occurs through musical action and meaning-making activities, both from the teacher and the students. Musical action is singing and vocalising, playing, dancing, movement, notating and symbolising, talking about music, active listening, ensembling (a word I am using for playing together), or collectively, "musicking". Christopher Small, music researcher and philosopher, coined the term musicking to represent that music is not static, like a musical work, but active. "Music is not so much a noun as a verb" (p. 9) and "music is not a collection of works that we study and play and listen to, but is an activity, something we do" (Small, 1999, p. 19).

The first section of this chapter will discuss why embodied cognition is a suitable framework for musical learning. The second section will discuss the musical world, in which the teacher, tools, objects and materials, other people, and the physical space all impact musical learning.

This will be followed in the third section by discussion of the brain and musical embodiment. The complexity of networks and cognition reflects the complexity of learning in the real world. Neurons are always in the "on" position, ready to fire in response to experiences, and primed for action. The study of neuroplasticity, among others, explains the role of action in learning and the development of memory through challenge, variety, and reward. These conditions for neuroplasticity then embed embodied musical cognition in enriched environments. Enriched environments foster memory, neuroplasticity and are supported by brain-based learning. The mirror mechanism is particularly pertinent to learning in music. It is the system that is involved in learning through imitation (Iriki, 2006; Oztop, Kawato, & Arbib, 2006), understanding action intention (Rizzolatti & Destro, 2007), facial expressions, empathy and emotion (Overy & Molnar-Szakacs, 2009; Rizzolatti & Sinigaglia, 2016), gesture (Cartmill, Beilock, & Goldin-Meadow, 2012) and affordance action recognition (Bach, Nicholson, & Hudson, 2014). In tandem with this system is the peripersonal system, that explains how tool use is incorporated into the body schema (Iriki, 2006). When tools are manipulated by the body, particularly the hands, they are regarded by the brain as extensions of the body, like "externalised hands" (Iriki, 2006, p. 661). This is important for skill development on musical instruments and other tools, and the acquisition of musical understanding (Reybrouck, 2006). The senses are explained to describe the feeling of being musical, a feeling that cannot be replicated without the engagement of the haptic and proprioceptive sensory system. Multisensory engagement cross references knowledge from one sense to another, to develop a deeper understanding of an experience and attainment of musical skills (Zimmerman & Lahav, 2012). This gives rise to rapid integration of musical information and an embodied access to memory (Schlaug, 2015).

The fourth section of this chapter discusses the body in musical embodiment and the many modes of musical behaviour. The skilled development of musical capacity is developed through using tools with musical affordances. Through acting on these tools, cognition is extended into using them to gain deeper knowledge and understanding. Joint action and attention are deeply involved in being musical. Understanding of being with others musically in ensembles, choirs or in class all depends on deep understanding of being together as one in music. Joint action and tool use are a function of the peripersonal and mirror mechanism. Communicating in music can be through language, but primarily, it is through sound, gesture and movement, and the integration of these. For this reason, gesture and movement, by the teacher, student and in learning about being musical, all embody and shape musical learning.

The final section culminates in proposing an embodied framework for experienced teachers to embed in their music pedagogy to demonstrate what embodied practice looks like in music education.

2.1 Placing music pedagogy in an Embodied Cognition framework, underpinned by cognition neuroscience

Description of Embodied Cognition – the brain, the body and the world

Embodied Cognition (EC) proposes that cognition is a result of the continuous, **sensorimotor** interactions between the brain, body and

environment (Thompson, 2007, p. 10). Merleau-Ponty, 20th century phenomenologist, described the body and the world as overlapping, an interweaving, as of threads of a single fabric (Carman, 2008, p. 80). He emphasised the role of the body as the primary access to the world, "Knowledge gained through bodily experience is not, however, 'objective knowledge' but, rather, contributes to one's unique subjective understanding of some particular matter" (Merleau-Ponty, 1962, p. 140). It is through these active, bodily experiences in the world that all cognitive, physical, emotional and spiritual meanings are developed.

Embodied cognition draws on cognitive science (Barsalou, 2008; Glenberg, 2010), psychological science (Beilock & Goldin-Meadow, 2010; Candidi, Aglioti, & Haggard, 2012; Chemero, 2013) and cognitive neuroscience (Anderson, 2016; Rizzolatti & Craighero, 2004) to describe how cognitive processes arise from engagement through interaction with the world through the body. Cognitive structures and systems such as action schemas ("maps" in the brain that relate concepts with motor processes) and process schemas ("maps" that describe how to get ready, begin, do and complete actions) utilize the same structures and processes in the brain when thinking about them, doing them and reasoning about them (Lakoff, 2012).

This neural unity is also reflected in conceptualising the brain, the body and world as a unified system. Conventional cognitive science of the 20th century conceived of a more disunified cognitive system. Disunity, conceiving of brain and body being separate entities, is rooted in the philosophy of Rene Descartes (1596 – 1650). He proposed that the body was not involved in the development of cognition. His ideas are referred to as Cartesian Philosophy, and through his Meditations, developed the argument that "I think, therefore I am".

Even though Descartes' later writings concede that the "ordinary human experience reveals a single, united being" (Cottington, 2000, p. 105), the Cartesian philosophy that is still discussed today, describes the mind as disembodied. "It consists of mental substance, while the body consists of physical substance" (Lakoff & Johnson, 1999, p. 392). This view of the mind, that the body is not involved in the development of reason, logic, thought and language, continues to shadow some contemporary educational practices and environments. Classrooms set up in rows of desks, separated from experience and context, where learning is expected to occur in sensory and action-deprived contexts, still exist, and still exist in music education. It is not uncommon to find music classrooms where there are no tools for being musical (instruments, media and other sound sources, collaborative activities), no space to express musicality (movement and dance), no sound (either recorded, played or vocalised), and while spoken language may be present, without the experience to relate to the language, of little meaningful use.

Embodied cognition in educational research focusses on the role of the active body, interacting with the world, in learning. There are many views of what embodied cognition is and how it contributes to the mind and cognition. Many theories are very similar, such as Situated (Roth & Jornet, 2013), Grounded (Barsalou, 2010; Prinz & Barsalou, 2014; Thelen, 2000) and especially, Enactive (E. Thompson, 2005) cognition. This thesis does not propose to outline the differences between all these, but instead offers a view of embodied cognition that advances the interrelated and integrative nature of body, brain and environment, and the action enfolding these together to develop cognition.

In Margaret Wilson's summary of Embodied Cognition (2002, p. 626), she outlines six claims in common amongst the many views. They are:

1. "*Cognition is situated*" (embedded) in the world. Where learning occurs has significance for memories that are created, and the place will exert influence over learning. For music educators, aspects such as what learners can interact with to be musical, who they interact with, what the teacher does in the place, what the learners see, hear, feel, use, tools for learning, where and how they move and so on all have significance for musical cognition.
2. "*Cognition is time-pressured*". It occurs in an ongoing time frame that pressures for speed. Time does not wait for the complex processing that brains action from moment to moment in managing in the world. Situations such as escaping from danger, playing a game, driving a car, all require fast, integrative perceptions and responses. Learning music is also time-pressured. A musical work occurs through time. We can slow it down or speed it up, but essentially, it is meaningful in and through time, with all the components working together. Learners develop the

ability to manage the time pressure through gradual development of musical interactions with music through time. For example, students can sing a song while keeping a beat, or they can play a rhythm pattern on an instrument with a song, or they can play a melody with an accompaniment, until they can improvise with others in real time, a time-pressured musical skill.

3. *Cognitive work is off-loaded into the environment* (extended) because the cognitive task might be so heavy that it is beyond our capabilities, so we utilise aspects of the world to off-load cognition e.g. use of pen and paper (lists), computers, phones. In music, cognitive work is off-loaded into musical instruments, notation, dance, materials, technology, musical structures such as chords and rondo form, and ultimately, the body, such as hand sings that represent pitch (solfa), breath to represent phrasing, beginning and ending, and so on.
4. *"The environment (the world) is part of the cognitive system",* and so tightly coupled to the brain and body, that to study the mind (brain) alone would not present appropriate analysis. The world includes place and everything in it, but also the invisible "histories" of the learner, the culture of their ethnicity, family, spirituality, community, values and past experiences through these. These all affect the musical learner, and the activities presented in the music education context are not simply contextualised in the moment, but every moment that led to that point. The environment that is already part of the cognitive system of the musical learner dynamically changes with each new musical experience as it relives the individual histories and reconfigures in new learning trajectories.
5. *"Cognition is for action"* (enacted). The brain is designed to guide action, through sensorimotor interactions with the world that develop perception and memory. These enable us to make

predictions for how to manage our interactions in the world, moment-to-moment. In music education, action involves the dynamic meaning-making through musical behaviour, such as singing and vocalising, playing to make sound, moving and dancing to express musical understanding, improvising, exploring and experimenting with sound, composing, notating and symbolising, being musical with others, listening and talking about music.

6. "*Off-line cognition is body based*". Abstract thought and imagination are grounded in our past experiences of action in the world. In recall, the mechanisms that processed these memories are activated and fire. In order to think abstractly in music, cognition is based on all those grounded, bodily musical experiences with instruments, people, events, repertoire, notations and conversations in the world.

(Wilson, 2002, p. 626).

4E Cognition – Embodied, Embedded, Extended, Enacted

It is this view of embodied cognition, I suggest, that resonates deeply with a music classroom. This view emphasises the interaction of the brain-body-world in a more integrated way and includes an extended view of embodiment. Embedded includes the physical, social and cultural environments; extended suggests the involvement of tools and devices with the body and enacted describes the action that represents the action of sense-making. Musical learning is *embodied* experiences by every student, *embedded* in every action, sound, tool and social interaction, *extended* into the world to contextualise and assist cognition, and *enacted* through movement, gesture, sound and expression.

In a 4E view, learning is self-organising, built upon past experiences, evolving in and through relationships with others, musical actions and the world. Music pedagogy fostering this would enact environments where students could "exercise their capacities as self-making musical beings – where exploratory, improvisational, creative and collaborative activities can play out" (Schiavio & van der Schyff, 2018, p. 11). Learning would be collaborative, not in isolation, which would give rise to musical social interactions and shared understandings. The world would represent the cultural orientations of the group in the development of the individual as well as shared musicking. Creativity would evolve out of collaborations and individual capacities in meaningful patterns of action and perception, continuously changing and developing over time.

In the last 25 years, the many views of embodied cognition have formed a "branch" that is referred to as "4E" cognition (Menary, 2010). 4E cognition combines the cognitive fields of **embodied** (Glenberg, 2010; Lakoff & Johnson, 1999; Shapiro, 2013; E. Thompson, 2007), **embedded** (Barsalou, 2010; Thelen, 2000), **extended** (Clark & Chalmers, 1998; Kirchhoff, 2012; Krueger, 2014) and **enactive** (De Jaegher & Di Paolo, 2007; Gallagher, Hutto, Slaby, & Cole, 2013; Hutto, 2005; Stewart, Gapenne, & Di Paolo, 2011). Each field has its own particular foci, that may not be agreed upon or as emphasised in all of those "E" fields, but there is a unifying aspect among them. They all affirm that, "cognitive processes are deeply rooted in the body's interaction with the world" (Wilson, 2002, p. 625). The added emphasis of all these four fields is on the dynamic nature of goal-directed activity, intentionality and context in the development of cognition.

4E cognition rejects traditional cognitivism that asserts that cognition is representational, in a sort of top-down process (Menary, 2010). A representational focus is on "computations and hierarchical cognitive structures" (Schiavio & van der Schyff, 2018, p. 4). Music pedagogy in line with a representational view would focus on transmission of information from teacher to student, and precision in performance. The end goal would often be in perfect performance rather than musical understanding. A 4E view of cognition explains the process as a "complex network of ongoing relational dynamics between the system's autonomous agency, its domain of interaction with the world, and the emergence of meaning" (Schiavio & van der Schyff, 2018, p. 4).

Music pedagogy reflecting a 4E approach would incorporate an individual's ongoing interactions in a richly musical environment. There would be much improvisation, movement, relational activity with others, informal and formal musical events in time, exploration and experimentation with musical ideas and tools, resulting in ever-evolving, self-organised, cognitive structures.

4E cognition and music education

In music education research, Schiavio and van der Schyff (2018) have promoted interest in 4E cognition and what it could offer for music pedagogy. They explore the notion of "autopoiesis". Autopoiesis, first coined by Maturana and Varela (1980) describes how individual life journeys dynamically compile unique cognitive structures that are developed in an ongoing and indefinite manner. The autopoiesis process is a sense-making process of perception and action in the world and gives rise to the emergence of self. The sense-making process is self-organised and deeply embedded in social interactions through shared embodied interactions, continually shifting and reorganising in real time, in authentic contexts (worlds). These interactions could be in ensembles or classrooms, but involve collaborative and individual interactions between self, others, and the world. Autopoiesis therefore means the creation of the autonomous self.

The processes involved in autopoiesis have implications for music education. Students, teachers, peers and the context are coupled through the shared activity in the world. Sometimes this coupling is difficult to imagine in a classroom where the teacher does not appear to "share" but "impart" or "direct". When the teacher views themselves as coupled in the learning world of the student, they are an active agent, collaborating, guiding, partaking and also learning (van der Schyff et al., 2016).

In a 4E view, learning is self-organising, built upon past experiences, evolving in and through relationships with others, musical actions and the world. Music pedagogy fostering this would enact environments where students could "exercise their capacities as self-making musical beings – where exploratory, improvisational, creative and collaborative activities can play out" (Schiavio & van der Schyff, 2018). Learning would be collaborative, not in isolation, which would give rise to musical social interactions and shared understandings. The world would represent the cultural orientations of the group in the development of the individual as well as shared musicking. Creativity would evolve out of collaborations and individual capacities in meaningful patterns of action and perception, continuously changing and developing over time.

Effects of embodiment on learning – long-term learning gains

Proponents of an embodied approach to learning music would advocate for learning as described in the former section. It might be argued from a critical perspective that it is faster and more efficient to just tell students the answer or tell them how to do something. For example, students might be told that aleatoric music is experimental music. On a test, if asked what aleatoric music is, they would probably get the correct answer, but with no knowledge of what it sounds like or how it works. This type of knowledge is not usable and is shallow.

If the student was involved in embodied experiences with aleatoric music, they might have experimented with a short extract from a piece of aleatoric repertoire, composed with it, moved to it, sung it or played it on a number of different sound sources. They might have designed some symbols to represent their aleatoric composition, performed it to others and listened to others' compositions using the same short extract. When they then heard the extract in the authentic context of the repertoire, they would have a much deeper understanding of what it sounds like and how it works. Embodied cognition practitioners would propose that the deeper learning through embodiment results in long-term learning gains.

In experiments looking at the strength of embodied learning in comparison with other ways of learning, it was found that while the short-term effects of learning were the same, the long-term learning gains were much stronger for embodied learning experiences (Johnson-Glenberg et al., 2014).

Mina Johnson-Glenberg conducted experiments with tertiary students who were learning about centripetal force (Johnson-Glenberg, Megowan-Romanowicz, Birchfield, & Savio-Ramos, 2016). The aim was to assess how the amount of embodiment designed into the lesson affected the learning outcomes. The experiment was based on the embodied cognition framework, that learning grounded in physical manipulation through sensorimotor actions in the learning environment, results in deep learning structures.

Groups of students learnt about centripetal force in either high or low embodied conditions. On tests immediately after the learning, results from both groups showed no significant difference. On later testing, the high embodied groups demonstrated significant delayed gain. The experimenters suggested that this was due to the high level of physical movement, gesture and manipulations that created strong sensorimotor memory associated with this learning. They propose that embodied learning enhances delayed learning gains. They further propose that because of the strength and depth of neural structures involved in embodiment, embodied learning could be useful in overcoming incorrect mental models (Johnson-Glenberg et al., 2016, p. 20).

The Johnson-Glenberg research (Johnson-Glenberg & Megowan-Romanowicz, 2017) has now been transferred to different fields to incorporate movement and gesture in mixed-reality contexts that capture and foster sensorimotor interactions. She suggests that educational content is never simply embodied or not. Abstract thought, based on past sensorimotor interactions, is engendered by perceptual symbols associated with past learning, such as text, actions (seeing somebody else doing the action, or oneself doing the action again), or sensory aspects (hearing a song, smelling a perfume, seeing an image). Everyone's past learning is individual to their own personalised experiences, and therefore, their abstract conceptual understanding is "grounded in complex simulations of combined physical and introspective events" (Barsalou, 1999, p. 577). Learning that is grounded in physical manipulation results in deep learning and long-term learning gains.

2.2 The musical world

Music teachers create "the musical world" in their classrooms. The musical world includes everything external to the body and in the environment, including objects and things, people and the relational factors such as culture, family and community, and in music learning, the world includes specifically, sound[6]. "The world" is the place where a

[6] One could even say, organised sound, though sometimes, disorganisation is where music learning starts.

person is and interacts with the environment and is the domain of meaning that is brought forth through the history of perception-action of the organism in interaction with the environment. Environment refers to the physical and social milieu the organism inhabits and shapes. "World" and "environment" is used interchangeably in this thesis and combines the meaning of the two.

The teacher – a model of musical embodiment

"The role of the teacher is to reveal, encourage and nourish" the learning process (van der Schyff et al., 2016, p. 94). The teacher as a model of being musical plays a central role in teaching and learning music (Bresler, 2004). Musical skills are often laid down in the movements and gestures of the teacher as they are synchronised with musical repertoire and sound making activities (Hermans & Bremmer, 2015; Nijs & Bremmer, 2019). For example, when a teacher sings a song and keeps the beat through body percussion, information about synchronising rhythm patterns through song lyrics to the underlying beat are communicated through the teacher's body and enacted in the student's body in joint activity. Singing a song and keeping a beat is more deeply understood through doing it than through talking about it or watching it.

The action of learning in the world is what Wilson (2002) calls online embodied cognition, where cognition occurs in real-time and is time-pressured, linked to all that occurs in that moment. In that moment of authentic musical action, sensorimotor mechanisms synchronise with knowing about musical concepts. Attached to that memory would be other aspects occurring in the world at the same time, not necessarily musical, such as who was there, what could be seen, heard, felt and so on. Everything can impact the memory in different strengths according to where the attention is held.

Offline embodied cognition develops in response to online experiences. Offline is internal or abstract thought and links to the online embodied states to engender memories that fire the same mechanisms in the brain as if the experiences were actually happening. "Stored embodied memories constitute the basic elements of knowledge" (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005, p. 187).

When the actions, expressions, movements, gestures and sounds that the music teacher makes in the music lesson are congruent with the musical information, deep learning occurs (Kiefer & Trumpp, 2012). The student knows what being musical looks like, and when a passerby looks into the classroom, it should be clear by the musical behaviour by the teacher and students that it is a music classroom[7].

Tools Objects and materials – to embody being musical

The brain-body system uses the world to think (Chemero, 2003), and for music teachers, their classrooms are the world. In that world, the students use the musical classroom to think. If what is in the world is used for thinking, it is important to intentionally assist thinking and learning by incorporating musical tools and affordances in the classroom. These tools are for physically using and acting upon, and change thinking when using them.

In thinking about the classroom in which musical learning takes place, the size of the space constrains the type of movement and action that takes place. How far travelling movement can allow, the height of the ceiling and visibility to the outside of the classroom, the sounds that can be heard while inside the room, the temperature, flooring material, air quality, every detail that can be sensed about the space affects

[7] Of course it is always possible that students are engaged in reflective musical activity that would not necessarily look like musical activity.

thinking. Teachers can make sure that all these details contribute to musical thinking. What students see, hear, feel and even smell are important considerations for music pedagogy.

Musical tools that are in the world that the music teacher creates, such as musical instruments, are not just for developing technical skills. Musical tools engage us in an embodied process of learning. As we engage, interact and incorporate them into our body's schema (see later in Peripersonal neurons section), what they feel like, how they help us be musical and how they "fit" into the musical world becomes available to us and develops musical cognition. For example, when experiencing the effort, energy and action of playing an instrument softly, understanding develops about the relationship between sound maker (instrument) and sound user (self), the effect of the dynamics in the meaning created by the sound, and how this all fits within the musical context.

Some musical tools are not physical but are still part of the world. Repertoire, for example, except in notated form, is not physical until we embody it. A poem can be a musical tool and it is embodied when it is spoken. The act of performing it makes the poem a musical tool as the words represent rhythm patterns, the subject of the poem becomes the framework for expression, the metric nature of the poem practises metre and accent and so on. The way we use tools and affordances changes cognition and the way the brain makes and stores memory.

Other people

Other people in the world of the music classroom assist in the development of music cognition through social collaboration, social affinity, cohesion and unity, and joint musical practice. Others in the music classroom can include the teacher, parents and carers, teachers' aides, and importantly, other students. Social aspects of learning also include the security, affiliation, and emotional support that others contribute, making the setting conducive to learning.

Social cognition and musical social cognition are developed through interaction with other people (Schiavio & De Jaegher, 2017). In music education, practising non-verbal social interactions builds important skills for ensemble performance and musical communication (Novembre & Keller, 2014). Socially- mediated experiences allow us to reduce the cognitive load by extending our thinking into the interaction between and with others (Michaelian & Sutton, 2013; Sutton, Harris, Keil, & Barnier, 2010).

Social interaction in music is integral to ensemble, playing in time and in the same expressive space as others. It involves coupling, where individuals join to generate an identity or meaning together or co-develop learning and knowledge (De Jaegher & Di Paolo, 2007). The mirror mechanism is implicated in coordinating behaviour together and is involved in understanding the intention and goal of others' actions (Gallese, 2009a). Being with others in musical learning practises embodied musical actions, such as breathing when about to start an action, gesture to indicate musical expression, or following the direction of a conductor.

Everyone in the musical world becomes part of the musical learning in "circular and contingent patterns of action and perception that continuously shape and renew the couplings" (van der Schyff et al., 2016, p. 91) between student-and-world, musician-ensemble, student-teacher, student-student.

Social interaction is a social tool to extend thinking into the interaction to support action and cognition (Froese & Di Paolo, 2010). For example, in the music classroom, being in joint action with others in a dance can support an individual's and group's ability to perform the dance. Perception of other's actions and intentions cues the actions of self, therefore supporting and scaffolding both learning and performance. The same process applies to improvisation between people. Each person supports the other's improvisation by responding to movement and expression cues, in acknowledgment and support of each other's performance.

The mirror mechanism is implicated in social cognition through identification of goals of motor actions and intentions of others and understanding of others' emotions (Rizzolatti & Fogassi, 2014). The sensorimotor experiences in social interaction, which are time-pressured and rapidly processed through the mirror mechanism, give rise to abilities to not just mirror others' behaviour, but develop independence and autonomy through understanding behaviour. In the example once again of improvisation between two people, when one is the leader, the other understands the intention of the movements of expression and the sound context through past experience with others, and maybe with this partner. Imitation is implicated through the mirror mechanism, but in improvisation, behaviour goes a step beyond through complementary behaviour, so the mirror mechanism also contributes to changes in sensorimotor behaviour adaptation (Catmur, 2013). Through the mirror mechanism, the individual recognises patterns of sensorimotor behaviour and can contribute other patterns of musical behaviour (based on past associations) to develop new complementary patterns.

Di Jaegher and Di Paolo describe social interaction as a mutual sense-making process, where actions and intentions are co-constructed in the interaction (2012, p. 9). Processes of social interaction are "complex, multi-layered, self-organising, and can shape individual intentions, orient individual perception and guide performance of individual action" (Di Paolo & De Jaegher, 2012, p. 1). They also identify that transitions of behaviour in social interaction can change relations and behaviour between the interactors. The behaviour can change between imitative and complementary and symmetric or asymmetrical (2012, p. 9). This is particularly pertinent to musical behaviour in ensemble performance and improvisation. When unexpected or even expected changes in performance occur, there is an instability where all involved in the interaction must adjust and restabilise the joint performance. Examples of these sort of transitions are such as during a performance when a player might break a string on their instrument, or play an incorrect note, or come in too soon and so on. The ability of the group to manage this instability successfully would depend on their experience as a cohesive group, the expertise of each individual player, and the perceived group intention of the task.

The idea of transitions and the challenge to stability is an interesting phenomenon in the music classroom, and one which can be created intentionally to develop social cohesiveness, joint attention and collective sense-making. It coordinates musical behaviour, an important aspect of being musical, and allows individuals to experience first-hand how to embody behaviour that solves these sorts of musical challenges and behaviours.

Classroom and group music classes favour socially-mediated, embodied musical learning through learning from others, learning through interacting with others, and extending musical cognition into interacting with others.

Physical space – constraints and effects on musical embodiment

The physical space, and things in the space, have an effect on embodiment in music. The teacher, tools and other people have been discussed, and now other aspects of the physical space in which the musical learning takes place are considered.

Embodied cognition asserts that cognition arises and takes shape through direct engagement and interaction with the environment (Anderson, Richardson, & Chemero, 2012; Bresler, 2006; Glenberg, 2015; Shapiro, 2013; Thelen, 2000). "There can be no cognition without physical, sensory experience of the surrounding environment" (Osgood-Campbell, 2015, p. 5). Action in the world with things in the environment develop cognition. This action can be overt, such as physically engaging with the world, or internal action, such as acting on seeing an image, or hearing a sound. Fundamental to action is movement, and it is not incidental to learning, but is embedded in cognition processes (Thelen et al., 2001).

Aspects that can affect embodiment in the music classroom can be the layout and size of the space. The size of the space can impact how much embodiment can take place. For example, a large space can encourage large movements and lots of physical activity in games, dance and instrument playing. A small-sized space would constrain high-energy movements and formations in dance, though movement that takes up just the body space can still occur e.g. body percussion, singing and so on. Size of space can prime students for moving to learn.

Use of space can affect musical embodiment. A musical space ideally has places for all musical activity. This activity can include movement and dance, playing in ensembles, singing in choir-like arrangements, as well as space for collaborative musical problem-solving and using technology. Space taken up with objects such as furniture can inhibit movement. How space is used and in what arrangements can affect musical embodiment.

The space can inspire musical engagement through what can be perceived in the space. For example, things that suggest musical engagement, such as having musical instruments visible in the space, sound equipment, images that suggest musical engagement can all contribute to an environment that inspires musical engagement.

Action and sensorimotor skill development arise out of interaction with the physical space. Thelen (in Smith, 2006) describes this as emergent behaviour, not dependant on the capacity to cognitively plan or maturational aspects, but dependent on sensing and acting on the environment in iterations that develop sensorimotor skills. Constraints that inhibit or enable development of skills and conceptual growth include the biology of the individual, the availability of tools, the materials of space (flooring, light, temperature), other people and the task to be accomplished (Abrahamson & Sánchez-García, 2016).

In music classrooms, teachers create the world and create enabling constraints through how they use the space. Spaces that afford musical action through movement provide physical opportunities for musical interaction. The musical action brings forth musical ideas through a process of goal-directed interactions with manipulable features of the environment (Abrahamson & Sánchez-García, 2016; van der Schyff et al., 2016)

Summary of the musical world and music pedagogy

The teacher creates the musical world for and with students through her pedagogy. The teacher embodies what it is to be musical by behaving musically, using tools, objects and materials in the environment that are available for the teacher and others to explore and interact with. Other people, especially other students in the music classroom, interact to extend musical thinking and problem-solving into the world. The physical space can provide enabling factors to facilitate musical behaviour, such as space for moving and playing, and sensory aspects and tools that suggest musicality. The world is part of music pedagogy.

2.3 The brain and musical embodiment – brain processes that impact embodiment

The complexity of brain function is reflected in the complexity of human behaviour. Though complex, there is much in neuroscience research that can inform teachers about learning, and for this thesis, about learning in music. For example, understanding how the peripersonal and mirror mechanisms in the brain impact learning in music can give much insight for teachers when planning how to teach. These systems enable use of musical tools (Mooney, 2010), understanding musical action (MacRitchie, Herff, Procopio, & Keller, 2018), learning through imitation (Overy & Molnar-Szakacs, 2009), managing musical joint action in ensembles and group learning (Pezzulo, 2011), understanding meaning of gesture and movement (Windsor, 2016). Teachers think they need to tell students about music, but the mirror and peripersonal systems, along with sensory and motor systems, generate their own understanding and knowledge through embodiment . When the teacher embodies musical action, the student learns to imitate and embody musical behaviour. When students hold, explore and embody musical instruments, their brains treat the instrument as another body part by enfolding it into their body schema. The body then is able to manage the musical instrument like it is an extension of their body, and they can develop sensorimotor patterns to skilfully engage with a musical instrument.

A basic understanding of how neurons "talk" to each other and are primed for learning informs the teacher that their pedagogy needs to create priming features for learning, such as embodying musicality, as already mentioned, plus making available musical affordances, musical behaviour opportunities and an environment that engenders these. A music classroom primes students for music through looking, feeling, sounding like a musical world where they can embody musical behaviour.

Musical experiences that are active, challenging, rewarding and sociable make the best of the way the brain makes strong memories, through neuroplasticity (Groussard et al., 2014). The strongest musical brains are embedded in enriched environments where stimulation and action promote deep musical learning through embodiment.

When music teachers have an understanding of underlying neuroscientific principles, they can embed this knowledge in their pedagogy and identify behaviours that indicate these neural processes.

Complexity – The Brain and learning

Teachers know that learning is complex. Learning in music, and any subject, requires the building of complex structures that interact to develop deep knowledge and understanding. It is no surprise then to know that the brain also works in complex networks and circuits of "softly"[8] assembled neural structures that change in response to experience (Litwin-Kumar & Doiron, 2014; Markus & Pulvermuller, 2012; Quian Quiroga, 2016). There are no functions that are simply processed in one area in the brain. Experiences and processes link all over the brain, to develop complex behaviours that allow us to manage and be successful in the world. "Cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks" (Bressler & Menon, 2010). This means that processing and learning engages multiple

[8] "softly" because they are not permanent and change every time they are reactivated.

areas of the brain, synchronously working in a concerted fashion (Spampinato & Celnik, 2018).

In conventional music classrooms, learning often isolates musical ideas, out of context, and focuses on small units of knowledge, unconnected to the authentic context, such as endless practice in identifying crotchets, quavers and minim rests. This results in what Whitehead called inert knowledge (1950), knowledge that is unusable because it is not utilised in real contexts and not put to use in new contexts. This type of learning is actually harmful, as it separates knowledge from function and the processes that bring understanding.

Learning is complex, but authentic contexts create complexity for the teacher. In learning music, the teacher can focus on learning about how concepts function through embodying small units of ideas but using them in context. For example, the teacher might sing a melodic theme from a piece of repertoire. Students could sing and devise a movement sequence to represent the theme, then when the repertoire is played, the students demonstrate their understanding of the theme by moving when it occurs in the repertoire. This would give rise to understanding how a melodic theme fits into authentic repertoire. Because it is in its context, it could give rise for many other conceptual understandings also, such as flow of pitch to create melody, the many ways a melody can be treated and so on. In this way, simplicity arises out of complexity.

Every moment in the music classroom, students' knowledge structures are updating and changing through responding to experiences. From understanding aspects of the core circuitry of the brain, current research suggests that the brain is designed for deriving meaning from the world as it is presented to it (Freeman, 2004; Quian Quiroga, 2013), in the moment, or, as stated by Wilson (2002), time-pressured. The brain is constructed for perception and action, so that as the world is perceived by the senses, it acts upon this incoming information by predicting meaning, error detecting, reassembles in response to this, continues acting on the world and so on, continually updating and reassembling constructs of the world, through time, in overlapping and interlooping ways (Anderson, 2016; Friston, 2005; Park & Friston, 2013).

Embodied musical learning, and all learning, is a continuous process and by nature, self-organising (van der Schyff et al., 2016). Music cognition is “co-constituted by the learner, the teacher, the environment, and their coupling” (Schiavio & van der Schyff, 2018, p. 12). In this coupling, each individual actively develops new, self-organised patterns of meaning, generated through sensorimotor interactions, continuously shaping and integrating neural structures through time. There is still much that is unknown about how cognition arises from complex systems and mechanisms (Bassett & Sporns, 2017). However, the emerging model is that the brain is generative, self-organising, integrative and dynamic.

***Generative, self-organising, integrative and dynamic*.**

Generative is the idea that the brain builds upon its own past experience of the world to predict the meaning of what it is perceiving moment-by-moment in the world (Campbell, 2015). Past constructs are compared to incoming information to come up with the best possible meaning and use of information (Vilares & Kording, 2011).

This model of how the brain works is an **Hierarchical Bayesian** model (Knill & Pouget, 2004; Rao, 2009). Reverend Thomas Bayes (1702 – 1761), after whom this model is named, first proposed this theory to describe how two variables could be used to make an inference or prediction. In describing cortical (brain) models, an Hierarchical Bayesian model asserts that prediction is based upon “the probabilistic integration of top-down prior information with bottom-up image likelihood information”(Rao, 2009, p. 125). In other words, interpretation of the world is based on past experience, which then provides a model from which to predict possible interpretations of what is happening. As new information is assimilated into that model, it becomes integrated into this hierarchical structure.

Self-organising refers to the way the brain reorganises itself as each new experience is processed. The process is **neuroplasticity**, and this describes changes in the neural structures as a result of experience (Martin, 2015). **Integrative** is a term used to describe the way multiple systems, distributed across a variety of structures, interact in order to meet the demands placed upon the organism, species or people (Bassett & Sporns, 2017).

Action is key to any discussion about learning. Embodied action is "**dynamic**", a core tenet in what the brain is designed for and how behaviour relates to learning. Neural dynamics refers to patterns of activity between neurons and neuronal systems (Schöner, Reimann, & Lins, 2015), creating networks, circuits and patterns of meaning. These networks and circuits develop complex connections that constantly reorganise and couple with other systems in response to experience. This creates a "metastability" across many systems and is thought to favour adaptive behaviour (Kelso, 2012).

The most defining feature of the mature brain is its connectivity, and this develops over time as the brain adapts to the world and becomes more efficient in processing information (Dennis & Thompson, 2013).

Neurons and neural reuse

When a student enters a rich musical world, created in the music classroom by the teacher, their neurons are primed for being musical. As the student perceives the teacher, the musical tools, the musical action taking place, the other people in the space, millions of neurons would be in the ready position, waiting to fire. All the neurons connected to being musical would be ready to make new connections and change in response to new activity, challenges and combinations of musical elements. Teachers who understand that the brain is primed by the world and everything in it can embed how to make this happen into their pedagogy.

Neurons are brain cells that fire in response to action and make memories. Contrary to popular beliefs, neurons are always "on" and primed for action (Merzenich, 2013). Neurons fire in response to action, whether that be internal (thinking) or external, from the world.

Neural reuse and music pedagogy

The principle of neural reuse is the idea that the process creates efficiency through reuse of hardware (neurons) for multiple functions, which saves neural space and energy. This idea of neural reuse applied to music pedagogy translates to the way teachers can use repertoire for multiple functions and use musical skills to practise lots of different concepts in music.

Repertoire is a tool for learning about music. When students learn a new piece of repertoire every time they are learning about new musical ideas, the cognitive load is taken up with learning new repertoire, at the expense of learning about how music works (Kersten & Wilson, 2016). In line with neural reuse, it is more efficient to use the same tool for multiple functions (if possible). Then, what is new is the application, understanding how the tool works in many different ways, and neural energy is taken up with learning how music works.

A musical skill, such as movement, can be used in many different ways to learn about how music works. Body percussion, for example, has multiple affordances for being musical. Body percussion can keep a beat, develop a feeling for metre (beat grouping), express dynamics, get faster and slower, explore tone colour (difference between the qualities of sounds) and so on.

“Neural reuse is a form of neuroplasticity whereby neural elements originally developed for one purpose are put to multiple uses” (Anderson, 2016, p. 1). Neurons, systems and networks can be used for many different behavioural and cognitive purposes and result in a repertoire of behaviours. These “neural coalitions” (Anderson, 2016) may overlap but ultimately provide many different possible solutions to whatever is perceived and acted upon in the world. This can be observed in the music classroom when students might be asked to provide a variation on a theme. They will try all the solutions they have tried in the past to see if those can be used to change the theme. When the teacher introduces a different strategy for making a variation, the procedures for changing the theme can be used again, but novel processes involved in applying the strategy will generate cognitive changes, creating new neural coalitions. Arriving at a solution involves the student acting in and with elements, increasing capacities for managing and manipulating the world and embodying learning (Anderson, 2016).

Neural reuse occurs through a process of priming and switching neurons on and off. Many neurons can be ready, or primed, through detecting patterns in the world that they recognise, but once one of the primed neurons has fired its signal, other neurons are chemically inhibited from sending a signal, or switched off (Hawkins & Ahmad, 2016). This is referred to as an “all or none” phenomenon (Morgan & Ricker, 2018, p. 66). From much neural activity, it moves to sparse activity of only the necessary neurons being active in the connections. The phenomena of sparse integration could explain how the brain does not overuse its capacity

(Hawkins & Ahmad, 2016) and accounts for efficiency. This is important for sequential memory and functions. Neurons are thought to have thousands of active dendrites and synapses that recognise many patterns of cellular activity and can detect these patterns. The neurons can detect patterns as long as the neural activity is sparse (Hawkins & Ahmad, 2016).

Neuroplasticity

When neurons are activated and form networks, the process of change is called neuroplasticity. Neuroplastic change occurs in response to experience and is how the brain-body-world system learns and develops memory. Music teachers can implement pedagogy that enhances learning through providing conditions for neuroplasticity to occur.

Music teachers have long understood the value of repeated practice to develop musical skills. Michael Merzenich (2013) says that specific activities focus the neurons to make the right links. Neurons that fire at the same time make relationships. When musical ideas are actively practised synchronously with music, other people, using musical tools in a rich environment, learning is increased through improving "speed and synchrony of impulse transmission between cortical regions" (Fields, 2011, p. 185). Once these connections have been made, neurons are primed for noticing those patterns in the world when they occur again. On repeated firing of these connections and circuits, the pathways become stronger, more efficient and faster through a process called myelination[9].

When we have experiences, the place, time, other people, objects and materials, and sensory aspects all become associated with the memory. "Things that happen near each other in time or space become

[9] **Myelin and Myelination:** The membranous wrapping of axons by certain classes of glial cells that makes brain regions with axonal pathways look whitish. The process, myelination, is where glial cells wrap axons to form multiple layers of glial cell membrane that electrically insulate the axon, thereby speeding up the conduction of action potentials (Purves et al., 2013, p. 575)

associated with each other" (Maes, Leman, Palmer, & Wanderley, 2014, p. 3). In the mid 20th century, Canadian behavioural psychologist, Donald Hebb, proposed the process of cell assembly theory (Hebb, 1949) that explains a form of neuroplasticity. His research looked into the way cellular and molecular processes underly the "rewiring" of the brain, summarised by neuroscientist, Carla Shatz (1992), as "neurons that fire together, wire together" (Doidge, 2007, p. 63). Michael Merzenich continued developing this theory, that neurons that fire at the same time develop connections amongst one another, even if some of the neurons are not directly related to the topic of the learning (Merzenich, Van Vleet, & Nahum, 2014). When creating musical learning environments for developing connections and associations that richly entwine to make meaningful memories, teachers should consider how their pedagogy reflects these ideas. Isolating ideas and experiences would be less effective than entwining many ways of creating conceptual development.

Conditions for neuroplasticity

In order to create Ideal conditions for neuroplastic growth, teachers need to consider:

- Attention – In order for strong learning to occur, students must be attentive to what is occurring and sustain attention. When the body is holistically involved through embodiment, there are more attention processes occurring to maintain attention.
- Challenge, motivation, effort and goal – To create the greatest amount of neuroplastic change, a task must be challenging but within achievement level to motivate students to persist. The task must be goal-oriented to create alertness and focus, and the more effort that is exerted to achieve a task, the more rewarding it feels when achieving it.
- Strength-building – Hard, strong memories are created through revisiting of skills and knowledge along with making new

connections to these. When new connections are made, it is more likely that the hard pathways are reactivated more often because they are more widely connected.

- Novelty – Part of maintaining attention of students is introducing novelty. This should not be confused with changing attention, as this reduces the depth of memory formation (Koch, Poljac, Müller, & Kiesel, 2018). Novelty when developing neuroplasticity is concerned with practising the same concept or skill in a variety of ways. Variety means that multiple sensory, motor and cognitive pathways converge and connect within the memory.
- Memory - Memory guides and manages predictions and associations between old and new memory. The more actions and ideas are practised and reactivated, the better and more refined memory becomes. This reduces "noise", or the action of neurons not necessary for skilled behaviour. When the brain has decided what neurons and networks are needed to perform skilled behaviour, it discards old connections, making the memory fast and efficient in function and the amount of neural space it uses.

(Merzenich, 2013).

The importance of action and novelty and conditions for neuroplasticity to occur was recently illustrated in research on the brains of Antarctic researchers. On December 9, 2019, a press release in *Live Science* reported that, "Lonely Antarctic expeditions shrink people's brains" (Lanese, 2019). The related research appeared in *The New England Journal of Medicine* (Stahn et al., 2019), released the same day, and stated that enriched environments could be the solution to preventing brain shrinkage due to environmental monotony, lack of exercise, and social isolation. To prevent brain shrinkage and cognitive reduction, researchers are looking at special physical exercises and virtual reality to augment sensory stimulation in the hope that "enriching" a person's environment with new items and activities could shield the brain from shrinkage (Stahn et al., 2019).

Music pedagogy that results in rich learning incorporates the conditions for neuroplasticity. These conditions are achieved through creating enriched environments.

Enriched environments

Creating enriched environments through music pedagogy results in deeply musical understanding by students. Enriched musical environments provide great opportunities for challenge, options, reward, novelty, social stimulation and collaboration, through active, embodied engagement in a richly musical world.

Enriched environments and neuroplasticity

As discussed earlier in this chapter, cognition arises from the integration of the brain, the body and the world. "The role of the world" has already been discussed, but in this section, ***enriched environments*** will be discussed in relation to neuroplasticity.

Emphasising enriched environments in music classrooms is particularly important, as there seems to be an entrenched practice for a context where students sit at desks and listen to a teacher talking, lesson after lesson. This becomes monotonous, unmotivating and unstimulating, and not conducive to neuroplasticity. The room may not even look like a music classroom, there may not be instruments, sounds, collaborations and little movement. Students might be using computers, which may very well be musical behaviour, but equally, may not, or just be indistinguishable from scientific or mathematical behaviour with technology. Students might continually be encouraged to read from musical notation and perform. Again, this may be appropriate and musical. However, enriched environments would engage the whole body / brain / mind in being totally immersed in actively and personally making relationships between performing, creating, symbolising, problem-solving, improvising, discussing, analysing, socialising and everything to do with being musical. Deep musical cognitive development is a result of richly complex interacting elements in an enriched musical environment.

Enriched environments promote neuroplasticity through a combination of complex social stimulation and environmental interaction (van Praag et al., 2000). In experiments by Will, Galani, Kelche & Rosenweig (2004), rats kept in environments that contained good nutrition, lots of social interaction, lots of toys, change of toys and placement of things, challenges, physical activity, choice and so on, were found to be more robust, developed complex neural connections, had accelerated early development, improved learning, problem-solving skills, and memory, decreased cognitive impairment due to ageing, increased exploratory activity, longer life, and less mental health issues (*Fig. 2.1*). The control rats kept in a cage with no socialisation or toys failed to thrive. Rats kept in social groups but with no stimulation failed to thrive. Rats kept in the same environment on their own did not develop the beneficial neural effects. The research has demonstrated in a number of different experiments that no single factor accounts for learning in enriched environments. Learning in rich environments is a result of the *combination* of all the factors (Rocha, Costa, Ferreira, & Fregni, 2018).

Enriched environments and learning

Enriched environments was nominated by a group of neuroscience experts to be the overarching idea for "brain-compatible teaching" (Radin, 2009). Enriched environments promote neuroplasticity and therefore, learning, through a combination of complex social stimulation and environmental interaction (van Praag et al., 2000). These provide an environment where multiple factors interact in ongoing and changing states, creating meaningful, authentic relationships for learning.

Based on a number of learning theories supported by cognitive neuroscience, Caine and Caine (Caine & Caine, 1997, 2005) nominated twelve principles for brain-compatible teaching:

1. "All learning engages the entire physiology;
2. The brain/mind is social;
3. The search for meaning is innate;
4. The search for meaning occurs through patterning;
5. Emotions are critical to patterning;
6. The brain/mind processes parts and whole simultaneously;
7. Learning involves both attention and peripheral perception;
8. Learning is both conscious and unconscious;
9. There are at least two approaches to memory (rote learning system, spatial/contextual/dynamic memory system);
10. Learning is developmental;
11. Complex learning is enhanced by challenge and inhibited by threat associated with helplessness and fatigue;
12. Each brain is uniquely organised."

(Gülpinar, 2005, p. 3; Kitchen, 2017, p. 9)

Brain-based learning principles were developed to help educators optimise how the brain learns through providing enriched environments (Gülpinar, 2005). Caine and Caine (1997) proposed three elements that were essential for complex learning to occur:

- Relaxed alertness, created through having supportive and emotional and social environments, with challenging but achievable tasks and social interactions;
- Carefully developed immersion in multiple, complex and authentic contexts, providing time for experimentation, reflection, making constructive and meaningful relationships between ideas, concepts, and structures;
- Active learning, through personal engagement with manipulating, changing, recreating, repeating, extending and consolidating knowledge.

(Gülpinar, 2005, p. 3)

Enriched environments in music pedagogy

There is much literature about the value of music in enriching learning and brain plasticity, and about how a musically enriched environment would have an effect on instrumental learning, but I am not aware of any research as yet that describes what an enriched musical environment would look like in music pedagogy. For this reason, I propose enriched environments be envisaged by fulfilling the principles for brain-compatible teaching, outlined in section 2.3.4.2 (above) and an embodied cognition framework.

An enriched environment in music pedagogy would prime the student for musical behaviour. The world would include a teacher who modelled musical behaviour; opportunities for embodied musical behaviour and engagement by students and others with tools and materials; in a space that stimulated sensorimotor behaviour; with repertoire that provided holistic and authentic engagement. Everyone would look like they were being musical and produce musical artefacts. Students would be challenged to be engaged in skill development, problem-solving activity, joint musical activity and individual solution building through extending thinking into the world. Students would be music making to understand how music works.

The mirror mechanism and musical learning

Mirror neurons are nerve cells in the brain that fire both when an action is perceived and performed (Rizzolatti & Fogassi, 2014). They are particularly important in music teaching, as it is the body that shows musical behaviour and mirror neurons are the primary way that we understand movement and behaviour. For this reason, what the teacher's body does, and how she embodies musicality is very important for students to perceive. The act of synchronising the body, the brain with sound is strongly associated with the mirror neuron system. In classrooms where the mirror mechanism is utilised for learning about music, the teacher and students are behaving musically, singing, playing, improvising, moving, dancing, composing, doing this together, jointly with others, symbolising and so on. Music teachers especially have an advantage in using face, hands and gesture to convey musical meaning, as mirror neurons fire especially in response to facial expressions and hand actions. "When observers see a motor event that shares features with a similar motor event present in their motor repertoire, they are primed to repeat it." (Rizzolatti & Craighero, 2004, p. 180). In a subject where language is not the principle way of conveying meaning, the face and hands have great impact.

Mirror neurons are both sensory and motor neurons, so when we perceive someone doing an action, our motor cortical areas fire as if we ourselves are performing the action (Rizzolatti & Sinigaglia, 2016). Additionally, we understand the intention of the action through our own past experiences of doing that action. For example, if we saw someone about to hit a drum, we would understand through past experience what the expected sound would be and if we had past experience of hitting a drum, we would have deeper understanding of exactly the type of drum sound certain hand shapes would elicit from the drum. Mirror neurons provide us with heightened awareness about those actions for which we have expertise. "The richer people's motor expertise is, the greater the sensitivity of their mirror mechanism to other's actions and the better their ability to identify the outcome to which those actions are directed will be" (Rizzolatti & Sinigaglia, 2016, p. 759).

The mirror mechanism is implicated in social cognition through perceiving and understanding facial expressions and emotions (Gallese, 2009a; Gazzola, Aziz-Zadeh, & Keysers, 2006). Again, this is a very important part of being musical as performing together involves understanding both the intentions of others' movements while performing, and understanding the conventions of jointly sharing musical intention (Overy & Molnar-Szakacs, 2009).

Mirror neurons perceive opportunities for tool use, and play a large part in language and communication development (Arbib, 2011, 2017; Corballis, 2010; Fadiga, Craighero, & Olivier, 2005; Garbarini & Adenzato, 2004; Iacoboni et al., 2005; Iriki, 2006; Kohler, Keysers, Umilta, Fogassi, & et al., 2002; Rizzolatti, 2005; Rizzolatti & Destro, 2007; Rizzolatti & Sinigaglia, 2016). Learning through imitation, use of tools, language and social cognition are all abilities that have allowed humans to evolve and survive (Arbib, 2005).

When teachers understand the mirror mechanism, their pedagogy can reflect use of imitation, tools, language and social cognition. For example, when learning about specific rhythm patterns, the teacher might model many ways of performing the pattern for students to copy. They might use speech patterns, body percussion, musical instruments, movement patterns, sing, notate/symbolise. Through this imitation process, the student not only perceives the concept (the rhythm pattern) but also actions it, developing skilful cognitive and behavioural capacities.

For teachers, understanding about how mirror neurons work has implications for understanding how students learn and what impact this has for pedagogy.

Peripersonal neurons

The significance of peripersonal neurons for music pedagogy is their role in social cognition in music and using tools and instruments. Social cognition in music involves understanding conventions of being together with others musically, so peripersonal neurons are important in musical joint activity such as in ensembles, choirs and any other musical activity where one person is in time, in music with others.

Using tools is implicated in the peripersonal system because these neurons are involved in managing the space around the body. When using musical instruments or managing the body in space, an individual needs to understand the instrument as if it is part of their own body so that the body will be safe, the tool will be safe and managed efficiently and not encroach on others. Instrumentalists who have an integrated perception of a musical instrument, feel like the instrument is part of their body. “Tools or instruments can be seen as body-extensions” (Leman, Lesaffre, Nijs, & Deweppe, 2010, p. 205).

Music pedagogy can develop the musical peripersonal system through providing many opportunities to practise managing self in musical activity with others, and with tools and musical instruments. Peripersonal neurons are crucial to our ability to manage and manipulate the space around our bodies - the peripersonal space. Peripersonal neurons are specialised, multisensory neurons that encode the space around our bodies and specific body parts (Makin, Holmes, & Zohary, 2007). This is an unconscious space and it affects how we interact with objects and people around us (Graziano & Campbell, 2018, p. 3). Michael Graziano (2018) describes these neurons as being "bubble-wrap neurons" that guide our movements in relation to objects and people (p. 8).

Peripersonal neurons and musical performance

Musical performance requires finely managed peripersonal systems. Cooperative behaviour required in ensemble activities, managing safe space between dancers and instrumentalists, and incorporating instruments into the body schema are all required for skilful and successful musical interactions.

Performing in an ensemble or choir or any musical group requires a sense of:

- The role of self with others
- What others are doing
- The intention of others' movements
- What information is communicated through the actions of self and others
- Community, jointness
- Synchronicity of purpose, performance, musicality
- Space between and with self and others

Performing with a musical instrument requires a sense of:

- The space of the instrument in relation to the body
- Incorporation of the instrument into the body
- The physical space around the body + instrument in relation to others
- The sonic space around the body + instrument in relation to others
- Posture, balance, energy, motion, touch

- The relationship between the body, instrument, notation
- The relationship between the body, instrument and conductor (if there is one)

Tools use incorporates both the peripersonal and mirror mechanisms

Using musical tools is an important aspect of being musical and important to include in music pedagogy. When students acquire skilled behaviour with musical tools, this assists them in musical thinking. They can reflect on how music works through using the tool and apply this thinking to solving musical problems. It is like the tool is in their heads. When imagining how to play a melody or when looking at notation, imagining what it sounds like, the instrument in their head would provide a mental model of how to play and what it would sound like. The peripersonal system provides students with mental skills for musical cognition.

The brain manages tools through the peripersonal system by considering them as extensions of the body (Iriki, 2006, p. 660). Just as there are places where the hand, finger lips and other body parts are represented in the brain, so there is for the tools that humans use. This cortical place develops over time in repeated experiences with the tool. As the body and the tool become more integrated, the movements become more refined and we are not consciously aware of every part of the motor act of managing the tool.

This information about the body and the tool is stored in the body schema. The body schema is an understanding of "posture, location and movement of the body in space, together with assessments of the anatomical and functional relationships of different body parts" (Iriki, 2006, p. 661). If, for example, a person was playing a large and extending musical instrument such as a trombone, the peripersonal system would focus attention to the space around the arms and hands holding the instrument, as well as the space to the end of the extended instrument, thus incorporating the instrument into the body schema. This assists in refining movements so that the tool is safely, efficiently and skilfully manipulated (Iriki, 2006).

In humans, the neural processes involved in tool use include the mirror neuron system and the peripersonal system. The mirror mechanism recognises that a tool will achieve a goal (function) and suit the physical structure of the user. Mirror neurons also have a role in understanding and imitating the actions for tool use when observing others using tools (Maravita & Iriki, 2004). The peripersonal system then incorporates the tool into the body schema.

Musical social cognition incorporates both the peripersonal and mirror mechanisms

Successful musical activity with others depends on highly developed understanding of peripersonal space. Music pedagogy that practises this would provide opportunities for students to sing and play together so that they could develop understanding of how to be in time and in tune with others, how to cooperate in behaviour and balance and complement musical behaviour between self and others.

The peripersonal and mirror mechanism together have key roles in social cognition and being musical together (Koelsch, 2013; Walton, Washburn, Richardson, & Chemero, 2018). Both systems are highly sensitive to face, arms and hands. The mirror mechanism is involved in empathy and in understanding facial expressions (Chemero, 2016; Gazzola et al., 2006). Observed facial expressions are mapped back onto the mirror mechanism of the observer. This creates a simulation effect, that engenders the emotions related to the expressions so that the observer can predict the meaning of expressions of others (Gallese & Sinigaglia, 2011). Gestures, actions and body postures accompanying facial expressions add further information. These all contribute to the ability to empathise and understand the intentions of others when being musical together.

Critical to being musical with others is learning to cooperate. If we perceive that the other who is performing with us understands and is "in tune", or attuned with us musically, it means that both people involved are monitoring the peripersonal space (Fink-Jensen, 2007; Masataka, 2010). Peripersonal neurons are multisensory and are very sensitive to tactile, visual and auditory stimuli that is perceived near the body (Teneggi, Canzoneri, di Pellegrino, & Serino, 2013). We unconsciously construct a margin of safety and, according to what is happening, that space can expand if threatened or contract if safe (Graziano & Cooke, 2006, p. 848). Peripersonal space is sensitive to the presence of others and also shaped by social interactions with others (Teneggi et al., 2013, p. 408).

Perceived actions and emotions that the mirror mechanism processes together with the peripersonal system monitoring space, impacts how skilfully and successfully humans can interact with others musically. Our sense of self, ability to use tools, sensitivity to cultural information and our social and emotional behaviour is shaped by these interactions (Patané, Farnè, & Frassinetti, 2017) and is critical to our skilful use of musical tools and musical interaction with others.

The role of the senses in developing music cognition

This section will discuss the role of the senses in developing cognition, and how this applies to music education. While music is strongly sensed through auditory and visual information, it is through active experiences in the world, between the body and tools with musical affordances, such as musical instruments, sounds, materials, and in social interactions, that deeper knowledge and understanding is generated. Active experiences involve the whole sensory system, beyond just auditory and visual information, and the other primary senses. It is only through personal, firsthand experiences that the internal senses are triggered. This system involves the haptic and proprioceptive senses, which provide us with what it "feels" like to play an instrument, sing a song, dance and play in ensemble, experiment with sound, understand and invent symbols and language for this perception, and synchronise all these with sound and other people. It is the full, integrated multisensory experience that engenders deep learning and the feeling of being musical.

Haptic and proprioceptive sensory systems

The haptic and proprioceptive sensory systems provide us with the deeper understanding of how experiences *feel* and can only be achieved in personal interactions between the body and the world. Music pedagogy that involves personal engagement with what it "feels" like to be musical, by interacting with a musical world, will benefit learners in developing deeply embodied, musical knowledge.

Most people can identify the primary senses of vision, taste, touch, smell and hearing, and these senses provide access to information that is external to the body from the world (Tuthill & Azim, 2018). However, because internal senses are not visible and are activated through the motor systems, the haptic and proprioceptive systems are not always understood.

The haptic sensory system is involved in touch and movement. Mechanoreceptors and thermoreceptors in the skin derive information about temperature, texture, slip, vibration and force (Johansson & Westling, 1984; Johnson, 2001). Mechanoreceptors in joints, muscles and tendons provide information about what movement and actions feel like to perform (Frisoli, Solazzi, Reiner, & Bergamasco, 2011). The haptic system allows perception of the properties of objects by how they feel (Thelen, 1995, p. 89).

Proprioception is the sensory system to do with body awareness (body parts), position of the body, motion, equilibrium, balance, and posture. Its most basic function is to stabilise and protect the body (Tuthill & Azim, 2018). This sense is largely unconscious, so if this sense is disrupted, we lose our sense of our body in the world (Bach-y-Rita & Kercel, 2003). Proprioceptive feedback to the motor system allows the generation of complex motor behaviours such as playing a musical instrument, and coordination of a number of complex behaviours simultaneously, such as playing an instrument, reading notation, following a conductor, playing in time with others and so on (Tuthill & Azim, 2018, p. 198).

Active exploration in the world through the senses reveals more information than passive reception of sensation. For example, seeing someone play an instrument provides some sensory knowledge, but actually holding and experimenting with the sound- making mechanics of an instrument can only be determined through the interaction of the body with the instrument (Glenberg, 2010). Equally, perceived weight of an object can be detected when it rests in the hand, but on lifting and manipulating the object, more enhanced information is gained about its weight (Lederman & Klatzky, 2009). When holding a musical instrument, there has to be a movement to make a sound, and in the developmental process of becoming skilful at playing an instrument, it takes many repetitions to develop motor patterns that achieve the required sound. These motor patterns develop in response to the sensory interactions between the perceived sound and the feel of how that sound was made. Skilled instrumental performance is a primary, haptic and proprioceptive process of acting on sensory information. Over time and through exploration, the learner synchronises the body with the repertoire and this occurs through multisensory integration, all the senses synchronising to develop an integrated perception. This process is dynamic and self-organising. Action through embodiment "provide[s] the means to explore the world" (Thelen, 1995, p. 89). Action shapes perception and is a form of perception.

It is a delight to watch such changes and development take place in the music classroom. Children are naturally attracted to musical instruments and as their attention is drawn by how their bodily movements change the sound, how interaction with the instrument comes more into their power, skilled, musical motor behaviour develops. This is a process whereby the primary, haptic and proprioceptive systems interact to develop deep knowledge structures about playing a musical instrument. "People perceive in order to move and move in order to perceive" (Thelen, 1995, p. 89). We often turn our head to "hear" sound better, move our hands to feel the texture of materials, or come close to a flower we want to smell. It is through our own action and movements through the world that the full sensory picture is revealed.

It has been traditional in music pedagogy to isolate sensory information. For example, quite often, much time is spent on practice in identifying musical symbols, such as a crotchet, without any association to the sound or what it feels like to play, listen to, or feel the length of space and sound of a crotchet. When the sound is not related to the symbol, the conceptual understanding is disconnected. The whole sensory system provides the best representation of the world when sensory information is combined to create a unified, perceptual object (Purves et al., 2013, p. 575).

Multisensory integration

Integrated, multisensory experiences engender deep learning through developing understanding of how parts work together in a unified whole. When we sing with others, keep the beat through moving, and play an instrument to accompany the song, this whole integrated sensory experience creates an understanding of how all the senses work together to create a meaningful, musical whole.

However, contrary to an integrated sensory model, popular unisensory educational theories, such as learning styles (visual, auditory, kinaesthetic), suggest that people have a preferred or dominant style for learning that relate to the senses, such as visual, auditory or kinaesthetic (VAK). With this approach, if students are assessed as having a particular learning style, such as a "visual learner", all their learning materials and activities are presented in that style. This actually prevents connections being made between different aspects of the whole experience, and reinforces a single mode of "sensing" the world, if that were possible. Even when information is presented in only one sense, if vision was prevented, such as being in a dark room, an individual automatically uses all their sensory apparatus to derive meaning from the experience.

In a research report commissioned to assess the validity of learning style theories, it was concluded that "the contrast between the enormous popularity of the learning-styles approach within education and the lack of credible evidence for its utility is… striking and disturbing" (Pashler, McDaniel, Rohrer, & Bjork, 2008, p. 117). By artificially isolating sensory information, authenticity of naturally coinciding sensory information is distorted, resulting in missing information, and therefore, disconnected knowledge structures. We naturally go about in the world, gathering information from whatever sense is available to best guide our attention and meaning-making in a multisensory environment. Our brains have evolved to learn and operate in a multisensory world, and memory benefits from the larger sets of encoded memories that are activated during multisensory events (Shams & Seitz, 2008). Many senses synchronising and encoding many aspects of an event result in more retrieval pathways for memory. "Learning mechanisms operate optimally under multisensory conditions" (Shams & Seitz, 2008, p. 415).

Multisensory integration is the combining of sensory information to provide a complete and coherent representation of the world (Dionne-Dostie et al., 2015, p. 32). This facilitates the linking of that information together into one perceptual object (Purves et al., 2013, p. 575). Being and behaving musically is a complex multisensory activity. It requires the ability to integrate multiple senses quickly to make sense of the musical event and perform. Multisensory integration in music benefits musical learning and performance (Fortuna, 2017; Zimmerman & Lahav, 2012).

The ability to process information about the world as an integrated and comprehensive representation depends on the integration of complex sensory stimuli. "Combining information from multiple senses creates robust percepts, speeds up responses, enhances learning, and improves detection, discrimination and recognition" (Chandrasekaran, 2017, p. 25). For teaching, this means that knowledge that is developed through multiple senses will enable learners to perceive the world knowledgeably and skilfully, quickly and efficiently. For example, when observing someone playing a musical instrument, the information is auditory and visual. When one plays the instrument oneself, the information is auditory, visual, haptic and proprioceptive, and all simultaneously processed. This produces richly integrated, multisensory structures in the brain (Pascual-Leone, 2003).

Integrating sensory information reduces errors in perception and increase the reliability of the combined information (Ernst & Bülthoff, 2004). For example, there is a piece of repertoire that has an instrument that, when only heard, is perceived to be a stringed instrument, as it sounds as if it is plucked. On seeing the instrument being played, people realise it is hit, not plucked, to produce the sound (the instrument is a thongaphone, which is made of tubes and hit on the open end with a "thong" or paddle). When more sensory information is perceived, such as seeing the instrument being played, ambiguity reduces and reliability increases (Ernst & Bülthoff, 2004, p. 162). Multisensory systems also provide independent predictions about perceived meaning and in a sort of cross-referential process, are able to reduce error of prediction and "noise" (noise is the continual background neural activity in the brain), and therefore improve precision (Hartmann, Lazar, Nessler, & Triesch, 2015). For example, when a stringed instrument is played and note is found, this requires a cross-reference between position of finger (visual, proprioceptive, haptic senses) coupled with matching the exact pitch required (auditory sense). Because the two sensory models can interact and adjust, and develop patterns of activity, there are more ways of creating precision and therefore reduce error and "noise".

When more sensory information is available, musical perception is increased. For example, when attending a live performance of music rather than just hearing a recording, not only is there auditory information, but also visual, and if we consider the mirror neuron system and its ability to map others' movements onto own motor memories, expressive elements of the performance would also be perceived. When viewing a performance, we hear what we see and see what we hear. In other words, when we see an instrumentalist playing, we hear them because their actions are mapping onto our mirror neuron systems and we recall the sound we expect to hear from viewing their movements

(Mathias, Palmer, Perrin, & Tillman, 2015; Overy & Molnar-Szakacs, 2009; Zimmerman & Lahav, 2012).

Sometimes more sensory information can confuse perception. Experiments by Behne & Wöllner (2011) looked at the impact on perception of performance of seeing musician's body movements. Video recordings of the same performance with different people "pretending" to play the repertoire resulted in viewers perceiving differences in the performance. The amount of movement for example, had an effect on perception (Behne & Wöllner, 2011). There were even more findings that suggested gender effects, as the male performances were perceived as more precise, and the female as more dramatic (Behne & Wöllner, 2011).

In music education, cognition that is generated through multiple senses into an integrated, multisensory representation, develops a complete, coherent and unified perceptual object (Hollich & Bahrick, 2008; O'Regan & Noe, 2001; Schoenfeld et al., 2003).

Perception

How we perceive music depends on all our past experiences. Music pedagogy engenders meaningful perception through multiple ways of embodying musical behaviour. Embodiment is the way the brain senses and understands the feeling of being musical.

Perception is the meaning we ascribe to sensory information from the world. It is not just accumulation of sensory information that develops this meaning. It is the interaction of the context, the action, people, tools, artefacts, and the body and its sensory machinery that develops meaning. With each new experience, our perception changes or shifts. "Every perceptual experience is… a work in progress (Noë, 2012, p. 4).

Perception is a result of sensorimotor action in the world. It is an active process. "Think of perception as a movement from here to there, from this place to that" (Noë, 2012, p. 5). In music, when we first experience the sound of a drum for example, it is in moving that we understand the effect of our bodily interaction with the drum to produce loud sounds, soft sounds, scratchy sounds, long and short sounds and rhythm patterns and so on. We also unconsciously accumulate haptic and proprioceptive information about holding, feeling and balancing the instrument with our body. When we later hear a drum, those accumulated memories engender deeper understanding about all those perceptual qualities of the drum, than if someone just showed us a picture and named the sound "a drum", or if we only heard it without all the other sensory information.

Music perception is based on intentional movement to interact with sound, so when music is heard, it induces a feeling of having produced the sound. Research in neuroscience on the mirror mechanism demonstrates that the same neural areas that are involved in performing an action are also involved when perceiving the same action, demonstrating the tight relationship between perceiving, acting and cognition (Gallese, 2009b; Gallese & Lakoff, 2005; Rizzolatti & Fabbri-Destro, 2010; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996).

Learning a musical instrument is a tightly integrated process between the body and the instrument, involving the body's sensory mechanisms guiding action. Repeated explorations develop associations between "performed actions and heard sounds, and internal models are developed as a result, capturing the relationship between actions and sound" (Maes, Leman, Palmer, Wanderley, et al., 2014, p. 4). These sensorimotor relationships change the function and structure of perceptual systems in the brain. Studies on passive listening to music show that trained musicians exhibit stronger auditory-motor couplings compared to non-musicians (Bangert et al., 2006; Haueisen & Knosche, 2001), due to their many experiences of coupling sensory and motor actions during training. Perception is an exploratory activity of the body and senses, combining sensations with motor actions, to develop cognition grounded in our own active construction of mind (Reybrouck, 2005).

We need to perceive the world in order to have an internal or abstract representation of it in the mind. Alva Noe beautifully described this as, "To perceive something, you must understand it, and to understand it you must, in a way, already know it, you must have already made its acquaintance" (Noë, 2012, p. 20). This resounds deeply when considering, for example, how musical genres are introduced to students. A popular approach to music education is to use repertoire that students are familiar with so that they will "like" it. We like what we perceive as familiar, but the role of a music educator is to open the ears of the learner by making "the acquaintance" of many different genres and sounds of music.

Music perception is shaped by our experiences of interacting with the world, an embodied process. Active experiences of pairing sound and action, such as singing a song and clapping to keep the beat, result in faster motor responses to sound (J. L. Chen, Penhune, & Zatorre, 2008; J. L. Chen et al., 2006; Lima, Krishnan, & Scott, 2016). This research supports the idea that action is induced through auditory information. Music is processed in motor parts of the brain and the brain is primed for perceiving music through action (Jensenius, Godøy, & Leman, 2010; Leman, Desmet, Styns, Van Noorden, & Moelants, 2009; Maes, Van Dyck, et al., 2014). Music pedagogy that reflects the sensorimotor, active grounding of music perception would include activities such as:

- dancing that expresses understanding of metre, structure, and other concepts;
- performing rhythm patterns in body percussion and on instruments to songs and instrumental repertoire;
- making actions to songs;
- exploring tone colours (sonic qualities) of sound-making devices;
- creating sound scores to poems and stories;
- performing rhythm patterns that will occur in music that will be presented at a later date;
- performing the same chord structures in many different pieces of repertoire;
- improvising movements in response to changes in tempi.

These and many other action-related experiences within the musical world exerts influence on how and what will be perceived in music. What we do, what we sense and how these interact in sensorimotor processes develops perception and cognition in music. Leman and Maes assert that “embodiment is a necessary concept for understanding music perception” (Leman & Maes, 2015, p. 242).

Sensorimotor integration

An embodied approach to music pedagogy would involve continual, dynamic opportunities for the development of skilled, sensorimotor integration. Sensorimotor integration is a process involving perception and action in the world. The most skilful people are those who have highly networked sensorimotor systems, developed through active engagement with the world. Expert musical performance is the result of many experiences and repetitions of musical engagement, resulting in highly networked sensorimotor systems. People may have highly networked sensorimotor systems across many areas of musical behaviour, or deeply in one area, such as instrumental playing or singing.

Playing a musical instrument is a sensorimotor skill that requires acquisition and memory of complex motor programs. The sensorimotor experiences during playing are haptic (touch), proprioceptive (body awareness, position, motion), visual (watching the body while playing), and auditory, which become more synchronised and more skilled with practice over time.

Held and Hein's research on sensorimotor integration demonstrated that a skilful knowledge of the world is developed through integrated, dynamic, sensorimotor interactions with the world (1963). Their ground-breaking experiments demonstrated that skilful navigation of the world requires self-produced action in order to integrate all the components involved in perceptually guided behaviour.

Skilled sensorimotor behaviour is a result of the "dynamic interplay of the brain and the body embedded within a rich context" (Spencer et al., 2006, p. 1532). These were the findings of Esther Thelen, who conducted intricate experiments on the development of cognition in babies. She described how babies gained control of their bodies and became "active participants in their own learning" (Spencer et al., 2006, p. 1522) through their dynamic explorations within their environments.

Musical, skilled, sensorimotor behaviour is a result of the self-organised, coupling of perceptions and actions to develop musical cognition (Chemin, Mouraux, & Nozaradan, 2014; Janata, Tomic, & Haberman, 2012). In learning to play a musical instrument for example, this is a goal-directed and intentional act to produce sound. In order to do this, the player needs to move in exploratory ways to discover what actions result in the desired sound. This involves auditory- motor couplings. After much exploration and repetition across many musical experiences, internal models are created that link performed actions with specific sounds. The relationship between action and sound becomes deeply integrated so that other components of musicality can be layered into performing the skill, such as expressive and dynamic qualities, and these can be flexibly accommodated into varying arrangements of motor performance.

Highly skilled interactions can be destabilised however, when transferred into entirely different motor plans. For example, in a workshop, a highly skilled cello player was confounded by trying to play a simple wind instrument, the recorder. The motor planning involved in relation to pitch is completely different between the two instruments, and she said that she was confused because she did not realise how deeply her sense of pitch and movement were related. To her as a cello player, pitch rising meant more fingers on the string. In the recorder, pitch rising, in the basic notes on the instrument, required less fingers. This example demonstrates that knowing about music did not mean she understood the skilled interaction between the body and this other instrument. Nothing replaces the personal interaction, over time, between the body and the instrument, with much repertoire and experiences, creating strong sensorimotor integration. "Musician's music-producing actions affect their perception of musical sounds" (Logan & Chaffin, 2020, p. 2) and demonstrates again how much musical perception is embodied.

Auditory-motor linkages are developed as a result of many experiences between the body and sound (Bangert & Altenmuller, 2003; Hyde et al., 2009; Maes, Leman, Palmer, & Wanderley, 2014). Learning in music that involves many experiences of interaction between the many ways of being musical, making of sound, and meaning-making through sound, develops strong sensorimotor networks in the brain. This occurs through action and embodiment. Being musical means we move, and the way we move shapes what we hear and how we perceive music (Phillips-Silver, 2009). Music education that emphasises embodied learning achieves strong, sensorimotor interactions.

Relationships between sensorimotor integration and multisensory and multimodal integration

Multisensory, sensorimotor and multimodal integration are intricately related systems and processes. Multisensory refers to an integrated model of sensory information. In music, the auditory and visual senses are tightly integrated, but also, the haptic and proprioceptive sensory systems unite to make a highly integrated sensory model. In playing a musical instrument for example, making a sound requires the proprioceptive understanding of which body parts integrate to manage the instrument, posture, balance between the body and instrument, as well as the haptic sense of weight, feel (tactile) of the materials of the instrument, and how the body "feels" when playing the instrument, the vibrations of sound that resonate through the body, and the difference between sounds in response to much energy (loud), or sounds in response to more managed, light energy (soft), and so on. Playing a musical instrument is a multisensory activity, and only personal engagement with the instrument results in the full sensory model. Multimodal, in this thesis, refers to the multiple "modes" of musical behaviour and delivery of information. For example, in transport, the different modes would be cars, trains, ships etc. In music, included in the different modes of musical behaviour are vocalising, moving /dancing, playing, improvising and composing, symbolising and notating, and using language to represent, express and discuss musical ideas. The affordances through which this behaviour emerges are songs, recordings, dances, types of movements, instrumental repertoire, body percussion, gesture, notation and musical terminology. Sensorimotor integration tightly combines sensory and motor processes with musical modes of experiences.

Multiple modes of musical behaviour will be discussed further in the next section on, **The body and musical embodiment**.

The brain, embodiment and music pedagogy

This section has sought to describe some of the behavioural and neural processes that are pertinent to musical cognition, so that understanding of how these support musical thinking can be embedded in music pedagogy. The functioning of the brain is complex, and neuroscience research shows that the brain integrates many areas, sensory, motor, and affective to develop memory. "Cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks" (Bressler & Menon, 2010, p. 277). At the cellular level, neurons are always on and ready to detect patterns and join networks of softly assembled neural structures that change in response to experience (Litwin-Kumar & Doiron, 2014; Markus & Pulvermuller, 2012; Quian Quiroga, 2016). These circuits become more refined and use less cognitive power through neural reuse, where circuits established for one purpose can efficiently be used in others, making richer connections (Anderson, 2010). Refined circuits become "hard" memories through neuroplasticity, and enriched environments engender strong neuroplastic change through social modulation and active, meaning-making in the world (Bengoetxea et al., 2012; Hohnen & Murphy, 2016). The peripersonal and mirror mechanisms are very important in music pedagogy, as these systems are at the core of learning through imitation, managing social cognition and musical tools, and musical communication. The peripheral senses plus haptic and proprioceptive senses combine information during experiences to develop complete and coherent representation of the world (Dionne-Dostie et al., 2015, p. 32) and they account for the feeling of being musical. Sensory and motor couplings are an "important part of musical meaning formation process"(Leman & Maes, 2015, p. 241). Finally, making musical memory is not passive and cannot be fully understood by observing or reading about music. Being musical is embodied, and it is "an engaging, multisensory, social activity" (Overy & Molnar-Szakacs, 2009, p. 489).

2.4 The body and musical embodiment

This section is about how embodiment is the act of learning through the body. In music, embodiment is multimodal. There are so many ways of being musical, and the more ways we are musical, the more each mode informs, reinforces and strengthens learning in another mode of musical behaviour. This section will discuss how tools with musical affordances make us more skilful and increase our capacities for being musical. We can also extend our thinking into using the tool to lighten the cognitive load. Why imagine making music when we can just use the tools and leave all the cognitive work to unfold in embodying the act of making music? This is what Rodney Brooks discovered as he and others were trying to make intelligent robots. They simply could not make robots that could work on every possibility of how the world presented itself. There were too many variations and combinations, so he and his team instead looked at the human sensorimotor system and worked from there. He said that "it is better to use the world as its own model" (Brooks, 1991, p. 140), because that is how the human brain manages the world. The human brain does not think it up first and work out how to act. Humans act in the world as it presents itself in real time.

Throughout this chapter, there has been continual reference to the interaction of the body and the brain in the world. The brain would have no perception of the world without the body, and without the world, the body would have nothing to sense. In addition, in the discussion of peripersonal neurons, a description of how tools are included into the body schema as if they are a body part, which makes things outside of the body become part of the brain. Through the mirror mechanism, other peoples' actions become our actions as neurons fire as if we were doing what they are doing, so now other people become part of our brains. The world becomes an extension of our bodies as we use it to make sound and the actions on the world become our cognition. In the description of embodied cognition, extending thinking into the world to lighten the cognitive load was discussed, so now the brain is in the world. It sounds confusing but explains how integrated we are in the world. It is beginning to feel like the world and the body is the brain, and if we think of it that way, it begins to tell a story to teachers and their pedagogy, the focus of this thesis. Whatever the body does in learning about music is the action of learning. We are embodying learning, and in this thesis, we are embodying musical learning.

A traditional view of music cognition focuses on training and rule-following for exact replicas of expert performance models. An embodied music pedagogy would focus more on the learner being actively immersed in a meaning-making musical setting, free to explore, create, play by ear, and improvise; in other words, actively and physically engaging in developing their own embodied, music cognition.

Embodying music – the body in action

In musical learning, "the body-in-action becomes the ultimate source for meaning ascription" (Schiavio & van der Schyff, 2018, p. 9). This bodily knowledge drives musical learning. Body / sound interaction is fundamental to music processing not only early in life, but throughout the lifespan. Every culture coordinates music with movement, through dance, playing instruments, telling stories and passing on histories, using gesture and making sounds (Bannan, 2014). The body influences how humans learn in music, how we perceive and how we describe music. We describe music through the metaphors of the world (Lakoff & Johnson, 1999); high pitch as "up" and low as "down", volume in terms of turning it up or down, meaning softer and louder, silence as space, length of sound as long and short, the way music is played as flowing or bumpy or heartfelt. These descriptions are greatly influenced by the body in the world.

Jessica Phillips-Silver and Laurel Trainor (2007) conducted research on the role of the body in shaping musical understanding. Their research showed that "the way adults moved their bodies to music influenced their auditory perception of rhythm" (p. 533). In other studies, the role of the body was studied in detecting differences between melodies. Results indicated that both non-musicians and musicians remembered the melody better when they played the melody themselves. This suggests that "active sensorimotor experience plays a key role in musical skill acquisition" (Schiavio & Timmers, 2014, p. 21).

For music teachers, this demonstrates that movement has a strong influence on how music is learned and perceived, and "the primacy of … sensorimotor exploration" (Schiavio & van der Schyff, 2018, p. 7). Active engagement with musical learning in these cases was not limited to the body and the brain. It was extended into the instrument to develop sense-making behaviour. Musical learners play an active role in their own learning to develop autopoiesis (Schiavio & van der Schyff, 2018), a self-organised system of knowing about music.

Multimodal – multiple modes of musical behaviour

In many music classrooms, music is performed predominantly in one or two modes of behaviour. This means that students are missing out on experiencing all the other ways of behaving musically. Not only are they missing out on other ways, but they are also missing out on important ways of cross-referencing understanding in one mode to inform another. For example, when one can sing a melody, this can help with working out how to play the melody on an instrument through matching singing pitch to the instrument pitch. Cross- referencing modes in such a way also means the student can develop their own musical thinking strategies to solve musical problems. The same idea in sensory perception applies to cross-modal perception in using modes of musical behaviour. "Cross-modal perception is a form of multi-modal perception that leverages the information obtained in one modality to facilitate the interpretation of another modality" (Martin-Martin & Brock, 2017, p. 1).

In line with an embodied understanding of music (Hayes, 2019), multimodal[10], in this thesis, defines the type or mode of musical behaviour. The modes are expressed through using tools with musical affordances. These modes of behaviour are action-based, such as singing, playing and so on.

So that teachers can identify musical modes of behaviour, *Table 2.1 Multimodal uses of tools with musical affordances*, outlines musical tools and the mode of behaviour that is afforded by the tool. For example, it could be said that when I am in "singing" mode, I could use songs to be musical, or when I am in composing mode, I could use instruments, songs and so on.

The tools have been categorised as physical, conceptual, cultural or social. This table was inspired by James Mooney's "Framework ad Affordances" model (Mooney, 2010, p. 144). The "physical" and "conceptual" "frameworks" in his model are what this thesis has nominated as musical tools. He also stated that his list of "frameworks" were "arbitrary examples of the frameworks (tools) of music-making" (Mooney, 2010, p. 142), i.e. not a complete list. In addition to Mooney's list of musical tools, this thesis has proposed Cultural and Social tools that afford musical behaviour.

The list below is not exhaustive and there is overlap between modes of musical behaviour and tools. For example, language can be a social

[10] Multimodal is not to be confused with musical modes in music that refer to a system of tones and semitones.

tool and symbols can be cultural. This table is a guide for what the modes of musical behaviour are, and the tools that afford opportunities for such behaviour. Improvising and composing can use any tool with musical affordances, which is why they are included with all the modes in italics, except for language.

When concepts and skills are practised across modes, multimodally, information in one modality reinforces understanding in another, and the memory and mental schema become multimodal.

Table 2.1

MULTIMODAL USES OF TOOLS WITH MUSICAL AFFORDANCES

Musical tools afford modes of behaviour e.g. instruments afford playing

MUSICAL TOOLS	**MODES OF BEHAVIOUR**
Physical tools	
Instruments	**Playing**, *improvising and composing*
Materials (textiles, objects, etc)	**moving, dancing, playing**, *improvising and composing*
Movement	**Expressing** musical ideas and concepts, *improvising and composing*
Gesture	**Conducting, directing, focusing attention to,** *improvising and composing*
Games	for **practising** musical concepts and skills, *improvising and composing*
Technology	**Notating**/symbolising, recording, *improvising and composing*
Conceptual Tools	
Song	**Singing**, vocalising, *improvising and composing*
Symbols	**notating**, moving, *improvising and composing*
Scores	**Singing, moving, dancing, playing, reading**, *improvising and composing*
Language	using t**erminology, description, labels, conveying information**
Solfa handsigns	**Singing, Expressing** musical ideas and concepts, **Moving**, *improvising and composing*
Sound recordings	**Listening (active),** singing, moving, dancing, playing, *improvising and composing*
Scales, forms (e.g. rondo, sonata, ostinato etc)	***Improvising and composing***, singing, moving, dancing, playing
Cultural Tools	
Ensemble / Choir	**Singing, moving, dancing, playing**, *improvising and composing*
Dances	**Moving, dancing**, *improvising and composing*
Events (ceremonies, celebrations etc)	**Singing, moving, dancing, playing**, *improvising and composing*
Social Tools	
Other people	**Extending thinking**, the interplay between individuals and groups

Tool use, affordances, extended mind

Strong music pedagogy includes the use of a wide variety of tools that afford musical behaviour. In music, tools such as musical instruments develop musical thinking and behaviour. Interacting and playing with these tools creates strong, neural sensorimotor pathways in technical skill development. The most compelling reason for using tools in music pedagogy is the development of capacity for musical thinking, learning and understanding. Through using musical instruments, cognition is extended into the instrument, and other tools, and activates the cognitive processes of analysing, interpreting, reasoning, remembering, using logic, improvising, composing, categorising, perceiving and so on. "A cognitive system is extended whenever it is in part constituted by things outside of the biological body" (Chemero, 2016, p. 5). Cognition occurs through the action of using a tool. Tools and tool use are a defining feature of the human mind because of the way tools make humans think. Tool use changes perception and behaviour (Anderson et al., 2012) and "play(s) an active role in driving various cognitive processes" (Krueger, 2014, p. 5).

Affordance theory

An affordance is an aspect of the environment that provides opportunities for actions that fit within our capabilities as a species (Chemero, 2003; Pezzulo, Barca, Bocconi, & Borghi, 2010; Pols, 2012; Zipoli Caiani, 2014). An affordance "is an object's potential to allow some sort of interaction with an organism" (Deak, 2014, p. 153). Individuals perceive action affordances in objects and cognition emerges from the "goal-oriented, situated, adaptive interactions [with these] in the environment" (Abrahamson & Sánchez-García, 2016, p. 210).

The idea of affordances arose out of the research on an ecological view of cognitive development by husband and wife, Eleanor and James

Gibson (E. Gibson, 2000; J. J. Gibson, 1977). An ecological view asserts that cognition arises out of action in the world, and this affects the way that we perceive the world (Chemero, 2003; Scarantino, 2003). Because of the sort of bodies we have, we perceive objects that we can use to perform an action to attain a goal (E. Gibson, 2000, p. 55). The object might be graspable, such as a handle, or pick-up-able, such as a box (and so on). Some affordances have multiple uses for us, for example, a chair can be used for sitting, standing on to reach something, or for musical people, to play as a musical sound source. Gibson's example was to describe affordances in terms of "noun-affords-verb" e.g. a cup affords drinking (J. J. Gibson, 1977). When an individual perceives the affordance of anything – the layout, objects, other people – they are perceiving the relation between some feature of the layout and its use or value to self (E. Gibson, 2000, p. 55).

Music classrooms, tools and affordances

When tools are available in the world of the musical classroom, students will actively explore their uses in musical tasks. Perception is shaped by active exploration of the environment (J. J. Gibson, 1986b). When an individual has a goal, they intentionally search for a tool to achieve this. Because humans perceive things in-the-moment as usable (time-pressured (Wilson, 2002) and embodied cognition), they are drawn to these objects and explore the possibilities for action. The tool also evokes actions in the user related to the affordances it offers. For example, the strings on a violin afford plucking to release their sonic attributes of pitch. In this way, there is a relation between the tool, the user and the action, and this becomes a system when they smoothly act together (Dotov et al., 2017).

When an expert musician plays his/her instrument, such as a violin, the instrument becomes part of their body, and there is little awareness of how to play or hold the instrument. The instrument becomes the object through which they experience the music. When a system comes together and it works so well as a system that there is little conscious awareness of all the action components, this is what the phenomenologist, Heidegger, would call "ready-to-hand", (Abrahamson & Sánchez-García, 2016; Chemero, 2013; Dotov et al., 2017). The tool becomes part of the user's body and they think more about the experience and goal than the tool.

Music Pedagogy and affordances

The importance of individuals playing real instruments in real music settings is so that the tool becomes part of their body schema, and hearing, thinking and cognising musically evokes all the embodied memories. The peripersonal, mirror and sensorimotor systems all contribute to the strength of these memories and enable deep musical cognition. Learning becomes attuned to "more and more subtle affordances…which guide exploration and constrain action" (Windsor & de Bézenac, 2012).

Embodiment gives meaning to all interactions with music, so that when the tool or experience is no longer present, the internal memory can provide meaning-making strategies from past experience to new musical experiences. Meaningfulness is a critical property of an affordance. When humans search for tools and what they afford the user, they are looking for meaningfulness. It is not perceiving anything in the world; it is looking for meaning. In using a tool, meaning unfolds in the processes of discovering the new possibilities offered (de Wit, de Vries, van der Kamp, & Withagen, 2017). Without real, embodied experiences, deeply embedded musical cognition does not occur.

Research on musical affordances and music pedagogy is relatively small, considering the importance of music-making through the tools of instruments, cultural artefacts such as choirs and ensembles, and the body itself, through singing and body percussion. There is even less information on direct application to music pedagogy. In recent years, use of technology has created more interest in how the affordances can support composition, notation, provision of tone colours and music recording and mixing.

A number of studies have outlined the benefits of teaching computer-assisted composition through the affordances offered in technology (J. C. W. Chen, 2012; Gall & Breeze, 2005; Kirkman, 2011) and more recently, Cheng and Leong (2017) advocated that pre-service music teachers should have training in how to enhance learning in music though ICT. Reese (2016) proposed many future directions yet practical applications did not reveal how the pedagogy could reflect this.

Mooney (2010) has discussed musical affordances and suggested that when students are aware of how the tool affects their music-making, they can make more informed decisions about what each tool offers. His "frameworks and affordances" approach, in *Multimodal* (p. 80), discussed how tools can benefit music making. "A framework is any entity, construct, system, or paradigm – conceptual or physical – that contributes in some way to the composition or performance of music" and "Frameworks have affordances" (Mooney, 2010, p. 144). Using his approach, students can make judgements about what particular musical affordances they are looking for, such as how to create a feeling of tension in a composition, using a particular scale to reflect genre, or a blend of pitches to create consonance or dissonance. Some frameworks are easy to extract an affordance from, and some require more skills. For example, in the case again of a violin, it is relatively easy to pluck a string to obtain a pitch; more difficult to manage the bow across the string to produce pure sound; even more difficult to play a Bach *Chaconne For Solo Violin*, but the same tool offers all these affordances to people of novice to expert experience on the violin. For an expert violinist, this tool would elicit many musical affordances. For a singer, the voice as a tool may offer more affordances for behaving musically.

Mooney's work suggests that many different frameworks provide students with the ability to choose those most suitable for achieving musical goals. It could then be assumed that pedagogy would include many experiences with many ways of being musical, though this is not specifically articulated in his study.

Windsor and Bézenac (2012) discuss the more subtle affordances of music, particularly the social and psychological perspectives. The movements and gestures of performers affects the perception of the music for the audience or listeners, and also "moves the emotions" (Livingstone & Thompson, 2009). They acknowledge the primary role of action in perception of affordances and what can be perceived in listeners. When listeners hear and/or see a musical performance, the neural structures involved in action perception, as if they were doing it, also fire in observing action (Kohler et al., 2002), so being an audience or listening to music elicits action responses in the listener. In this way, the performer is a musical affordance for the listener. The performer's movements and action, synchronised with the music, resound in the sensorimotor systems of the listener, even more so if the listener has greater personal experiences with the instrument or repertoire (D'Ausilio, Altenmüller, Olivetti Belardinelli, & Lotze, 2006; Harris & de Jong, 2014). While Windsor and Bézenac do not propose any suggestions about affordances for pedagogy, they do state that, "the most obvious thing that a musical situation might afford would be movement" (Windsor & de Bézenac, 2012, p. 112). Rich, real-world contexts offer affordances for perception and action couplings with people, things and events from which musical behaviour emerges.

A more recent study in Finland looked at the affordances offered by traditional instruments and tablet computers to school students, and the pedagogical implications of the findings. Working in small groups, primary-aged children were given a creative musical task to solve together, using either traditional instruments or tablet computers (Huovinen & Rautanen, 2019). The traditional instrument group engaged in much "multimodal negotiation" (p. 6), communicating and combining their ideas through gesture, musical sounds and talk. They rapidly, collaboratively solved problems and used facial, gestural and musical demonstrations which created a sense of flow to develop a final group composition. "The embodied playing gestures and visual distinctiveness of the traditional instruments afforded spontaneous peer affirmations, thus allowing the negotiations to quickly process to other new suggestions" (p. 7).

Students in the tablet groups progressed in a more isolated and individual exploration of the task. There was little musical negotiation and when there was, it was more in terms of a leader and turn-taking, rather than in interweaving ideas. Additionally, the tablet groups seemed less satisfied with the product of their creative works (Huovinen & Rautanen, 2019, p. 13).

From this study, the researchers offered a number of suggestions for pedagogy about the affordances offered by traditional and computer-based technologies. First, they suggested that teachers should ensure that they choose and scaffold the appropriate processes for the creative expressiveness when using digital technology. Using traditional instruments demonstrated that visual, verbal, gestural and action-based communication was more easily available, while digital tools relied on either device interaction or social interaction, but not both at the same time. Screen sharing could alleviate this, and the use of software that advances musical communication and collaborative creativity (Huovinen & Rautanen, 2019, p. 15).

The closest that any studies have come to offering pedagogical information about what musical affordances are and their use for musical learning comes from Menin and Schiavio (2012). They state that musical affordances are the properties of an intentional relationship between a musical object and a musical subject embedded in a musical context. This process is a perception-action process of meaning-making, involving exploration, intention and motivation to achieve goals. Cognition arises from embodied interactions with the musical affordances offered in these tools. New models of learning should address the provision of such tools (Menin & Schiavio, 2012, p. 211).

Extending musical thinking into the world

When a musical world is full of tools with musical affordances, other people, and guided, embodied action, thinking can be extended into interacting with these. If we try to imagine using these tools, it is a much harder cognitive task. It is much easier to think while using the tools and engaging with others in being musical.

Thinking in the real world is "time-pressured", as it emerges moment-to-moment. The importance of using tools is not just to be skilfully engaged in the world, but it is the way using tools makes humans think. "A cognitive system is extended whenever it is in part constituted by things outside of the biological body" (Chemero, 2016, p. 5). This means that together (coupled) with the external artefact, a music student is able to do more than if they were not coupled with the tool. They develop specific musical thinking skills that are enabled through acting with the tool.

Teachers assess evidence of musicality by what students do. Musical behaviour through performance is a strong indicator of musicality, though lack of skill impedes successful demonstration. For this reason, music teachers will search for tools that can elicit musical behaviour so that students can extend their thinking into using the tool, and can develop skilful, musical interaction. For example, being in a choir enables students to use their singing voice in joint action with others. They practise pitching the voice with others. They learn the social musical conventions of being in such an ensemble, such as keeping a communal beat, balancing one's voice and actions with the group, expressive qualities of a choral voice, developing a "oneness" with the group rather than an individuality and so on. Choir students learn about repertoire that suits the singing voice represented in that specific choir, the audience they will perform to, and the genres of choral music. These are but a few of the affordances offered by choir as a tool for being musical, and opportunities for extending thinking into these actions to become more skilfully musical. Without the choir, many of these actions and opportunities for being musical would not be available.

Objects used as extended tools serve a number of cognitive roles. The most obvious role is to serve as memory aids, such as notebooks (Clark, 2005), computers, mobile phones, and in the case of music, notation etc. Physical actions on external objects in these cases simplify mental actions (thinking) (Kirsh & Maglio, 1994) and a more efficient use of neural space (Clark, 2017; Hawkins & Ahmad, 2016) . However, it is in the intrinsic properties that an extended tool offers that holds much for music pedagogy. Musical instruments, for example, offer not only affordances for making sound, but in the action of using them, they are part of the cognitive task of problem-solving, reasoning and decision making. Especially for the novice learner, this is not available internally, in abstract thought, or without the tool. External tools enhance our sensory and thinking capacities and become active components in shaping our neural organisation (Bruner & Iriki, 2016, p. 99).

Extended mind is quite a contentious topic in cognitive science but makes sense for musical thinking and behaviour. For example, a tool with musical affordances for me is a guitar. It fits my bodily capacities and as I have used it many times, it has become part of my body schema. I don't think about the instrument when using it unless trying to change something about the way I interact with it, such as when I want to learn a new chord. When I hear music and think about the guitar, I know what chords to play. When I am creating a new composition, playing around with chords helps me use and develop new musical ideas. Therefore, I am extending my thinking into the tool, in ways that would not be available without using the tool. When I play the piano, I think differently about composition because my body acts differently with it. The piano is more visual and spatially available for exploration so I am likely to combine different musical ideas that I would not when using a guitar. The guitar and piano have different spatial arrangements which provide different affordances for composition and extending thinking into the world.

Extended mind hypothesis applied to music

Extended mind was first proposed by Clark and Chalmers in 1998 as "active externalism", where cognitive processes occur outside of the brain and are driven by activity of the body with structures in the environment (p. 7). There must be a causal, interactive relationship between the structure and the human agent. This relationship is seen as a cognitive system in itself, where if one of the components were removed, the system would be incomplete, and its success would be compromised.

Clark and Chalmers also discuss epistemic and pragmatic actions on structures. Pragmatic actions are simple actions needed to perform a task (Fjeld & Barendregt, 2009), such as highlighting information in a text so that you remember that this was important information. Epistemic actions uncover hidden information or help discover information that would be hard to compute in the head (Kirsh & Maglio, 1994). They are sometimes called the trial-and-error activity (Sharlin, Watson, Kitamura, Kishino, & Itoh, 2004) and are easier, faster and more reliable than computing in the head.

Identifying types of actions emphasises how cognition arises from these external manipulations. Exploratory activity, such as in epistemic action, requires more physical manipulation in the search for a solution. Physical manipulation results in not only learning opportunities but is often quicker than trying to imagine it.

Figure 2.2 - Extending thinking into objects (blocks)

An example of an activity inspired by the conceptual tools of extended cognition, in a music class, musical thinking was extended into actions on small wooden blocks (*Fig. 2.2*). The students in this class were undergraduate Teacher Education students with no formal expertise in music. The type of actions the students used on the blocks were both pragmatic and epistemic actions. The pragmatic actions were just using the blocks to denote and synchronise which beat was occurring in the music at that moment. However, it became more epistemic as the action revealed hidden information about accent and metre. The students were instructed to arrange the blocks on their hands to represent five-beat metre, each block representing a beat. While the repertoire was being played, they touched the block according to the specific beat (e.g. beat 1, 2, 3, 4 or 5). This could be described as a pragmatic action, as it was extending their thinking into the block to make their thinking visual and action-based. Students made comments such as, "I found it easier to keep time with the music because you had a visual there, but also, um, when we stopped and came back in, it was easy to come in on the five, and you had the block there and you could tap on five and that was like a preparation for one [beat]" (student 1, personal communication, 24 April, 2014). Another comment was that using the blocks made it easier to focus on hearing the beat, "like it was really relaxing doing it" to which another student said, "like rosaries [beads]" (student 2, personal communication, 24 April, 2014), and he made gestures as he said this of the way one feels the beads, relating the touch memory to the idea.

To deepen the cognitive experience, they were then instructed to just touch one block, any one of their choice, on a specific beat and note what they "felt". This was an action that would have been very difficult to perform "in the head" and was designed to focus the students' thinking more deeply into the finer aspects of metre. It was an epistemic action, designed to reveal hidden information. "It sounded really different" (student 3, personal communication, 24 April, 2014), and "I could hear the instruments, like, where they were coming in" (student 4, personal communication, 24 April, 2014). Accompanying these comments were facial expressions of wonder, surprise and happiness in response to discovering that these aspects were unexpectedly revealed through exploratory action.

Preceding this task were lots of energetic activities to do with learning about five-beat metre. Working with the blocks in the hand was much more intimate and closer, and the atmosphere in the classroom completely changed from lots of energy, noise and big movements, to quiet, fine movements and absorption in focussing on the blocks in the hand. A comment from a student on this point was, "This was so meditative" (student 5, personal communication, 24 April, 2014), and many others nodded in agreement.

This experience with the tool extended students' thinking into the world and changed their perception of the music, the way they were thinking about the music, and the concept of five-beat metre. The activity "prime[d] a particular way of thinking" (Wilson, 2010, p. 182) and allowed students to:

- couple their thinking with the tool;
- receive feedback from the tool;
- increase their sensitivity to the concept;
- make physical manipulations that increased their ability to think and discover new ideas

Using the blocks is an example of an epistemic action on an object that extended thinking into the world. It combined the object, the recorded music and the body to develop an integrated circuit "based on coordinated feedbacks and sensitive to reciprocal dynamics" (Bruner & Iriki, 2016, p. 99). Tools, material or abstract, have an important role to play in cognition and therefore play an important role in music education.

Internal and external action

Thinking arises out of using things in the world, and cognitive processes that drive this involve both internal and external action. This last point, about internal and external action, is where there is debate as to whether thinking is online (non-representational and in the world), off-line (abstract or representational thought) or both. Along with Chemero (2013), this thesis proposes both.

Chemero and Kaufer (2016) say that we do not need to rebuild a model of the world internally if we are already in it. “Thinking is something we do rather than something that happens to us” (Chemero, interviewed by Campbell, 2015). Sometimes we have representations[11], and sometimes we do not need to bring them to mind, such as when playing an instrument we already know how to play. We do not need to think about the complexity of playing it if we can just do it (Zhang, 1997, p. 181). When a musical instrument is available, it is easier to just play it than to imagine it, such as when working out how to play a piece.

The act of playing the piece of repertoire on the instrument provides an external representation. For example, the piano provides a very good visual presentation of the spatial arrangement of pitch. Perception of performing a piece is a visual, auditory, haptic and proprioceptive sensorimotor experience and as the piece unfolds, this gives information to the performer about what comes next. Most people who perform a piece from memory do not recall the full internal representation before performing it. Imagining before performing would be too great a cognitive load, and unnecessary. It is better to extend the thinking and recall into the body and the tool and let the memory unfold during the interaction. In this way, the experience is both internal and external, representational and non-representational.

Extended musical cognition involves interaction with objects and structures that are musical because of the way they are used and the environment. For example, a baton is just a pointy stick, however, when a conductor of an orchestra uses it, it becomes a tool with affordances for musical behaviour. A conductor extends his/her thinking into the baton and the ensemble, as his/her action in the world interacts with

[11] Representations: ongoing information processing in the brain (Strasser, 2012). Representations can be sensory or conceptual and involve the object or content, the user and the inner state or character of the memory (p. 2218)

others. Using a baton involves sensorimotor interactions between the sensory modalities of sight, sound, haptic and proprioceptive senses + actions for conducting and playing, all interacting in the individual and between all players. The conductor, the musicians, instruments, audience and repertoire all form a coupled, musical system that use each other to extend their thinking in an ongoing process (Schiavio & van der Schyff, 2018).

Attending a concert is another example of an extended cognitive experience. While viewing a performance, there is an added aspect to the experience of the music when the audience can see the conductor and players. The audience can extend part of the experience of understanding the music through watching the conductor's actions, interpreting these in relation to what is heard, watching the instrumentalists and how they interact with other players. These aspects become part of the cognitive system of the viewer through extending their thinking into viewing the performance. The environment plays an active role in shaping the mind (Clark & Chalmers, 1998, p. 7).

Summary Tools, Affordances, Extended Mind

Strong music pedagogy uses musical tools beyond just performance tools. Performance is important, but the greater gain is to develop the capacity to think musically. Using musical tools extends our abilities to be musical. In the act of using the tool, we feel the sound, the energy to play and the interaction between the body and the tool gives rise to understanding about how to make music work. When we are using tools, we can extend our thinking into using the tool. This lightens the cognitive load and allows focus on developing mental tools to solve musical problems and meeting musical demands. The peripersonal and mirror mechanisms have a role to play in embodying tools and perceiving their musical affordances, as well as giving rise to using tools with others.

Joint action and joint attention

In the music classroom, pedagogy that develops joint action has many opportunities for performing, collaborating and solving problems together. These opportunities develop important musical skills for understanding how to perform in ensembles with others, understanding about self and others in musical activity, and musical social skills.

Joint action is fundamental to successful musical performance and interaction with others. Joint action is the coordination of cognition and behaviour between two or more individuals (Keller, Novembre, & Hove, 2014, p. 1). Coordinating one’s behaviour with others allows humans to develop the social skills for successful communication and interaction (Nalepka, Kallen, Chemero, Saltzman, & Richardson, 2017). Humans favour cooperation over competition, as competition undermines joint action, when the objective is to perform a task together (Suchak et al., 2016, p. 10215). In choirs and other musical ensembles, what makes it cohesive and successful is joint action, the cooperative behaviour that makes the group feel, and perform, as one. Even when there are soloists or primary performers with a background ensemble, there is still a cooperative behaviour to enable the group to perform cohesively together.

Social interaction involves joint action and can be seen in the alignment of facial expressions, postural attitudes and language use, which are often unconscious and not pre-planned. Coordination of social behaviour, rapport, trust and other prosocial behaviour are enabled through joint action, and when others perceive joint action, there is the impression of unity and shared goals (Michael, Sebanz, & Knoblich, 2016). Music making has a special way of seemingly effortlessly and simultaneously engaging groups of people in this way through musical joint action (Koelsch, 2013). Musical joint action promotes “synchronous arousal, action synchrony and imitative behaviours … which facilitates social bonding" (Trehub, Becker, & Morley, 2015, p. 1).

Some joint actions are unconscious, pre-planned and rehearsed, such as those involved in playing in music ensembles and dance performances. Instrumentalists and vocalists coordinate and synchronise their actions to create a coherent and unified sound. Orchestral musicians coordinate and synchronise their actions with the conductor, and dancers coordinate and synchronise their actions with each other and the music (Keller et al., 2014). Joint action involves a heightened awareness of others. Joint actions that are precise, flexible and coordinated between individuals involve an understanding of goals of actions, accommodations to the situation, mutual motor capabilities, and enacted over time (Keller et al., 2014). Rhythmic joint activity occurs when these factors synchronise accurately, such as in musical ensembles, where each individual may have complementary parts that fit together to perform as one, tightly coupled in their unity of musical understanding.

Attunement and joint action

In the teaching-learning process, attunement emerges in opportunities for joint activity where sense-making unfolds between and among students. Those who are most attuned to each other are those who commit to engagement with trust and a responsibility to the others, and the outcome. Collaborative tasks, ensemble playing and singing in choirs are examples of where attunement can take place to achieve successful joint action.

Attunement is an aspect of joint action. It occurs as groups collectively become sympathetic and empathetic to each other's actions and intentions. When groups are described as attuned, they noticeably perform with an acute awareness of each other. They coordinate perspectives through "togethering… the committed engagement in joint activity with a common ideal" (Radford & Roth, 2011, p. 242).

Joint action is an aspect of social cognition and can happen at many levels, such as bodily movement, posture, physiologically (heart rate and breathing patterns). It can occur spontaneously, even when the intention is not to coordinate behaviour (Di Paolo & De Jaegher, 2012).

Types of musical joint action

There can be two types of coordination of movements, or joint action, amongst musical groups; **spontaneous** and **intentional** (Palmer & Zamm, 2017).

Spontaneous joint action occurs when a group maintains a common beat (keeps in time), matches expressive style, breaks out into song at a football match and so on. **Intentional joint action** is goal-directed, such as when a conductor leads an ensemble. The conductor facilitates joint action between conductor and musicians, whereas, without a conductor, joint action occurs *between* musicians (spontaneous). When there is a soloist, accompanists synchronise and coordinate with the soloist (Palmer & Zamm, 2017).

Both Intentional and spontaneous joint action can occur in contexts such as in improvisation in Jazz, where there might be a "Question and Answer" style of interaction. The Question and Answer In these interactions is intentional, and there is a musical, social understanding of turn-taking. There is also a spontaneous joint action in matching responses to each other in pitch, rhythm patterns, tonality, tempo, structure and so on. In this way, the flow of music would sound unified and as if it belonged together. To achieve this, musicians need strong sensorimotor integration to manage motor and sensory information both synchronously, and in the creation of a responding behaviour. This is a complex, skilled interaction, based upon each participant having deeply connected knowledge structures, developed and refined over time.

Joint action has an effect on how people perceive social interactions and this behaviour can strengthen feelings of social affiliation and group cohesion (Pacherie, 2014, p. 30). Collective joint action in musical ensembles, dance and in team sports are examples of how humans are able to coordinate their behaviours to achieve a common goal (Moreau, Galvan, Nazir, & Paulignan, 2016). Sometimes, the goal of joint action is to pursue joint goals, such as when soldiers march together, it might assist them in protecting each other in working together. Performing ritualistic dances might induce a tribal, belonging sense so that hunting, for example, might be able to be achieved more successfully (Valdesolo, Ouyang, & DeSteno, 2010).

When people engage in cooperative tasks, to attain joint action, they unconsciously mimic each other's movements and gestures and synchronise actions (Sebanz, Bekkering, & Knoblich, 2006, p. 73). This creates a feeling of affiliation, fosters rapport and facilitates the smooth execution of the task (Valdesolo et al., 2010).

Managing cooperative tasks, such as playing a duet together, requires not only an assessment of what one's body can do, but also an assessment of what others' bodies can do, especially in relation to the instrument and the repertoire. For example, when playing together, each will assess the capabilities of the other and manage the task accordingly, keeping in time together, matching expressions and dynamics, and complementing each other's performance. "This suggests that the way members of a group perceive the environment might be a function of the resources and action capabilities that are inherent to the group" (Sebanz et al., 2006, p. 73).

A crucial mechanism enabling joint action is the mirror mechanism (see p. 40) which enables understanding of others' actions (Arbib, 2008; di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Iacoboni et al., 2005; Rizzolatti, 2005). Neural processes of one brain couple with neural processes of others' brains. This is called brain-to-brain coupling and occurs via actions and artefacts in the environment. This coupling develops complex, multi-faceted cognition that would not be possible in isolation (Hasson, Ghazanfar, Galantucci, Garrod, & Keysers, 2012, p. 1).

Joint attention

Joint action requires understanding of what each other are *attending to*. Attention to an object or event provides important contextual cues as to the intention of movements and behaviours. Directed attention provides a "perceptual common ground" for joint action (Sebanz et al., 2006, p. 70), coupling two or more minds to a unified goal. Joint attention can be initiated in a number of ways, such as gaze (intentional directing of gaze), gesture (pointing), posture (leaning, inviting, sense of shared space) or through physical interaction during a task, such as balancing while both holding heavy object.

When performing musically together in groups, attention is conveyed through these aspects of gaze, gesture, posture and additionally, quite subtly, through breath. An expert ensemble performs as one. They start with a breath, phrase jointly with breath, lean and change posture according to expressions, move to emphasise pitch and show deference to a solo, all non-verbally, through movement of the body.

Joint attention begins early in human life. By about 6 months of age, babies show joint attention toward the food that carers are eating and will start to match movements as if they are eating. A little older and babies will start to interact in building a tower or playing turn-taking games such as peekaboo. Babies also understand the give-and-take of conversation conventions from an early age, and similarly, the give-and-take of musical conversation in song (Phillips-Silver, 2009).

Individuals in a joint event must have motor control of their own movements so that they can synchronously manage their movements with others. These movement patterns are mapped in their own motor systems, so that observation of others' movements fire predictions of the outcomes and intentions behind their movements (Pacherie, 2014). "Resonance" between own and others' actions is higher when there is a high level of expertise in performing the observed actions (Bläsing et al., 2012; Calvo-Merino, Glaser, Gre` zes, Passingham, & Haggard, 2005). A low level of expertise and understanding of actions, or even lack of shared perceptual space, degrades joint action and reduces the ability to predict the intention or goal of an action (Vesper et al., 2017). This might occur when vision or auditory information is obstructed, such as when there is not a clear line of vision with others, or sounds are muffled and unclear.

Obhi and Hall (Obhi & Hall, 2011) suggest that when people are acting cooperatively together in joint action, finely coordinating their movements and actions to achieve a common goal, they become entwined in the each other's internal sensorimotor map. Their combined actions create a perception action loop that binds them (Tanaka, 2015). Integrating self and others allows not only prediction of the others' action, but also complementary and appropriate response.

Joint attention and attention in music pedagogy

As joint action is integral in musical behaviour and performance, opportunities for development of this skill involve musical communication non-verbally in ensembles, moving together in dance, Question and

Answer play and improvisation with others and other collaborative activities. To do this requires motor control, perception and sensorimotor integration. Coordinating the sound and actions between performers is facilitated through understanding musical social interaction and communication. This requires interpretation of intention of movement and involves multisensory and cross-sensory perceptions.

Peripersonal and mirror mechanisms in musical joint action

Mirror neurons and Peripersonal neurons are implicated in tool use, affordances, extended mind, language and joint action/attention. Mirror neurons are neurons that fire both when an action is perceived and performed. In other words, when we see someone else perform an action, we understand the intention of their movement through a mapping back to our own experience of performing the movement. The perceiver's mirror neurons in the motor cortex would fire as if they were performing the action, and hence, intention understanding would occur (Rizzolatti et al., 1996; Sinigaglia, 2013). Peripersonal neurons monitor the space around our bodies. They allow us to manage tools and social cognition.

Both of these types of neurons have particular significance for music education. Mirror neurons allow understanding of others' actions, which is important for performing in musical ensembles, following the gestures of a conductor, moving together in time with others in joint action, and interpreting musical behaviour. Since music is the language of sound, much knowledge is acquired through perception of others' movements to make sound, so understanding musical intention is important in musical learning. Peripersonal neurons are involved when using musical instruments and performing with others. Being musical involves moving through space, such as when performing in ensembles, movement sequences that represent musical understanding, or using gesture, such as in conducting and tonic solfa gestures. All these activities require a sense of the space around self, the space around self and tool, and how to negotiate the space between self and others, the musical peripersonal space. Peripersonal neurons also work in tandem with mirror neurons. Tools are perceived by the mirror mechanism but managed by the peripersonal system. Facial expressions and bodily actions are interpreted by the mirror mechanism but again, managed by the peripersonal system. Being able to perform musically with instruments, ensembles, to an audience or just in the classroom requires the action of these systems.

Embodying music through gesture and movement

Gesture

"Gestures and action-perception couplings are now acknowledged to be an important part of the musical meaning formation process" (Leman & Maes, 2015, p. 241). Gestures by the music teacher can bring attention to important aspects of musical learning and gestures by students can indicate to the teacher what they have embodied in their musical learning. Gestures also offer a non-verbal musical and pedagogical tool that does not interrupt the sound space in a music lesson. Instead of using language and explicit instruction, gestures can communicate in deeply meaningful and musical ways, and "contribute to the generation of new meaning in teaching and learning processes" (Simones, 2019, p. 141)

Gestures are movements that are involved in making meaning. People use gesture when they talk. Gestures are movements mainly with the hands and can accompany speech. Gesture can be used instead of talking and can even change and influence others' thoughts; for example, if using a defensive gesture while describing something, the message will be received with wariness. If an inclusive gesture was used, the message would be more likely to be received as positive. Gesture emphasises and enhances meaning and grounds understanding in action (Beilock & Goldin-Meadow, 2010).

Types of gesture

Different types of gesture can have different strengths and meaning for music teachers. There are generally considered to be three types of gesture; deictic, conventional and representational. Deictic gesture, such as pointing and gaze, draws attention to objects (Reybrouck, 2013). This is important in dance as it conveys direction or body part or "where" in space. Conventional gestures use standardised forms to convey cultural meaning, such as nodding the head for "yes" in some but not all cultures. Representational gesture captures aspects of an action; iconically (demonstrating how to play drum) or metaphorically (moving hands down as if to lower volume) (Cartmill et al., 2012, p. 131), and spatially (capturing aspects of relative space to indicate amount of volume).

Gesture and learning

Gesture in the music class by students and the teacher can indicate what words cannot capture. Music is conveyed through sound, and gesture can sometimes represent more than words, or enhance the meaning of words when language is used to discuss musical ideas.

When children use gesture in learning, it helps construct knowledge, explain ideas they might not yet have language for, and indicate conceptual change (Kirk & Lewis, 2016). Susan Goldin-Meadow has written extensively on the effect of gesture on thinking, what gesture represents and how it can create abstract thought. Her research has shown that across domains and age groups, learning with language accompanied by gesture is better than without gesture (Alibali & Nathan, 2012; Congdon et al., 2017; Goldin-Meadow, 2015). Gesturing during problem solving helps generate ideas and focus on salient features of the task (Beilock & Goldin-Meadow, 2010). Of great importance when thinking about teaching, Goldin-Meadow proposes that “gesture and speech form an integrated and … synergistic system in which effort expended in one modality can lighten the load on the system as a whole” through shifting the cognitive load from verbal processing to motor processing (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001, p. 521).

Gesture is thought to be powerful in learning because the action embodies meaning (Anderson, 2003; Glenberg, Witt, & Metcalfe, 2013; Niedenthal, 2007). The meaning is mapped onto motor systems through the gesture and this facilitates a link to the words (Glenberg, Goldberg, & Zhu, 2011). When used concurrently with speech, the message is more powerful as there are two ways of conveying the information, and retention and insight improves (Congdon et al., 2017).

When a teacher uses gesture to represent knowledge and ideas, this helps the learner recall, understand and map onto their own systems. When learning about heaviness of sound in music, gestures and movements that relate to heaviness help to embody the meaning, more than words alone would do. Movements related to learning, or when learning, reflect processes of the mind, and also exert influence over learning. Gestures can help the learner both expressing their knowledge, and also perceiving and recalling knowledge.

When learning language, children display language learning skills through gesture earlier than they can actually use language, and using gesture early, predicts later larger spoken vocabulary (Rowe, Özçalışkan, & Goldin-Meadow, 2008). It is thought that gestures such as pointing and following gaze facilitates attention to objects and the related spoken language. This is achieved through joint attention, the ability to coordinate one's attention with others. In a Hebbian process, meaning is grounded in the perceptions and actions in the event in relation to the object, and is stored in multimodal brain connections (Tomasello, Garagnani, Wennekers, & Pulvermüller, 2017).

Gesture in the music classroom

Music teachers can use gesture instead of language to convey both musical and non-musical information. Gesture to convey musical meaning would be related to enhancing or demonstrating musical action. Non-musical gestures convey information such as guided attention (pointing for direction, rising hands to indicate to stand) or feedback (nodding or shaking head). At times, gesture can be more useful than language to use in the music classroom as gestures communicate, at times, at a more basic level than words (King, Gritten, & Welch, 2011, p. 4). As language is sound, it can interfere with the "sound space" that may be created in the music classroom. Additionally, the cognition that is developed in music classroom should be primarily developed in musical ways, so use of language should be carefully selected. Words that engender musical thinking, such as "step", "clap", and "move", and specific musical terminology and words associated with activities practising musical ideas, such as "tempo", "accent", and "beat", would connect well to what is happening musically in the lesson. Gesture conveys much information that could replace erroneous words, not interfere with the sound space and keep musical cognition at the foreground of learning.

Gesture in music can be physical and auditory (M. R. Thompson & Mendoza, 2014). Physical gestures can be those associated with musical performance, by the performer when playing, the conductor when leading an ensemble, the teacher or listener. The movements of the performer are those associated with playing the instrument and expressing the musical qualities. These include the body as a whole, separate body parts, facial expressions, breath, and gaze. Conductors' gestures convey conceptual aspects of the music, such as metre, dynamics and expression, and contain conventional features that are readily recognised. Performers' and conductors' gestures create an audio-visual perception of the music, mapped onto the actions of performance; a sensorimotor representation. This resounds in the mind of the listener, whose gestures, such as swaying, are the perceived resonance of their own sensorimotor system, mirroring the performance.

Auditory gestures are those motor resonances that come to mind when hearing sound and music. These gestures are related to past experiences of making sounds and music. The auditory-motor memory of the sound is mapped onto sensorimotor systems through mirror neurons, so that when the sound is heard, the system fires (Kohler et al., 2002). When music is heard, the system associated with that experience fires according to its own past experience of the sound and identifies what it perceives. This action of the mirror mechanism accounts for knowing what instruments are playing, identifying a song and so on. However, sometimes the mirror neuron system can be tricked, such as when a sound is categorised incorrectly as being played by a certain instrument. An example of an instrument whose sound is often mistakenly identified is the thongophone, an instrument made of varying lengths of tube and percussively hit over one end of each tube to make a sound. This instrument is often mistaken for a stringed instrument, as it sounds like a plucked string. However, when performance on the instrument is seen as well as heard, the sensorimotor mapping differentiates to note the differences between the type of sound made on a stringed instrument and the thongophone.

The gestures that a music teacher uses can be dietic, conventional or representational. Dietic gesture draws attention to objects or specific aspects of the world. A music teacher might use this type of gesture to indicate which hand starts an action or plays a note, or the direction to move in. Conventional gestures are not specifically musical, though the musical conventional gestures would include solfa gestures, hand signs that indicate relative place, highness and lowness of pitch (Wakefield & James, 2011).

Musical representational gestures support conceptual understanding. For example, when a teacher is bringing a melody in recorded repertoire to the attention of students, the teacher may make an arching arm movement to represent the melodic contour. Synchronised with the melody as it sounds in the recording would couple the understanding with the action and musical meaning. “Musical gesture…reflects a conceptual mapping in which knowledge in one domain of experience (namely, *physical gestures*) is used to structure another domain of experience (*sequences of musical materials*) with the goal of organising our understanding of the second domain” (Zbikowski, 2016, p. 84). Musical gesture is dynamic and creates a picture of the sound moving through time, which is not conveyed through language.

Movement embodies and shapes the musical mind

When music teachers conceive of the body as the mind, the body as the active cognisor, the moving maker-of-mind, they plan for the body to learn, knowing that the mind is learning through the moving body. Embodiment means putting the learning into the body. “Knowing is inseparable from action: knowing is doing, and always bears the body’s imprint” (Bowman, 2004, p. 25). “Movements are at the centre of mental activity” (De Jaegher & Di Paolo, 2007, p. 489). We make, know, feel and understand music by embodying it.

When students move, teachers can observe their musical understanding. Embodiment in musical learning “provides a means of developing skills, competencies and understanding necessary to work in the expressional mode of musical knowing" (Juntunen & Hyvönen, 2004, p. 200). Bodily movements can be a physical metaphor for what is happening in the music that words cannot express, but once expressed through the body, can be seen or heard, made physical, and then words can begin to become a conscious description of sound. Body movement is an external representation of how the mind conceives of its musicality (Maes, Leman, Palmer, & Wanderley, 2014) and is a window into the mind of others.

Working in classrooms, teachers can take advantage of how musical knowledge is actively constructed jointly. Musical meaning can be generated together or transformed in evolution between self and others. The action in joint activity can be intentional and expressive, synchronised or adjusted in response to each other, "and is deeply affected by the coordination of movements in interaction" (De Jaegher & Di Paolo, 2007, p. 497)

Movement makes sense of sound

Music pedagogy can design activities that guide action to solve problems, make sense of sound, and respond to changing elements in music. Sense-making actions reveal hidden information into how music works and it is in the exploration of the body that these are revealed. Sometimes, it is not until we move to music that we consciously notice what music evokes in us. "Body movements can help selectively direct attention to certain cues, and accordingly to impose a certain structure onto the music" (Maes, Leman, Palmer, & Wanderley, 2014, p. 7). This bodily cuing can then direct listening to musical elements and refine and shape our understanding of music.

In movement and exploratory activity, learning is distributed throughout the body in the world, with others, and creates "mind in the body" (Bowman, 2004, p. 11). When we contemplate and reflect on experiences, the body is in the mind. Dewey discussed that one of the greatest flaws in education was in conceiving in any way that mind and body were different. He saw them as an integral whole (Dewey, 1916).

Movement changes music perception

Music pedagogy that engages the student in movement experiences develops and enhances auditory perception and refines the acquisition of music cognition. Movement becomes integrated with auditory perception and these two sensory modes give meaning to each other. We hear what the body feels (Phillips-Silver & Trainor, 2007, p. 544) and what the body feels, guides our attention.

How we move influences what we hear, and critical to this is the movement of one's own body, not just observing others. In experiments by Phillips-Silver and Trainor, babies responded more to music that they had moved to, than music they had not moved to. In addition, when babies had watched adults move to two versions of music, but did not move themselves, they showed no preference (Phillips-Silver & Trainor, 2005, 2007). The critical factor that drove a response was self-directed movement. Sensing the music and moving in response engaged sensorimotor processes that developed musical cognition. This research demonstrates that movement plays a strong role in music perception. This is in line with neuroscience research that demonstrates that self-produced movement in sensorimotor experiences changes the structure of the brain. Passive movement or just observation does not produce the same changes in the brain (Held & Hein, 1963).

Movement in one mode prepares the body for another mode

In the discussion on multimodal ways of behaving musically, it was stated that information in one mode facilitated understanding in another mode (Martin-Martin & Brock, 2017). Music pedagogy can reflect this through preparing the playing body through the moving and singing body. For example, when learning to play a melody on an instrument, the action sequence can be prepared through moving in space while singing the melody. This couples the playing action with the sound. The body also gains a feeling for pitch production through the effort of producing melody in the voice. The effort and shape of movements provide a feeling of the energy in production and shape of the body while being musical (Laban, 1947). The body enhances hearing through movement memories, so that when music is heard, it is like the memory is in the muscle (Bowman, 2004, p. 19; Sedlmeier & Weigelt, 2011).

Making actions of the body shape understanding

Music pedagogy immerses students in music making, and it is these experiences that give the fullest and deepest understanding about how music works. A world that is created in the classroom that immerses the student in the fullest possible context of musical understanding, with cultural artefacts and knowledge built into the experiences, provides enriched environments.

Sometimes, not all the experiences seem like musical experiences, but in the contextual whole, they build a deeper musical cognition. The emphasis is on making, because making reveals all the hidden steps of learning. In making, it is essential to touch materials, make judgements, react to changes and think about how parts come together (El-Zanfaly, 2015). In research on "making", reacting to surprises is emphasised as part of the process of improvisation. Reacting to surprises as they emerge gives rise to new understandings (El-Zanfaly, 2015). And finally, deeply embodied knowledge comes about through the interaction of active making, with materials and tools, in context.

When Henry John Drewal was involved in apprenticeships in art and mask making in Nigeria in the 1960s and 70s, he began to understand that it was his active, bodily immersion in the making of the art works as much as the modelling and words of the teachers and artists that enabled him to learn deeply about the culture.

> The senses are crucial to the understandings of the arts…my own bodily multisensorial experience was crucial to a more profound understanding (*oye*) of Yoruba art and the culture and history that shape it. This process of watching, listening, carving, making mistakes, being corrected by example, and trying again was a transformative sensorial experience for me. Slowly my body learned to carve as my adze strokes became more precise and effective and the image in my mind took shape through the actions of my body.
>
> (Drewal, 2016, p. 325)

He emphasised that it was the complete, active, immersive experience by his body, in the place, surrounded by the culture of these people that changed and shaped his thinking and understanding about these arts.

Musical learning comes from direct engagement in body and mind with the world. Musical learning is embodied, embedded in rich environments, extended through tools and engagements with others, and enacted through bodily experience.

2.5 Summary and conclusions

The impact on music pedagogy of embodied cognition underpinned by neuroscience.

This review of literature outlined why embodied cognition is a suitable framework for musical learning. Embodied cognition asserts that cognition arises from interactions between the brain, the body and the world. The world, created by the teacher in the classroom, consists of the teacher, tools, objects and materials, other people, and the physical space. Neuroscience that underpins actions by the body in the world described in the complexity of brain processing, order and efficiency is created through neural reuse, and neuroplasticity ensures that the networks and neural pathways become hard memories. Enriched environments provide a description of how behaviour and neuroscience together describe how strong learning can take place using specific principles.

In music learning, peripersonal and mirror neurons are particularly pertinent. These systems are implicated in tool use, learning, socialising, understanding processes and procedures and communication. Integrated with the peripersonal and mirror mechanisms are sensory and motor systems that develop action maps and memory.

In looking at the role of the body in musical learning, the modes of musical behaviour are identified and matched to tools with musical affordances. Thinking is extended into using these tools to lighten the cognitive load and enable deeper musical thinking. Acting together with others helps to deepen music cognition and builds essential skills in musical performance. Finally, the role of movement and gesture describes how musical perception is shaped by embodiment, and the wider, richer musical context contributes to a deep understanding of making music.

Embodied cognition provides a strong framework for music cognition and learning, and neuroscience informs music pedagogy. Research by Luc Nijs and Melissa Bremmer (Hermans & Bremmer, 2015; Nijs & Bremmer, 2019) has begun to describe what embodiment and neuroscience look like in practice, and Andrea Schiavio (Matyja & Schiavio, 2013; Menin & Schiavio, 2012; Ryan & Schiavio, 2019; Schiavio et al., 2018; Schiavio & De Jaegher, 2017; Schiavio & Høffding, 2015; Schiavio & Timmers, 2014; Schiavio & van der Schyff, 2018) and Dylan van der Schyff (van der Schyff, 2017; van der Schyff et al., 2016; van der Schyff, Schiavio, Walton, Velardo, & Chemero, 2018) also point their research to learning and elucidating the aspects of pedagogy. The work of these researchers has all contributed greatly to the wider understanding of music pedagogy.

This thesis seeks to provide clarity about music pedagogical practice, and the central question of:

How do music teachers embed embodiment, informed by neuroscience, in their music pedagogy?

In Chapter 3, the methodological processes and practices applied to this thesis are detailed.

Chapter 3 – Methodology

The purpose of this thesis was to identify and describe how music teachers embedded principles of embodied cognition and neuroscience in their music pedagogy. The focus was twofold: to discover what embodied cognition looks like in pedagogical practice, and to develop usable theory to the wider music education field.

This chapter discusses and rationalises the methodological approach utilised to examine the central research question:

> ***How do music teachers embed embodied cognition and neuroscience, in their music pedagogy?***
>
> The two associated questions are:
>
> ***What does music pedagogy informed by embodied cognition and neuroscience, look like?***
>
> *and*
>
> ***What impact does the setting have on what it looks like?***

This thesis was seeking to determine the benefits to pedagogy in music education when embodied cognition and neuroscience are embedded in the teachers' practice. Embodied cognition asserts that knowledge and learning develop through the dynamic interaction of the brain and the body in the world. Cognitive neuroscience emphasises that knowledge which is attained through physical manipulation develops deep neural structures in the brain. The common link between these two theoretical stances is that the "dynamic interaction" of one and "physical manipulation" of the other are achieved through movement and action.

Using a Design Research methodology, a three-phase process was employed to study how embodied cognition and neuroscience aspects were embedded in the pedagogy of music teachers.
Chapter 3 begins with situating the research within a qualitative paradigm and discusses how this approach suits this thesis.

There are three phases in this research design, and these are described in terms of data collection, and analysis methods used to identify answers to the research questions, and how they led to the next design phase. The chapter closes with a summary of benefits of this methodology for this thesis.

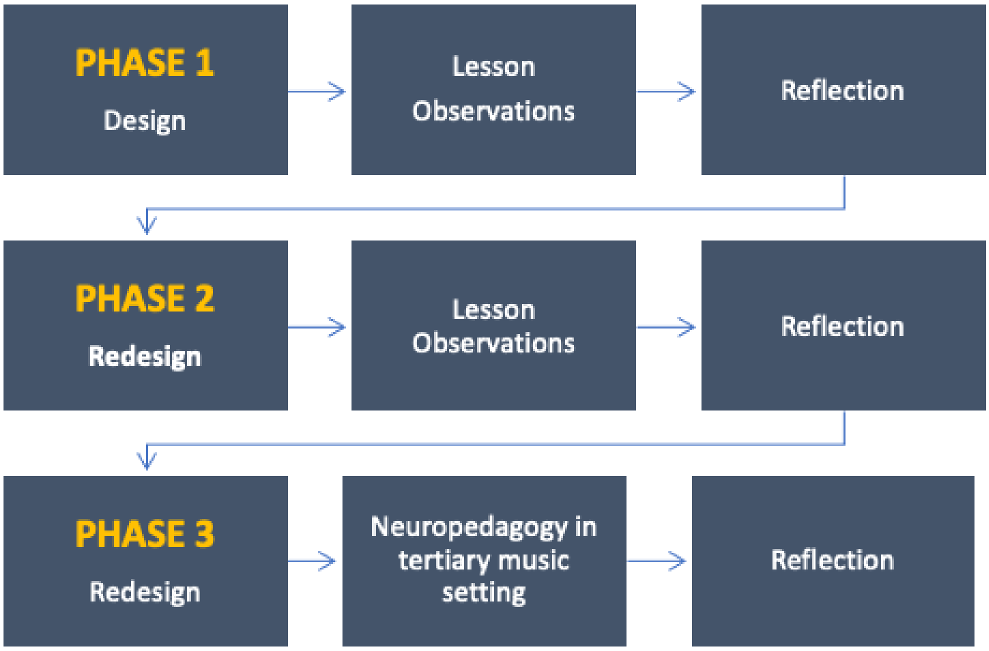


Figure 3.1 - Research design diagram

3.1 Design Research

Design research as a methodology for this thesis was an appropriate choice for two main reasons. Firstly, the method is designed to study real classrooms with real teachers teaching real students and this leads to practical outcomes for teachers' pedagogy. Ann L. Brown (1992), a pioneer in design research, said that this type of research is "designed to inform practice" (p. 143) and "craft usable and effective solutions" (p. i).

Secondly, design research as a methodology fits the theoretical framework of embodied cognition, as the results are driven through the embodied practices of participant-researchers. Design research embeds embodiment in the interventions and "produces theoretical understanding as an *output*" (McKenney & Reeves, 2019, p. 43).

The pedagogy and practices of music teachers are often difficult to describe in words. In pedagogical studies in Visual Art in Finland, it was noted that artists often find it difficult to talk about the processes of their work, as there is much experience-directed and tacit knowledge that is not expressed through language (Jokela, Hiltunen, & Härkönen, 2015). So too with the work of music teachers in expressing what their bodies do when they are being musical and teaching musically. An embodied approach values and seeks to "enact" the knowledge that is inherently musical. This research is about the physicality of teaching and learning, and what it looks like in practice; "embodied knowing" (Schroeder, 2015).

Characteristics of design research

There are specific characteristics of design research that The Design-based Research collective have outlined (2003). These are summarised below and are particularly pertinent to the music educators in this thesis as they all relate to research using the knowledge and wisdom of practising teachers applying theory in their classrooms. These music teachers are already experts in understanding what musical knowledge and skills to teach, and through taking part in the study, demonstrate their desire to explore theory that can enhance and strengthen their music practice.

The first of the characteristics of Design Research is that theories of learning and design of learning environments are connected. When theories and design are connected, the researcher and the practitioner can ensure that practices are created that are authentically related to the theory. Theory-related practices emerge while exploring evolving outcomes in real and complex settings. The setting is observed holistically, considering the interaction of the teacher, learners, materials and tools and social interaction. An holistic setting is more like a real classroom than when learners and their interactions are isolated, however, making the outcomes generalisable can be difficult. For this reason, the intervention can be seen as the aspect that can be generalised and the setting creates new outcomes or foci according to each setting's unique characteristics.

Secondly, the cycle of design in Design-based Research is a continuous process of design, enactment, analysis and redesign. Based on the findings of the first version of the design, revisions can be made to improve and refine the applications until some clarity arises from the findings (Collins et al., 2004). Refinements can also bring more clarity to theory.

The third characteristic of Design Research is that the research should lead to sharable theories that describe and translate theory to show the implications for practitioners. The outcomes should be inspired through use by practitioners, be usable throughout contexts and be responsive in context-specific ways (McKenney & Reeves, 2012, p. 76).

The fourth characteristic of Design Research is that it shows how the design functions in authentic settings, with successes and failures, and refines the understanding of the issues. Teachers value solutions that are based on the messy situations of real classrooms, rather than the limited-variable laboratory settings that do not reflect real life. When research is applied in the classroom setting, all the complex aspects that contribute to learning, such as interactions with artefacts, tools and others, occur in real time. The focus is on the role of the teacher in managing all these complex factors while applying the theory, rather than on a summative effect (The Design-based Research Collective, 2003, p. 6).

Managing complex factors is both a limitation and a strength of Design-based Research. In complex, real settings, it can be difficult to control variables and verification of theory applications would need to be practised in a number of settings to test their validity. However, complex settings and many variables occurring concurrently is also a strength, as this is what real teachers in real settings need to manage all the time. Teachers value theoretical applications that have already worked in real classrooms. Teachers do not always feel skilled enough to apply theory, or simply are too time-poor to experiment with how to apply theory, so "usable theory" (The Design-based Research Collective, 2003) created by teachers, offers practical applications for connecting theory with practice (Gutierez & Kim, 2017).

Describing how the process of the research relates to outcomes for the practitioner is the fifth characteristic of Design Research. Educational theory is often criticised for its lack of relevance to practice. Design Research seeks to frame research in scientific theory and understanding, and then design a solution for applying the theory into practice in a real context (McKenney & Reeves, 2012, p. 14). The practical solutions are shaped by participant expertise in crafting practices to explore how the complex nature of real world settings interact with theory. These participant-researchers understand their students and how they learn, and attune their teaching and account for this in their individual settings (McKenney & Reeves, 2012, p. 15). Detailed descriptions of how the scientific theory is enacted in specific settings provides usable practices for practitioners.

3.2 Use of Video in data collection

Video was used as the main data collection method in this thesis. As embodied cognition is the theoretical framework, it was necessary to collect data where the body interacting in the world could be viewed. In this way, all the interactions between teacher and student, student and student, student and things in the world, could be analysed. Video allows repeated viewing, which is necessary when analysing complex interactions and when identifying subtle processes (Blikstad-Balas, 2017).

Data was informed by the researcher's theoretical framework of embodied cognition and cognitive neuroscience, and long experience as a music educator. The data is therefore viewed through an informed lens that Goodwin (1994) describes as "professional vision". Professionals involved in the practice of their field are likely to note subtleties and differences between aspects more sharply than those who are not involved in the field. Use of embodied cognition and neuroscience theory were used as tools for making sense of what happened.

While videoing the lessons, as a music teacher, the researcher's attention was drawn at times to the musical aspects of the lesson rather than the deeper aspects of embodiment and neuroscience. Away from the influence of the setting, more and more details were revealed in the video recording. With repeated observations of the data, "Unplanned observations" generated new and emerging insights (McKenney & Reeves, 2012, p. 100), especially about the breadth of some of the neuroscientific aspects embodied in the teaching practice. These unplanned observations and emerging insights became the overall feature of each setting.

The greatest advantage from using video to collect data was to see the interactional detail and the many viewings allowed selection of specific aspects for deeper analysis (Derry et al., 2010). For example, in the Primary setting, the use of gesture by the teacher was used numerous times. On deeper analysis, description identified what type of gestures were used, for what purpose and what the gestures achieved. This is especially important in education, where teachers are expected to use language to explain content, whereas in music education, content is not always spoken language, and using language can interfere with the musical environment. There is a place for language, but the video observations brought to light how gesture was an important intervention that enhanced musical learning.

The many viewings of the video data also allowed for changes in perspectives and opportunities to look for different features. As features were recognised in one setting, on looking back at previously viewed recordings, these features could be recognised as emerging in other settings as well, but in different ways, or with different strength. Sensorimotor integration was one of these aspects that was observed in all settings. Erikson (2006) proposed that there can be a number of distinctive or a mixture of approaches to reflecting upon video data, basically being part-to-whole, which looks for specific content; whole-to-part, which looks for patterns in the data; or manifest content approach, in which specific aspects are focussed upon. Reflecting on how data in this thesis was collected, all three approaches were used as it became a process of looking "in" for specific aspects (part-to-whole), then looking "out" whole-to-part, as it became evident that there were special features in each setting.

Data Analysis

The video content was examined and analysed according to specific aspects of the research. These were:

- Embodied Cognition - the interaction of the brain, the body and the world
    - Aspects considered in the world – the teacher; tools, objects and materials; other people; and physical space.
    - Aspects of the brain – complexity; neural reuse; neuroplasticity and enriched environments; the mirror mechanism; peripersonal neurons; the senses and multisensory and sensorimotor integration.
    - Aspects of the body – multimodality (many modes of musical behaviour); tools, affordances and extended mind; joint action and attention; movement and gesture.

These aspects were developed as specifically pertinent to music education and pedagogy. Preparation for analysis was a thorough review of literature pertaining to these fields. Each case was analysed for identification of these categories in the pedagogy of the teacher. The analysis was both informed by research and researcher-informed, as the researcher is a practising music teacher and informed by both practice and theory. The most salient of the categories that emerged from each setting became the focus of analysis.

Finding the focus in large amounts of video data

Collins et al suggest (2004) that as Design Research captures real classrooms in action, video reveals great detail and the researcher is in danger of being swamped with data. Only the related activity to this thesis and its questions were selected for transcription and description. As common themes emerged and became prominent across participant videos, these became the focus. Transcription described observed action, identified by the researcher as aspects of the theory.

Some researchers suggest that the massive amounts of data that are collected in Design Research is a methodological flaw, and little insight is gained (Dede, 2004). However, because there were massive amounts of data collected in each observation, the most salient aspects gradually arose from the complex background, which finally revealed themes that were unexpected. The settings, all being real classrooms, did have some activity that did not relate to the thesis, such as interruptions due to "school" matters, but in the main, there was a richness of data to study.

While trying to make sense of dense data, it seemed impossible to describe every aspect of embodiment and neuroscience revealed. Deciding which "elements of a complex environment….to select for study" (Derry et al., 2010, p. 4) became a process of noting action and naming themes, though this process did not reveal useful practices. The themes identified instances of the neuroscience, but not how to practise them within a cohesive music pedagogy. It was also difficult to ascertain what was important and what was not in the data. There was much overlap between settings, so even though seven participant-researchers were videoed in Phase 1, in order to focus on the most representative instances of each setting that revealed the best examples of embodiment and neuroscience, only two were chosen to discuss in detail. In Phase 2, six more participant-researchers were videoed, but once again, only four of these were described.

In order to really identify the most salient feature of each observation, there was a process of drawing away from the detail and diving beneath to find the underlying meaning of what was truly important (Thorne, 2016). It then suddenly became clear and noticeable that there were distinctive features that naturally occurred in each setting (Derry et al., 2010, p. 4). This distinction became the basis for separating the classroom observations into primary, secondary, instrumental and special education, instead of describing each neuroscientific aspect in each observation.

Site visits for video recording

Each site was visited once only, for one lesson. Each participant-researcher had attended the "Neuropedagogy in Music" course and understood that the intention behind the lesson was demonstrating how embodiment and specific aspects of neuroscience could be embedded in music pedagogy. Email and phone conversations ensured smooth coordination of site visit times and observations. The teachers were asked to provide a lesson plan with the aspects they intended to demonstrate in their lesson, however, some did not provide a plan, and those who did, reported that they found it difficult to describe in words how they were demonstrating the embodiment and neuroscience.

As the content of the lesson was contained in the video, it was not really necessary to have a lesson plan. The important part was how the participant-researchers enacted and embedded embodiment and neuroscience in their pedagogy.

Discussions with the participant-researchers after the lessons were valuable. However, schools are busy places, and some of the teachers had to teach other lessons immediately following the observed lesson, so discussing the lesson was not always possible. Those teachers who were available for discussion had the opportunity to describe what parts of the theory they were applying in their pedagogy, and how and why. The researcher was also able to affirm these and, in some cases, there were more aspects than the teacher was aware of, that naturally occur in embodied music pedagogy (Hermans & Bremmer, 2015). For example, quite often, the participant-researchers did not recognise that sensorimotor integration was practised when musicality was embodied, such as when singing a song while simultaneously clapping the beat and keeping in time with others.

3.3 Participants / Participant-researchers

All participants in the thesis were practising teachers and graduates of the Orff Schulwerk Teacher Training courses, Level 4. These courses are music professional development courses, registered and accredited through both the Australian National Council of Orff Schulwerk (ANCOS) and the New South Wales Educational Standards Authority (NESA). Level 4 of the ANCOS Teacher Training courses is the highest level and is reflective of a total of 144 hours of music professional development for teachers. Graduates of these courses have attained a high level of expertise in music teaching, demonstrated through practice-based assessment tasks during the courses.

This sample of teachers was a convenience sample. The researcher is a trainer in the Orff Schulwerk teacher training courses so had knowledge of the interest of these teachers in furthering their professional development. The Neuropedagogy course was advertised both through the NESA website and the Australian National Council of Orff Schulwerk (ANCOS) website. Any teacher could attend the course, but this course was particularly attractive to the Orff Schulwerk teachers as the Neuropedagogy course counts toward a further qualification in Orff Schulwerk, even though Neuropedagogy is not based on Orff Schulwerk. The further qualification, Master Practitioner in Orff Schulwerk, is designed to look more deeply into music teaching practice, research and philosophy, and more widely than just Orff Schulwerk. Hence, the Neuropedagogy course was relevant to teachers who have an interest in broadening their teaching perspectives, as well as contributing to a further qualification.

From the thirty-five teachers who attended the first Neuropedagogy courses, seven volunteered to participate as participant-researchers and explore how to embed embodiment and specific aspects of neuroscience in their music pedagogy. A further six participant-researchers came from Phase 2. Those who volunteered were asked to meet the ethical requirements (permission to video, read and complete consent forms or administer consent forms to schools, teachers or parents of school students) for their setting, prepare a lesson embedding the research in their pedagogy, then invite the researcher to visit their classrooms to video their teaching.

Participants – their participation in the study

All the participants in the semi-structured interview and the participants who chose to have their lessons videoed were practising teachers. Of these:

- 1 came to the interview only
- 3 came to the interview and were videoed
- 4 were videoed only
- 4 were videoed and in the final selection
- 2 came to the interview, were videoed and in the final selection

Table 3.1 – Neuropedagogy Participants

Neuropedagogy Participants				
Participants	**Setting**	**Interview**	**Video-observations**	**Final Selection of participant-researchers**
Dana	Secondary	✓	✓	✓
Lauren	Primary	✓	✓	✓
Bonny	Primary + Special Education		✓	✓
Phil	Instrumental		✓	✓
Merryn	Special Education		✓	✓
Steve	Secondary		✓	✓
Jake	Secondary + Instrumental	✓	✓	
Vanessa	Primary	✓	✓	
Beck	Secondary	✓	✓	
Anne	Primary		✓	
Jess	Primary		✓	
Celeste	Secondary		✓	
John	Instrumental		✓	
Davina	Primary	✓		

As the participants represented a distribution of educational settings, data was collected across Instrumental, Secondary, Primary and Special Education settings.

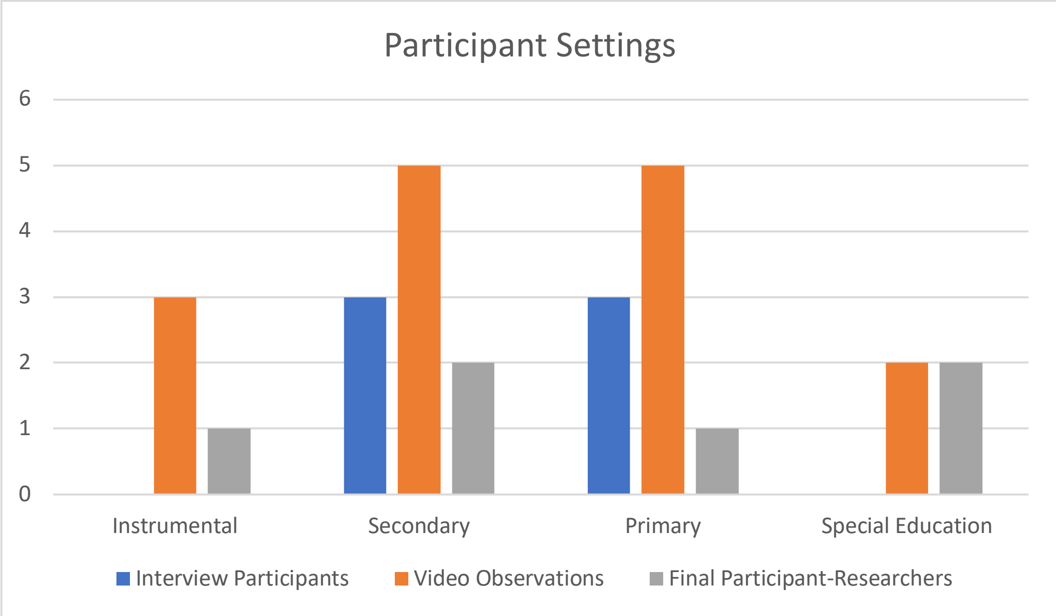


Figure 3.2 - Participant Settings

3.4 PHASE 1 – Professional development, lesson observations, semi-structured interviews in Reflection meeting

Figure 3.3 – Phase 1 of research design

Phase 1 focussed on three stages. The first was providing professional development to provide music teachers with the theoretical knowledge they would use to create usable theory. The second stage was videoed observations of teachers and the third a reflection by participants about the research through using a semi-structured interview.

A group of teachers attended a professional development course, designed by the researcher, in Neuropedagogy in Music. The three-day course introduced Embodied Cognition and Neuroscience in both theoretical and practical music sessions.

The first courses, held in Sydney in July and Melbourne in October 2016, had a total of thirty-five participants. This phase of the research allowed participants to interact socially both with each other and the researcher. Social interaction is a key feature of embodied cognition and important in knowledge construction. The sessions involved discussion, video examples, and short and long intervals of musical activity in relation to the theoretical information. Reflection discussions allowed collaborative construction of their knowledge.

Seven participants chose to become participant-researchers and explore embedding embodiment and neuroscience in their pedagogy. In November 2016, three of the participant-researchers and two participants in the Sydney course attended a meeting to reflect upon how the information in the course had affected their pedagogy.

Phase 1 Reflection – Semi-structured interview questions in reflection meeting

In October 2016, at the end of Phase 1 of this study, a reflection meeting was conducted with the participant-researchers and participants from the Phase 1 Neuropedagogy course. These people were considered to have vital information that could contribute to the next phase of the study. Three participant-researchers and two participants from the Neuropedagogy course met to discuss the embodiment and neuroscience theory that had been presented in the course, and their reflections on embedding these in their music pedagogy. The meeting was videoed so that the researcher could easily facilitate discussion and manage the focus on the interview questions.

Semi-structured interviews are used to ascertain participants' perspectives and subjective views, and to capture new insights (McIntosh & Morse, 2015). Participants in semi-structured interviews "are free to respond to … open-ended questions as they wish, and the researcher may probe their responses" (McIntosh & Morse, 2015, p. 1). The openness of questions allows lines of conversation to develop that may not have occurred had the interview been more structured, and meeting in a group can offer construction of meaningful topics as they emerge (A. Brown & Danaher, 2019).

Brown and Danaher provide guiding principles for "maximising the ethical and methodological advantages of semi-structured interview research practices" (2019, p. 76). A framework guided by Connectivity, Humanness and Empathy (CHE) ensured that the actions of the researcher developed rapport and respectful and reciprocal relationships among the research group and the study's research aims.

To provide a conducive atmosphere for discussion, participants were invited to the researcher's home, and lunch was provided. All the participants were working teachers, so the weekend suited most of them, with one taking the trouble to fly in from a regional area in order to personally engage in the discussion. All the participants were known to the researcher as they had all participated together in professional development, Phase 1 and conferences over a number of years and had become professional colleagues, so attending a meeting at the home of the researcher was perceived as a comfortable, conducive environment for feeling at ease.

Attendance at the meeting was voluntary, as were contributions to the discussion. The discussion was friendly, positive and in fact the time ran out before all the questions were completed. Prior to the meeting, the researcher distributed the questions via email, with a short precis of the course content points to remind participants of the theory.

Because all the participants were known to each other and were all experienced teachers who respected each other, they were comfortable enough to share with each other and the researcher where they felt they lacked enough knowledge of the research and how they felt it could have been stronger for them. This was extremely valuable for the redesign of the course for the next phase of the research. The participants also affirmed and built upon each other's responses as each relayed their experiences. As so much of music pedagogy is tacit knowledge, and not easily described in words, constructing a way of verbalising the pedagogy between each other was quite a joyous aspect of the meeting, also commented on by the group also.

The reason for using a semi-structured interview in this thesis was to generate knowledge about the value of the content of the Neuropedagogy course, and how participants embedded the theory into practice. Questions were designed to help the researcher understand:

- what knowledge was valuable and relevant for music pedagogy;
- what changes took place in their pedagogy as a result of this knowledge;
- how the knowledge made them feel as teachers in going through the process of embedding the research in their pedagogy;
- how the participants interpreted the theory;
- if participants felt positive about what happened in their pedagogy;
- if they thought it would work better with some students than others;
- what they would do next; future directions;

The interviews were either submitted as text in email or videoed at the meeting. The interviews were transcribed and collated with text responses. The overall results from the semi-structured interviews were that the course topic information needed to outline principles for application more explicitly, and provision of more usable terminology was needed so that teachers had the language to describe the research when justifying it to others.

All participants were already experienced, and highly regarded teachers so had a deep understanding of what to teach and how to teach it. What they were looking for was more knowledge that would tell them if what they thought was good practice could be rigorously supported or not with embodiment and neuroscience. Research such as the multimodal research, that explains that knowledge in one mode informs knowledge in another mode (Martin-Martin & Brock, 2017), justified why actively practising concepts in a variety of modes facilitated deeper understanding. This had been tacit knowledge for these teachers, but when reading the research and embedding it in their pedagogy, this provided the participants with powerful knowledge, language to describe it and usable theory.

The findings from the interview shaped the development of the next phase of the research design.

3.5 PHASE 2 – Redesign of Professional development, lesson observations, Reflection

Figure 3.4 – Phase 2 of research design

The strength of Design Research for educational settings is that the design can be adjusted following interventions (The Design-based Research Collective, 2003). Design Research allows and expects that time will be taken in between iterative processes so that ponderings, reflections and analyses can be done and revisions made to improve and refine the design (Collins et al., 2004). This design, enactment, analysis and redesign process suits an artistic field as outcomes are not always explicit or obvious. Outcomes reveal themselves over time as the researcher becomes "the foreigner" in identifying features, but "the resident in the field" through recognising what would be invisible to others (Petzold, 1995). Design Research is a research process that promotes adaptation and improvisation in a performative context (Jokela et al., 2015), which suits the arts natural "lived experience" of continual reinterpretation (adaptation) and modelling into different forms (improvisation).

Providing more specific terminology in the Neuropedagogy course was revealed to be an important part of being able to describe how and why the neuroscience research was embodied. This information was used in the redesign Phase 2. The way lessons were observed did not change, except lesson plans were not required, as these were not used for data analysis. Six more participants offered to assist in developing usable theory, though only three of these were used to develop the findings. The reason why only three were used was because there was considerable overlap of activities and to assist in making clear findings, decisions were made to describe the most salient features from each setting. Reeves (2006) says that often the refined cycles of implementation are similar to the first but with different participants. The changes seemed small but in making the changes and refinements, more clarity emerged from the theory. As the researcher observed each lesson more deeply, the process of analysis generated "theory-gathering" (Schroeder, 2015) and the theory-driven practices made the theory clearer to the researcher.

It was in this phase that the second research question was really answered:

What impact does each setting have on what it looks like?

The analysis divided the settings into what aspects of the theory emerged most prominently in each setting, rather than just in each lesson.

3.6 PHASE 3 – Application of usable theory in a new setting

Figure 3.5 – Phase 3 of research design

Phase 3 is where the first research question answers were applied in a new setting, the tertiary setting:

What does music pedagogy informed by embodied cognition and neuroscience, look like?

All practices highlighted by participant-researchers that had emerged in the settings were implemented under the framework of "enriched environments" (Kitchen, 2017; van Praag et al., 2000) with the goal of producing usable theory and practices that can be shared in the wider music education world. These practices will be described in the following chapter of "Findings and Settings".

3.7 Summary

This thesis implemented a Design Research experiment and described why this approach was chosen. The study was conducted in three phases with explanations for how each phase was designed and how data was collected and analysed.

The diagram below shows that Phase 1 involved the development of the Neuropedagogy in music course, lessons observations of seven

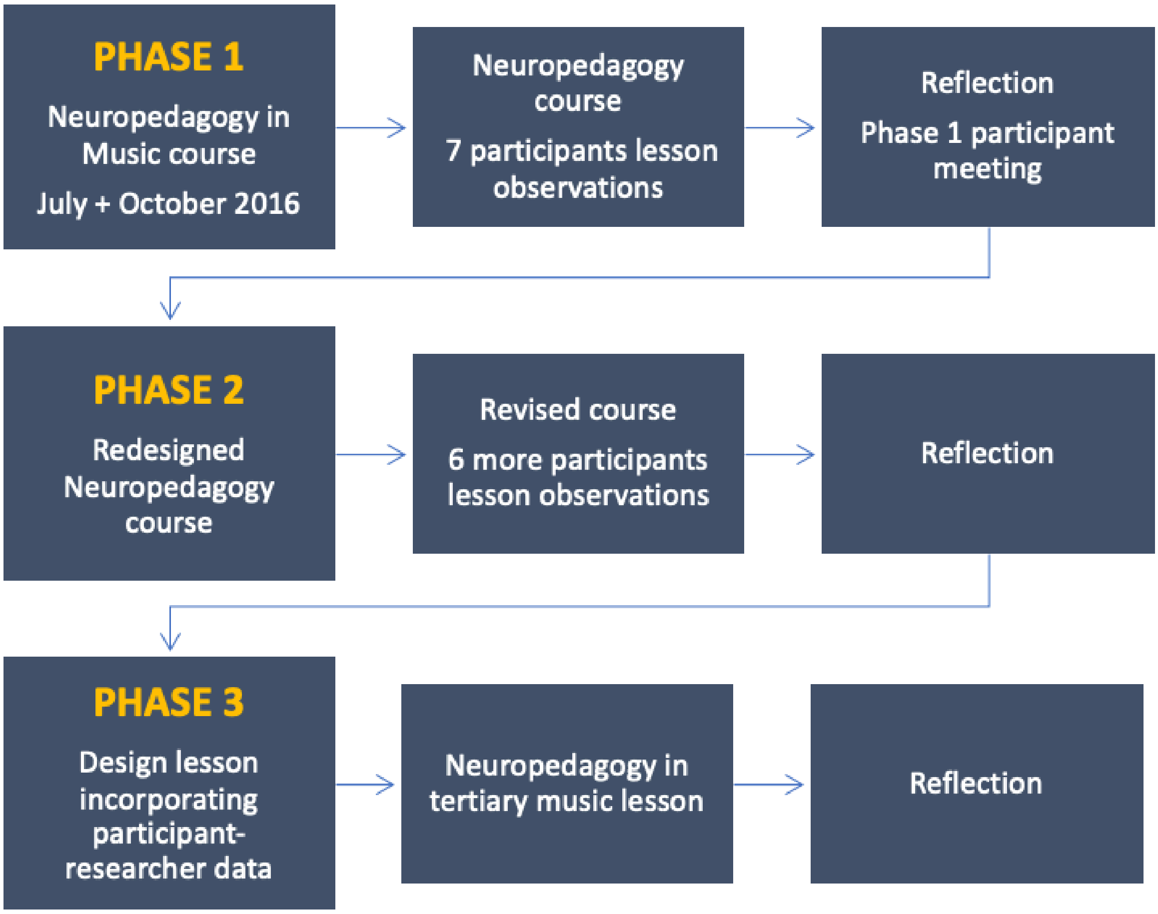


Figure 3.6 – Phase 1, 2 & 3 of research design

participant-researchers from the course, and a reflection meeting with Phase 1 participants. Based on participant insights regarding what research was strongest and most pertinent to their practice, Phase 2 involved a redesign of the Neuropedagogy course. Six more participant-researchers were engaged with the study, with a reflection by the researcher informing Phase 3 design of implementation of usable theory in the Tertiary setting.

Through a Design Research approach, teachers are involved in turning theory into practical pedagogy. As an approach to educational research, it inspires the making of links between the research and practice. Because the theory is practised in real classrooms, the outcomes are relevant to real teaching and learning. Teachers can feel confident that they can apply the latest research and be able to explain how it is applied and why. Because the embodiment and neuroscience theory does not directly relate to content of the music learning, the underlying principles can be applied to all content, and therefore, useful across many areas. For example, when teachers understand that tools and their affordances allow more skilful action in the world, teachers can include tool use in all areas of their pedagogy to strengthen many different concepts.

Working with many teachers in this study meant that there were many settings to draw practices from, which makes theory more viable rapidly, and for more diverse settings (Stephan, 2015). All teachers were motivated by a desire to inform their music pedagogy with real science and to improve and strengthen their practice, and contribute to creative insights in their field (McKenney & Reeves, 2019).

Findings are presented in Chapter 4 in terms of what emerged from the reflective meeting at the end of Phase 1, and the most salient features of each of the settings of Secondary, Primary, Instrumental, and Special

Education. From the insights gained from each setting, a design of principles if offered for embodied music pedagogy, underpinned by neuroscience. Chapter 5 concludes the thesis by relating the findings to the central research question: ***How do music teachers embed embodied cognition and neuroscience, in their music pedagogy?***

Chapter 4 – Settings and findings

Findings are presented in Chapter 4 in terms of what emerged from the reflective meeting at the end of Phase 1, and the most salient features of each of the settings of Secondary, Primary, Instrumental, Special Education and then, implementation in the Tertiary setting.

4.1 - Phase 1 Semi-structured interview meeting
4.2 - The Instrumental Setting – Multimodality embodiment
4.3 - The Secondary Setting – Problem-solving with the body
4.4 - The Primary Setting – Complexity through simplicity
4.5 - The Special Education Setting – Joyous, rapturous, exuberant embodiment
4.6 - The Tertiary Setting – An enriched environment

Each of the settings focus on a particular teacher (participant-researcher) and their lesson, with a brief introduction to their context.

Chapter 5, the final chapter, concludes the thesis by relating the findings to the central research question:

> ***How do music teachers embed embodied cognition and neuroscience, in their music pedagogy?***

4.1 Phase 1 Semi-structured interview meeting

Findings from the semi-structured interview provided some important points for the redesign of the study for Phase 2. The table below shows that Dana, Lauren, Jake, Vanessa, Beck and Davina (shaded in pink) came to the Reflection meeting and participated in the semi-structured interview.

Table 4.1 – Neuropedagogy Participants who came to Reflection meeting

Neuropedagogy Participants				
Participants	**Setting**	**Interview**	**Video-observations**	**Final Selection of participant-researchers**
Dana	Secondary	✓	✓	✓
Lauren	Primary	✓	✓	✓
Bonny	Primary + Special Education		✓	✓
Phil	Instrumental		✓	✓
Merryn	Special Education		✓	✓
Steve	Secondary		✓	✓
Jake	Secondary + Instrumental	✓	✓	
Vanessa	Primary	✓	✓	
Beck	Secondary	✓	✓	
Anne	Primary		✓	
Jess	Primary		✓	
Celeste	Secondary		✓	
John	Instrumental		✓	
Davina	Primary	✓		

Interview questions and responses

1. ***What aspects of cognitive neuroscience are the most relevant for music pedagogy?***

Neuroplasticity- attention, novelty, challenge, reward, goal-directed, authentic contexts.

Jake felt that for Year 12 students, maintaining and sustaining attention was crucial in order to reach their peak, ready for the HSC examination. He found that the strategies outlined in the neuroscience research assisted him in focusing his teaching on finding innovative ways to get attention; notice when attention was waning and consequently, adding novelty; providing short-term goals with extrinsic rewards to sustain attention; providing challenging tasks that extended their learning but was within reach; verbalising to the students how their efforts resulted in knowledge gains, which contributed to intrinsic rewards; all learning was in authentic repertoire and contexts, so that students understood what their learning practice meant in the real world. When thinking about authentic contexts, he felt that worksheets, a popular tool in teaching, is not authentic, though sometimes, useful, but the repertoire was always authentic. 4E cognition[12] (Schiavio & van der Schyff, 2018) and research on neuroplasticity (Tovar-Moll & Lent, 2016)[13] emphasise the importance and relevance to learning of choice, options and authentic contexts for meaningful and strong learning.

Jake also found that in the band setting, working on long-term goals was hard to focus. Neuroplasticity principles he felt reminded him to make short-term goals that were easier for school students to focus on and "kept them on track". He also felt that there were intrinsic rewards in the short-term goals, such as when he rearranged the way the band

---

[12] 4E cognition – see Chapter 2.1, p. 29
[13] Neuroplasticity – see Chapter 2.3 , p. 49

organised their seating arrangements. Students chose to sit next to whomever they pleased, no matter what instrument they played, as long as no two instruments were the same next to each other. Students were excited to have change, choice and especially, to hear something different to what they usually heard while playing the repertoire. It changed the way they thought about the piece they had played so many times before, and it helped them understand the role of their part within the whole piece of repertoire and the band.

Jake said that he had "made [the knowledge of] neuroplasticity a practice, a usable process for teaching" (Jake, meeting communication, October 23, 2016).

Mirror Neurons – After the course, Jake found that the research on mirror neurons made him think about his body and hands as a conductor, and how effectively he was "getting the message across". He explored how he moved and realised that when his conducting style reflected the repertoire more, the band played more to the style of the repertoire.

The mirror mechanism allows understanding of the action of others. Following the gestures and movements of a conductor is processed through the mirror neuron system (Rizzolatti et al., 1996; Sinigaglia, 2013) and influences the way the repertoire is interpreted. The players imitate the conductor's style in the way they play the repertoire and create a shared meaning in joint action together (Overy & Molnar-Szakacs, 2009).

Extended Cognition

Lauren and Vanessa both commented on how extended cognition had made them look differently at how they could get their students to think, using their own bodies as tools, and with other tools. Lauren said she got the students to use their hands more to denote beats, how many times something was played and so on. She thought that students were "more visual" because of computers, so using their hands made their thinking more visual. She also found it allowed her to "see" what the students were thinking and working on. Vanessa though that "fingers are extending thinking, taking it to the next level, using fingers to make own four phrases" (Vanessa, personal communication, 23 October 2016).

Dana used drumsticks to extend her Year 12 students to think differently. When using the sticks, the students found new ways of expressing patterns, and had to find ways of doing things, *because* they were using the sticks. Working with partners also extended their thinking.

Coupling

Lauren started to notice coupling; how many things happened simultaneously that made meaning clearer. She noted that there was always more than two things happening at the same time; for example, singing, music, actions, playing, "even when they were putting the music into their heads, the sounds were happening and they were moving" (Lauren, personal communication, 23 October 2016).

Sensorimotor Integration

Dana said that the understanding about sensorimotor integration made the biggest impact on her teaching. She felt that it impacted her planning for how the students would embody their learning, what would be happening for students to respond to, such as playing the repertoire while responding to other's movements, and so on.

Overall embodiment and neuroscience aspects

In general, Davina felt that the information in the Neuropedagogy course had changed the way she perceived her teaching. She said that she was still doing the same things, but the structure changed. She and Vanessa reported that because of the embodiment research, they were thinking more about what their body was doing to be musical, how the students' bodies were being musical, and where this fitted into the lesson. Vanessa realised that until there was "complete embodiment, being able to improvise was limited" (Vanessa, personal communication, 23 October 2016).

Lauren felt that she was allowing things to happen more, that she was watching for connections, but that allowed them to happen at different times. "Transfer doesn't happen as quickly and I'm looking at individuals a bit more, focusing more on my own teaching and allowing time for connections to occur" (referring to neuroplasticity) (Lauren, personal communication, 23 October 2016).

2. ***What changes took place in the pedagogy? What do you do? What do you perceive in your students as a result of this?***

Jake said that he had made his assessment tasks more embodied rather than just written tasks. He recorded more observations of how students embodied their musicality across all modes, such as singing, arranging, playing, improvising and so on, so that he had a fuller picture of their musical development, strengths and weaknesses. Embodiment in assessment made musical outcomes clearer.

Lauren said that in thinking about embodiment more, she was using language less during the teaching in the lesson. She realised she was now using language to get students to talk about what they had learned, something she had not asked them to do before. Her students said, "She really made us think". Lauren said that when students were explaining what they had learned, they were using some of the same gestures they used when they were doing the embodied learning, and she said that this helped them remember and understand what they were explaining. In Lauren's lesson, she used gesture a great deal to convey and communicate, and when her students were conveying their understanding, the strong associations of the gestures and actions they produced would be activated as they explained their responses to Lauren (Hostetter & Alibali, 2008).

3. ***Are there aspects of your teaching that you can now see are reflective of neuroscientific processes?***

Jake felt that he could now understand why movement was so important in deeply understanding musical ideas, and the scope of what movement meant. He thought movement was just dance, but now realised it was more subtle, such as moving to another place to hear something differently, or changing the way something was played by breathing differently. "Movements are at the centre of mental activity" (De Jaegher & Di Paolo, 2007, p. 489) and shape how we perceive music (Phillips-Silver & Trainor, 2007).

Beck found that she was thinking about what was being "wired" differently by all the different modes of being musical that she was using in her Year 8 music class.

4. ***How does it make you feel as a teacher going through the processes of embedding this research in your practice? Does it empower you?***

Many commented that trying new practices based on the theory reinforced and affirmed much of what they already do. They said that "a new bar had been reached for equating what real learning had occurred" and they were really thinking about what the students were learning and how. Jake felt empowered by being able to use the "brain words". He said that parents take "this" much more seriously. Vanessa agreed and also said that her colleagues were interested and having to find the words to explain the ideas helped her understand the theory more.

Vanessa said that she was finding it rewarding to see the effects of the changes she had made in her pedagogy. By embodying pitch through movement, she described how one of her students (who had been unable to sing in tune), was more in tune and much more confident in her singing in just a couple of weeks.

Dana said that in the current climate of education focussing so much on STEM (Science, Technology, Engineering and Mathematics), she felt that the neuroscience knowledge had given her the language to “combat” being excluded from this conversation, and she found it affirmed her students’ learning as well, describing how they were learning in terms of neuroscience. She felt that her colleagues, students and the parents were taking more notice of musical learning because there was “science” behind it.

5. What would you do next?

Beck is a private instrumental teacher as well as a classroom teacher and is now thinking about how to embed embodiment and neuroscience in her teaching, but as her teaching is one-on-one, she said that she needs more guidance. She feels more able to add the aspects into her classroom teaching.

Dana wants to use more embodiment in her senior secondary classes as she said that the students were more active and responsible in their learning and found it more enjoyable. Jake found his students more inhibited in embodying their learning, probably because they were not used to it. Vanessa said she was using embodiment in all aspects of her teaching, such as choir, where all the singers who traditionally sing in the back row, now were at the front. This made differences in how they perceived their part in the whole performance, how close they were to the conductor, and how their part fitted with the repertoire. In other words, they were thinking differently simply by moving somewhere else to perform. Davina found, like Jake with his band repertoire, when the conductor and students moved appropriately to repertoire, the style emerged in the performance. This was explored in a piece of African repertoire which Davina said was "dead" until the choir moved to it.

6. *Would it work better with some students than others?*

Dana thought all her students had responded to the changes she had made in her teaching. Embodiment made learning stronger. "The students who have blossomed are the students who have issues". When asked why this had occurred, Dana said, "Because we've given them extra scaffolding and extra hooks to hang their knowledge off and their brains have extra pathways into knowledge" (Dana, personal communication, 23 October 2016).

Jake felt that motor "stuff" is how students learn and some students found it harder, more abstract, if they were not moving. They found it more challenging. He found that the more ways a musical idea could be practised, multimodally, the more the special students had an outlet to be able to do "things". He said that "Movement makes us ready to learn" (Jake, personal communication, 23 October 2016).

7. *What now? Future directions?*

Dana felt that while her teaching did not change so much, the embodiment and neuroscience research had given her understanding of why she teaches the way she does. Importantly, it had given her language to justify to her principal why she teaches a certain way when other teachers question why her students do not write or do written examinations as students in other subjects. Her students often say to her, "Can't we just have a sheet telling us what pitch is?". She said they know it will take more work to know it through embodying their learning, than if they just read it. "I just keep saying no, you can't have that because it gives you no genuine understanding".

Jake agreed with this comment, and added that he has told his students that when he gives them a sheet with the answer, if they forget what is on the page, they have no other way of knowing the answer. However, if they have embodied the knowledge, they will have so many more memories to draw on to remind them about the idea. The responses by Jake and Dana about genuine understanding and memories reflects the research and embodiment and the depth of memory created through multisensory engagement. When learning is embodied, the action of learning creates the feeling of knowing. When playing an instrument or singing a song, the peripheral, haptic and proprioceptive senses combine to create the feeling of being musical (Candidi et al., 2012; Lederman & Klatzky, 2009).

Overall outcome of the semi-structured interview and meeting

The general consensus was that the information in the Neuropedagogy course was fairly dense and participants felt that they had difficulty in describing it to others. For this reason, they focussed mainly on the topics that the course had provided principles for, such as neuroplasticity and extended cognition. Mirror neurons was also a topic they found easily understood and most pertinent to music education. They also said that they would like to be able to use the terminology more, so making that clearer in the course would be beneficial.

Most agreed that while their teaching had not changed a great deal, their understanding of why they would develop their pedagogy a certain way, through embodiment, and how the brain processes knowledge, was a powerful tool for them as practitioners. They also felt that the embodiment and neuroscience knowledge was important to explain to their students. When students asked why they were learning a certain way, the teacher could explain, and the students could also explain to others. The participants reported that they felt empowered in communicating to colleagues, principals, parents and the wider community about how deeply they understood not just what and how they were teaching, but why.

Points for redesign of Phase 2

Neuropedagogy in Music course

Because participants found the theory was too "dense" in the first courses, topics that none of the participants mentioned were deemed not appropriate for this thesis. Those topics included the specific structures of the brain (anatomy), different types of neurons and their functions, philosophical and phenomenological background to embodied cognition and neuromyths. The last topic, neuromyths (popular theories in education that were oversimplified or misrepresentative of the research), have been discredited more widely since the first course, so no longer necessary to include.

The topics they found the most useful were made more prominent, such as the research on mirror neurons, multimodal integration and sensorimotor integration. New topics were included that closely related to these, such as peripersonal neurons and enriched environments. All topics were presented with guiding principles, which participants reported made it clearer for them to verbalise and explain ideas, and therefore design application in their pedagogy.

Observations

As lesson plans were not necessary for analysis of embodiment and neuroscience, participant-researchers were not required to provide these. Phil from the Instrumental setting, Steve from the Secondary setting and Merryn from the Special Education setting were the participant-researchers whose lessons were analysed. Steve particularly demonstrated in later discussions that principles and summative statements in the course made a difference to his pedagogy. For example, he said that "cognition is for action" and "perception and action shape cognition" (Spencer et al., 2006) became his guiding principles. He said that understanding how proprioception and haptic senses[14] (Lederman & Klatzky, 2009; Wang, 2013) develop the sense of how music feels, really made him think about how to enable each individual student to experience being musical with their own body.

[14] Haptic and Proprioceptive senses – see Chapter 2, p. 63

4.1 The instrumental setting – multimodal embodiment

This setting is an instrumental classroom. Phil runs his own music studio in Sydney. His business runs piano music classes, but the pre-school students participate in music and movement classes in preparation for the piano classes when they start school.

The outstanding pedagogical features of this instrumental setting are the wide range of multimodal musical experiences, the use of space and the social aspects that contribute to the learning.

The instrumental classroom – piano studio

This section discusses how Phil has embedded aspects of embodiment and cognitive neuroscience in his teaching of piano in group lessons. The description captures observations on one day during an afterschool class in his music studio.

Introducing Phil

Phil has a private music business, primarily teaching piano, and has studios throughout Australia and internationally. He and his business partner have developed a highly-organised system for learning the piano. The system incorporates early music and movement classes, group piano lessons that include multimodal ways of being musical, use of technology, progressing to individual music lessons, where improvisation and composition are encouraged.

Phil's professional background

Phil is forty-nine years of age, and began teaching at the age of eighteen, teaching brass at an independent boys school. He has a Diploma of Teaching (Music), Associate Diploma: Piano, Electronic

Organ, and Grade 8 French Horn and Voice. PhilĀis a graduate of Level Four in Orff Schulwerk Teacher Training.

Classroom setting

PhilĀs classroom is on a floor of a low-rise building in a beach suburb of Sydney. It is a private studio and there are a number of music classes occurring at the same time in various-sized rooms. Most of the rooms are set up for group lessons. This class consists of 3 boys and 3 girls aged 5 – 7 years.

The Instrumental Setting story

The six claims of embodied cognition** (Wilson, 2002, p. 626) **and the related neuroscience

This section will discuss how PhilĀhas embedded specific conditions of embodied cognition and aspects of cognitive neuroscience into his lessons. His lessons incorporate all the conditions, but the special ways that are pertinent to instrumental teaching are described below.

1. Cognition is situated

"Place" impacts memory and primes the body and brain for learning. Musical "place" should engender musical behaviour and create memory through opportunities for musical action in the world. Many instrumental lessons are conducted in spaces that, apart from the instrument itself, have no other "clues" or action opportunities that engender musical behaviour. The place where learning occurs exerts influence over learning and will impact memory. The place where musical

Figure 4.4 - Front of room

learning occurs should allow the body to make musical memories that are different to other memories.

The music studio room where Phil 's lesson was observed is the size of a small classroom, with a whiteboard with staff lines on it, at front of room (*Fig. 4.1*). Next to this is a small grand piano, on which sits a large computer screen from which Phil controls the sound. Around the perimeter of the room (*Fig. 4.2*) are 8, small upright pianos with footstools, to ensure small bodies can attain correct posture to the size of the musical instrument, the piano. There is a chair in between each piano, on which a mother/father/carer (and sometimes sibling) sit. The middle of the room is empty space. The floor is carpeted.

Figure 4.5 - Around perimeter, small upright pianos

The lesson begins with students walking into room, gathering around the grand piano, and all singing and moving to a song they always sing at the beginning of the lesson, a welcome-to-music song that Phil composed. This room and its set up would instantly engender and prime musical memories in these students' minds. It looks, sounds, feels like and is a place where musical action takes place. Because this room is full of musical interaction possibilities and artefacts of musicking (staff lines, instruments, other people to be musical with, sound recordings and so on), students do not have to waste cognitive space on imagining these things. They can act upon them and extend their thinking into using them. This classroom allows complex thinking skills and conceptual development through extending thinking and action into tools and artefacts and place (Ryan & Schiavio, 2019).

The embodied, active memories are a result of the formulation of personalised action plans in response to environmental demands. These plans and memories are constantly updated in and through time. "Cognition is fundamentally bound to the real time bodily processes through which we act in a physical world" (Smith, 2005, p. 288).

2. Cognition is time-pressured

Music itself, as it occurs through time, is time-pressured, just like everyday events. The world does not wait for us to notice small bits of information. However, pedagogy can affect the time-pressured and embodied nature of processes of learning, and focus attention on small parts within a meaningful whole. Once again, place matters, because what is perceived and acted upon changes conceptual development and becomes embedded in the bodily experience in that moment. "If knowing is to matter in the world, in real time performance, it must be melded to the specifics of the here and now" (Smith, 2005, p. 285).

Phil manages time-pressure through synchronised action with repertoire, through the body. While singing, he models moving to the beat, the duration of the musical phrase, singing, and moving to indicate the music is coming to an end. The students copy as they all perform in synchrony, in real time. From the first moment of the class, Phil and the students are embodying musical behaviour as it happens through time. Phil provides a musical model which the students are able to imitate. This is achieved through the mirror mechanism, the neural system involved in imitation and action understanding (Rizzolatti & Craighero, 2004). Singing and moving to the recorded music develops their skilled sensorimotor integration. When one's own body is being musical, integrating the melody, the beat, patterns and other movements, it becomes a personal memory that is deeply grounded in sensorimotor systems in the brain (Schiavio & Timmers, 2014).

While Phil is teaching his students to be pianists, he is also teaching them to be musical. Preparing the bodies and brains to be musical before they go to the instrument makes performing on the instrument successful. This preparation makes their performance more musical because students have embodied not only the specific techniques for playing the instrument, but it has been practised through their own bodies in a number of different ways. It makes sense to practise being musical through the whole body, the musical tool that students can already manage well, before they perform on the piano, the external musical tool that requires new motor plans to manage it well. The multimodal preparation through the body makes musicality whole-bodied as well as embodied. "Active sensorimotor experience plays a key role in musical skill acquisition" (Schiavio & Timmers, 2014, p. 21).

In Phil's classroom, skill acquisition is in real time, connected to the authentic musical context of repertoire, and constantly updates musical cognition. Musical cognition is updated multimodally, as all the students sing, play, move, improvise, read, symbolise and so on. It is updated in multisensory ways through perceiving the effect of actions in real time in each new event, and cognition is updated through exploration. Personal exploration results in the development of cognitive strategies for problem solving. "Movement creates both tasks and opportunities for learning" (Smith, 2005, p. 293). Phil's pedagogy reflects constant opportunities for movement and exploration to gain complex cognitive dexterity in real-time, authentic musical contexts.

3. *Cognition work is extended into the world*

Figure 4.6 - Representing rhythm and pitch patterns

Instrumentalists manage their instrument as if it is part of their bodies and part of the space it takes up. When instrumentalists use their instruments to assist them in expressing their musicality, they are extending their thinking into the instrument. There were many examples of this being prepared for and occurring in Phil's class.

Figure 4.4 - Piano hand shapes

Phil extended students' embodied skill development into gesture and movement. They practised:

- Piano hand shapes during a song (*Fig. 4.4*)
- Crossing the midline in preparation for the many times hands cross the midline when playing piano (*Fig. 4.5*)
- Representing rhythm and pitch patterns through body movements while singing (*Fig. 4.3*). Because of this preparation, when the students came to their instruments, they were successful at playing the patterns. Additionally, they were able to extend their thinking into using the tool (the piano). When Phil asked them to think of another way to play the pitches to fit into the song (improvisation and composition), they already had the prepared skills to do this. Without the tool, this would not have been available to them. Instead of playing "me, fah, soh", they could explore using those pitches in a different way on this piano, such as "fah, soh, me", or using different rhythm patterns that still fit the structure. Extending their musical thinking into the instrument allows them to be independent in their musical thinking in an ongoing process (Schiavio & van der Schyff, 2018).

Figure 4.5 - Crossing the midline

4. The world is part of the cognitive system

The aspect of "the world" that is special in Phil's classroom is in the social aspect. Music making is most usually a social and collective process, and in many cultures, there is no distinction between composer, teacher, listener or performer (Windsor & de Bézenac, 2012). Music making is often a place of joint action, where groups of people "coordinate and regulate their actions to achieve common [musical] goals" (Windsor & de Bézenac, 2012, p. 110). Phil has created this in quite a unique and powerful way in his music pedagogy.

Figure 4.6 - Carer as part of social aspect of the world

Figure 4.7 - Carers assisting in performance skills

As stated previously, parents or caregivers are also in the classroom (*Fig. 4.6 & 4.7*). They are seated between the pianos and when students first go to play the piano, they sit with their parents. This aspect of the lesson is highly supportive socially, as the carers know what happens in the lesson as well as at home, and link the environments. In terms of elements that make successful neuroplasticity in enriched environments, highly supported social contexts result in relaxed alert states which are conducive to learning (Gülpinar, 2005). However, in between performances of the piece, the students get up and move to the next piano and sit next to a different carer, thus providing a shared social setting. They are encouraged to greet the carer and include them in their interactions. This all becomes part of a highly-structured, supportive social system. The carers contribute by acknowledging how the students are performing, offering suggestions, encouraging, and sometimes participating, such as through playing musical games.

Social engagement is part of embodied interaction in the world and especially part of the musical world (Hermans & Bremmer, 2015; Maes, Leman, Palmer, & Wanderley, 2014; Trehub, 2003). Music ensembles and choirs rely on special, musical social skills in order to be successful. Opportunities for ensemble are not always available in instrumental lessons, either because there are only the teacher and student in the room, or because everyone is playing the same line of music.

Social engagement between carers and students in Phil's classroom is practising social cognition and its benefits for supporting learning. Social collaborations between teacher and students, and students and students (*Fig. 4.8*) benefits musical social skills, of embodying communication through gesture, movement and sound. The mirror and peripersonal systems are involved in this complex processing and Phil's classes provide rich opportunities for these interactions in preparation for both musical and wider social cognition. The meaningful others in the room become tools to support student learning (Graziano & Cooke, 2006; Windsor & de Bézenac, 2012). "The richest and most elaborate affordances of the environment are provided by other animals and, for us, other people" (J. J. Gibson, 1986a, p. 135).

Figure 4.8 - Social collaborations between teacher and students, and students and students

Group instrumental classes fulfil other social aspects as well. They are less intimidating for young children. In experiments on learning music in individual and collective settings, a student reported that he felt more confident, comfortable and relaxed in a collective lesson as he felt "backed by my colleagues" (Schiavio, van der Schyff, Biasutti, Moran, & Parncutt, 2019, p. 10). Other students reported that the responsibility is shared in collective lessons, and the teacher is not so focussed on just one person. The student said they cared less on the quality of their work, and the article went on to point out that instructors in collective classes are less involved in the individual acquisition of technical skills (Schiavio et al., 2019, p. 9). This, however, is not the case in Phil's class, as the techniques are so carefully scaffolded through movement and gesture with singing and playing, and then socially mediated by both Phil and the carers when the students return to their instruments. Additionally, because there are other people in the room to assist in managing the learning, Phil is able to walk around the room and subtly adjust a posture or finger shape, all without bringing too much attention to who or what is being adjusted.

Multimodal learning

Phil's lessons are multimodal[15], which is very unusual in the instrumental context. Instrumental lessons are usually focussed only on reading music and playing a specific instrument. In Phil's lessons, all the modes interact to deeply connect musical understanding.

Multimodal, in this thesis, refers to the "mode" of musical behaviour. The multiple modes of musical behaviour include singing, moving, playing, notating, using language, dancing, gesturing, composing and improvising. When information is obtained in one mode then practised in another, the crossmodal interaction facilitates interpretation from one to

[15] Multimodal – see Chapter 2, p. 79

the other (Anderson, 2016; Rohlf, Habets, von Frieling, & Röder, 2017). This results in a cross-referencing mechanism for thinking and understanding information and gives greater depth of understanding about ideas and skills. It speeds up processing of ideas, checks for discrepancies and improves discrimination and perception in musical thinking (Fortuna, 2017).

Phil was masterly in integrating many different modes for knowing and practising the same skill or concept. In the five-year-old class, the students sang notes while Phil made little stories about the notes on the staff lines. The children sang and identified the notes while he was doing this and therefore, achieved the crossmodes of reading notation and singing modes.

The students then went to their pianos, with the music notation on the stand and sang and played the notes to solfa (reading, singing, playing modes). A music recording of an orchestral arrangement was then played that the five notes could be played with at specific points (reading, singing, playing, listening). The children all played the notes with both hands (*Fig. 4.9 & 4.10*), an intricate task when the first note on the left hand would be played with the little finger, while on the right, with the thumb. When the recording stopped, the children all changed pianos and started again, reorienting to the new piano. Phil and the carers ensured that the students were doing it correctly, synchronising to the music, and all to each other.

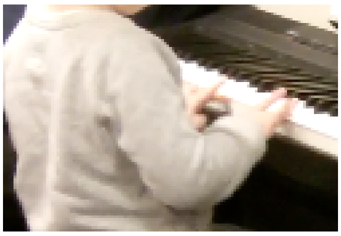


Figure 4.9 - Playing with both hands (1)

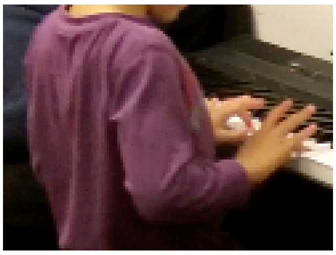


Figure 4.10 - Playing with both hands (2)

After this activity, the students returned to the front of the room and sang another song where the focus was on the 3rd, 4th and 5th degrees of the diatonic scale (me, fah, soh). Singing these notes was accompanied by movements that represented a rhythm and pitch pattern, thus preparing them for the patterns they would transfer to instruments. Small boxes of chime bars were handed to the students and they chose the bars that corresponded to the pitches they had been singing, setting them up on stools in front of them (*Fig. 4.11*). The patterns were then played and sung with the recording of the orchestral arrangement. This activity achieved the crossmodal integration of moving and singing to playing, listening and jointly acting.

Figure 4.11 – Setting up pitch chime bars

The conceptual development continued in another mode, playing, but again preparing the body before transferring to the instrument (*Fig. 4.12*). Still playing the me, fah, doh pitch pattern, the students lay on the floor in front of Phil and mirrored his finger movements as they sang and moved the pattern. They then "found" the notes on the piano, still singing the notes while they played, making the crossmodal integration of singing, playing and ensemble.

Figure 4.12. - Preparation of the pitch and rhythm pattern before transfer to instrument

Crossmodal and multimodal development primes the body for musical success. There are six aspects that are achieved through priming in this instance: **motor planning, reward through reinforcement, musicality, tool/body relationship, sensorimotor integration and error detection.**

Motor Planning and reward

Priming through embodied preparation (preparation through action - embodiment) ensures that by the time the students play the repertoire on the piano, the motor pattern is so precise and neurally mapped, that they experience immediate success. This immediate success again primes for future success, motivation and inspiration to keep going. In the brain, being motivated equals reward, and creates ideal conditions for the release of neurotransmitters that allow neuroplasticity, the changes that take place in response to experience (Carrasco, Serrano, & Garcia, 2015). When the activity is rewarding, the brain is more engaged and ready for action, and keeps the person in what Michael Merzenich calls, "learning mode" (2013) . This is the state where we are "alert, concentrated and focussed - the brain's plasticity switches are "on" and ready to facilitate change" (Merzenich, 2013, p. 53). This learning-driven neuroplasticity also strengthens connections between neurons and networks of neurons, so that every part of a motor plan of action/s is connected in a "continuous associative flow" (Merzenich, 2013, p. 56), so necessary for deep knowledge and understanding.

Being successful helps develop a self-concept about one's ability to be musical and encourages persistence. When this self-concept is developed at an early age, students develop positive beliefs about their abilities (Marsh, Craven, & Debus, 1991).

Musicality

The other aspect that preparation through embodiment has achieved is that success within the musical moment "keeps it in musical place" (time-pressured/ real time). There is no instability to interrupt the flow, and every beat, tone and timbre arrives in the moment synchronously. This only occurs when the performer is deeply and skilfully engaged with the music.

Mihaly Csikszentmihalyi, renowned for positive psychology and flow theory, describes "flow" as occurring when "our abilities are well matched to the opportunities for action…Action and awareness are merged." (Csikszentmihalyi, 1997, p. 2). In order for this to occur in learning, the activity must match challenges to skill level, so that the task is "neither too difficult nor too easy – [which] is essential for students to be attracted to learning" (Csikszentmihalyi, 2015, p. 175). The attention and concentration must be so deeply engaged that one loses track of time.

"Distraction interrupts flow" (Csikszentmihalyi, 1997, p. 2). When there is an interruption through unstable motor plans or other distractions, this stops the "flow" of the music through time and disrupts the inner sense of the way the repertoire should sound. Because Phil prepared and primed the students through the embodiment of the glissando technique for example, the students were successful in performing it in the repertoire. There was no disruption or distraction to the flow of the repertoire. The performance was musical and created a motor plan in memory to represent a sequential flow. It is only when there is a musical flow that musical behaviour can be achieved.

Peripersonal space

Phil's pedagogy facilitated the piano (and other musical tools) becoming part of the brain-body system of his students. This was achieved through his use of space; the effect that this has on peripersonal space is again unique to this instrumental context. Most instrumental classes do not have students moving from instrument to instrument, socialising with other students and carers and using many different musical modes.

Peripersonal neurons are specialised, multisensory neurons that encode the space around our bodies and specific body parts (Makin et al., 2007). This space affects how we interact with objects and people (Graziano & Campbell, 2018, p. 3). The social aspects have been described previously under "the world is part of the cognitive system" (see p. 20 of this section). However, this section focuses on the body-spatial aspects of tool use and how this is developed in Phil's pedagogy.

Instrumentalists become more and more skilled as they repeatedly interact with their instrument. The action, motor plans become refined and myelinated (the neural, chemical process to make hard memory) to create strong, fast, efficient, unconscious memory (Purves et al., 2013). This results in fluid and skilled action on the musical instrument or tool. "Tools or instruments can be seen as body-extensions" (Leman et al., 2010, p. 205). While using the tool or musical instrument, it becomes an extension of the body and takes up neural space, as if it is a body part (Iriki, 2006, p. 660).

In Phil's lesson, students repeatedly returned to their instrument to refine these motor plans. This achieved a constant reorienting of the body to the instrument, but there was another feature of the pedagogy that was really clever in making these memories even stronger. The students repeatedly changed places and instruments, providing repetition of repertoire, a vital aspect of developing strong memory, but also reorientation of body and instrument. This embodied information becomes part of the body schema and contributes to an understanding of "posture, location and movement of the body in space, together with assessments of the anatomical and functional relationships of different body parts" with the instrument (Iriki, 2006, p. 661).

Later in Phil's reflection, he mentioned that this was a carefully designed aspect of his pedagogy as most students do not have a piano at home, though some have a keyboard. This makes this interaction and variation more vital for their development of the piano they imagine in their brain.

Imagining the piano, or instrument, is due to the peripersonal and mirror mechanisms and is a vital aspect of being able to develop abstract memory for skilled musical thought. When I hear a melody and think about how to play it, I "see" the piano in my brain, even though I am not a skilled pianist. The piano is very visual in its spatial arrangement of pitch, and being "before your eyes" while playing, is easy to imagine. An instrument that is not in your visual landscape, such as the flute, is harder to visualise, though motor memory contributes to the ability to imagine how to play a melody. Phil's pedagogy quite deliberately builds the neural space for the piano in his students' brains.

Tools, affordances and extended cognition

The use of many tools with musical affordances, such as the body (movement and gesture), the voice, instruments other than the piano, provides skilled, musical action opportunities. In terms of the four categories of tools with musical affordances proposed by this thesis, Phil's pedagogy achieves them all.

- **Physical** – musical instruments, movements, gestures, games;
- **Conceptual** – Scales, forms (e.g. rondo, sonata etc), repertoire, symbols, techniques, language, songs;
- **Cultural** – dances, choirs (singing together), ensembles;
- **Social** – the interplay between individuals and groups.

All of these tools support music cognition (*Fig. 4.13*), assist students in becoming more skilled in musical behaviour and allow cognition to extend into the world through using tools (Clark & Chalmers, 1998; Krueger, 2014; Menin & Schiavio, 2012; Mooney, 2010; Windsor & de Bézenac, 2012).

Figure 4.13 - Multimodal, social cognition

Phil's reflection after the lesson and course

Phil attended the 3rd neuropedagogy course in Sydney, February 2017.

Neuroplasticity, mirror neurons and learning

Phil also teaches swimming and on the 2nd day of the course, left to teach one of his swimming students. He said that he believed that the process of teaching swimming and piano are quite similar, as they both involve technique and lots of repetition. He said:

> Many things I believed about teaching and learning had been solidified and actually given a name. I explained [to his students] I was at two days into the course, I could be "dangerous" (**joking**) with my knowledge because now I could explain in detail why things were happening in their brain and what the outcome would/could be.
>
> (Phil. personal communication, 21 February 2017).

Neuroplasticity was the neuroscience aspect Phil was discussing with his student, and he went on to explain to him why changing his swimming style was going to be quite challenging, because the motor plan the student had developed would need to be changed. He then explained about myelination, hard memories and so on, and he said that the student was interested that correction of his swimming stroke was a process that was achievable by effort, not because he was "wrong" but because it was a neural process.

Use of technology as a tool with affordances to support Phil's pedagogy and the students' learning

Phil used his iPad as a tool with affordances for supporting the learning of the student, by videoing his swimming stroke. Phil was able to slow down the video and frame by frame show the student about head position, hand entry and so on. The student then understood what they needed to change. Recalling the information about mirror neurons, Phil then entered the water and the student imitated the positions as Phil did them. Phil said he was thinking about the mirror neuron system and learning through imitation and embodying the learning. They then put on flippers to enable the "drills" to be easier and Phil suggested that this was extended cognition as they were extending their thinking into using the flippers, an external object that became part of the cognitive task. Phil said that the outcome of the swimming episode was that the student swam with a sense of achievement because they found it easier to swim.

Phil said he thought a lot about the affordances provided by technology in his teaching, and while there has not been a description of this in this section, it is evident in his studio and materials how technology enhances his teaching. For example, he uses the affordance of technology to change the speed of the music. This allows him to precisely match the tempo of the repertoire to the needs of the students. Another way he uses technology to enhance learning is through use of the mobile phone. As previously mentioned, most students do not have a piano at home, though some have a keyboard. He asked parents to take a photo of students playing at home so that he can check that the piano stool is at the correct height, their posture is correct, and their hand shape is ideal.

Phil also uses the space as a tool with musical affordances. For example, he lies down on the floor to demonstrate hand shape because he can closely check this with their hands beside his, they can closely see his hands to imitate, and the action of pressing down on the floor emulates the action on the piano keys.

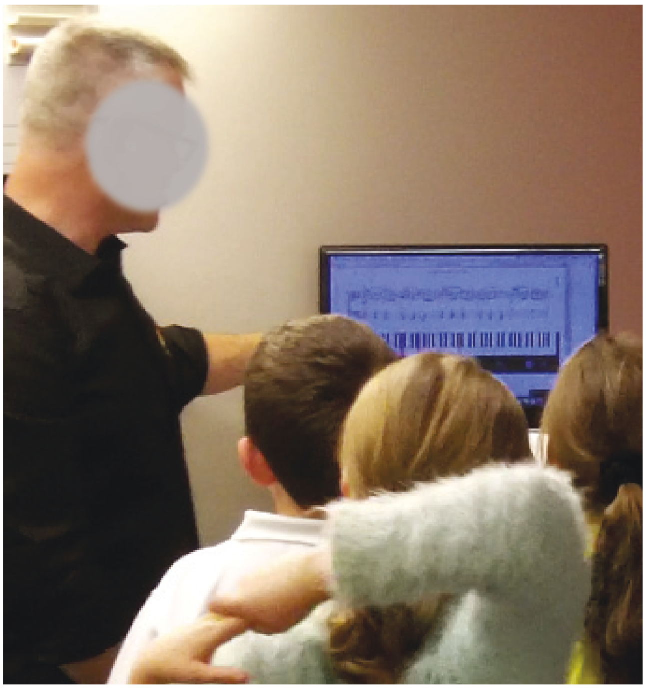


Figure 4.14 - Learning to use "Practice Buddy"

Use of technology is a big feature of Phil's instruction system. He finds it is a strong tool for enhancing learning. He has developed apps and online videos, that he calls, "Practice Buddies" (*Fig. 4.14*), that demonstrate hand position, motion and help link the sound, symbol and techniques in real time, or at an appropriate tempo for the student. This use of technology means that when the student is not in the classroom, they still have access to meaningful tools to enhance their learning. Mirror neuron research impressed Phil and he felt, confirmed the validity of this aspect of his pedagogy. He said, "they can see the piano being played by a hand, so they can copy the hand, and that's why I went, oh yes, mirror neurons". Parents also strongly confirmed the benefit of this aspect of his pedagogy. While they come to the lessons in the younger classes, it is often not the same parent who practises with the student at home. Phil said that 20 years ago, it would be the mother who came to the lesson with the child. In the lesson I saw, there were 3 fathers and 3 mothers. Sometimes it is a carer who does not supervise home practice. However, having the Practice Buddy app provides the model that the students had in the classroom so that the parent also understands what needs to be practised.

Phil also discussed that the idea of neuroplasticity was strong in his teaching. He incorporated challenge, attention, repetition, change and novelty when the students changed the position of the instruments, changed the musical tools, changed the social collaboration and so on. His students also do external music examinations, more as a challenge than a requirement. However, he ensures that the teaching of the examination repertoire still incorporates strong multimodal, social and skilled musical development through embodiment of being musical.

Multimodal aspects in Phil's pedagogy

The multimodal aspect of learning and how this strengthens and interconnects musical understanding is another strong feature of Phil's teaching. He said that the students usually begin their musical training with him at about 4 or 5 years. At this stage, there is much movement, singing, playing lots of percussion instruments, socialising and so on to develop these deep multimodal memories. He said that at about the age of 12 years, this learning begins to be clearly apparently, as they can identify chord structure easily through listening, they can play by ear as well as from notation, they can compose and play with others, they can improvise in response to musical style. This all builds a highly interconnected and deep understanding about playing their instrument and being musical.

Reflection by Phil, two years later, on the impact of the neuroscience and embodiment research in the Neuropedagogy course

Phil has often sought time for chats with me over coffee, to hear about new research, to ask questions and discuss what he has been doing with his music pedagogy. Two years on from the neuropedagogy course and the lesson observation, he discussed the importance of multimodal teaching. He observed the brain's frustration with changing old habits that had become a hard memory (neuroplasticity) and the importance of social interaction between teacher and students, AND students interaction with other students, be that performing (ensemble) or teaching each other.

He felt that the research presented was very pertinent to learning in music and confirmed and verified his pedagogy. He said that it gave him the words and understanding about what to do, and that it was wonderful to have the academic research that explains why embodiment results in “kids who now just love playing music for the fun of it” (P. personal communication, 14 August, 2019).

The instrumental classroom and music pedagogy informed by embodied cognition and cognitive neuroscience

The overall feature that immediately is apparent in this lesson is action. The students are very busy. This observation was so full of action it was impossible to take notes as well as look. Video was essential for capturing all this. The action was strongly informed by embodiment and neuroscience in Phil’s use of space, social cognition, use of tools and their affordances and multimodal learning.

The place and space in Phil’s classroom contribute to musical cognition and behaviour. The place invites musical behaviour because of the arrangement of the environment. There is a place to instruct, a place to move, places to be in position with the piano, and enough space to incorporate use of other instruments.

Social cognition and musical social cognition are a strong feature of this setting. There are others in the room to facilitate and support learning; the parents and carers. There are many opportunities for students to interact with each other in musical activities such as games, but importantly, also in ensemble, an opportunity that is often missing in instrumental lessons, especially on the piano.

Multimodal learning reinforced concepts in rich and interconnecting ways:

- What was sung was moved and played and often integrated in the same moment.
- A song was accompanied on the body with body percussion while singing and moving.
- A recording played while students sang and played.
- Gesture and movement prepared for instrumental technique before students performed these on the piano.

Technology is used by Phil as a tool that has affordances for developing musical behaviour. The "Practice Buddy" app reinforces what has been learned in the class. It also uses aspects of embodiment by having a real hand playing the piano to provide a model of the sound and action. The app reinforces the in-class model so that when students practise at home, they can see and hear an accurate demonstration. Parents report that this keeps their child motivated nor expect their parents to be able to help them. Quite often, while parents attend the class, they may not be able to assist their child with the finer details of movement and sound. Video was also used to ensure that good playing habits were practised both at home and in class.

In terms of an instrumental lesson, the most unusual feature was the use of tools and affordances. Usually in an instrumental lesson, one learns one instrument. In Phil's class, the use of tools and their musical affordances supported understanding in one way of performing to another. For example, a song was accompanied by gestures to represent beat, or rhythm patterns or instrumental techniques. The knowledge and skill from doing that was then transferred to the instrument. The students had already embodied the melody through hearing and singing it and embodied the instrumental techniques and beat and rhythm patterns through movement and gesture. The musical process was highly sensory, as students saw, heard and felt all the intricacies of what their bodies felt like while doing these actions. The experience of actively embodying and creating knowledge developed skilled, sensorimotor networks to represent musical cognition.

4.3 The secondary setting – Problem-solving with the body

This section is about secondary school classrooms where Dana and Steve teach. The most salient features of these lessons are how music cognition was extended into the body and musical tools and enhanced through joint action.

Dana's secondary music classroom – Multimodality, embodiment and joint action

This secondary music classroom is a Year 11 class, at an independent, co-educational secondary school in Tamworth, NSW. Dana is Head of Music.

Introducing Dana

Dana is a highly skilled music teacher. As with all the participant-researchers, she is a graduate of the Level 4 Orff Schulwerk Teacher Training courses but is widely interested in developing her professional practice and has long been involved in workshops, conferences and research to improve her practice. She is a very positive and "smiley" teacher and the students have a comfortable rapport with her. The students also are positive and confident when in her classroom. They openly discuss and show her what they are doing, ask questions, and freely explore lots of sound (musical) possibilities. They are also happy to move to music and use all the space in the room. When one enters

Dana's classroom, there is a feeling of expectation, possibilities, exploration, and that students are ready for action.

Dana's professional background

Qualifications: B.Mus.Ed.

Classroom Setting

Dana's classroom is a dedicated music classroom. It has lots of musical tools available in the room, from melodic and non-melodic percussion instruments, some band instruments such as a drum kit, sound and other technology equipment. The space is large and, while there are chairs and tables, these are stacked to make lots of room available for flexible use of space. Year 11 students are fully grown and need a lot of space to move. They do not wear shoes in the room. No shoes allow safer movement activity.

The class has ten students, five boys and five girls. Being 16 – 17-year olds, they are very exuberant and active in a setting where movement is encouraged. There was lots of laughter and action. All students were fully engaged with the activities.

Cognition is time-pressured *(Wilson, 2002)*

In real-time, cognition arises and unfolds in the moment. The world does not wait, though good music pedagogy can provide tools for bringing attention to musical elements in real-time. Such tools include embodiment[16] and tools with musical affordances[17].

The very first activity that students performed in this lesson was movement. The repertoire was "in their ears" and in the body instantly.

---

[16] Embodiment – see Chapter 2, p. 25

[17] Tools with musical affordances – See Chapter 2, p. 82

There is no time to waste in the secondary classroom, where lessons are in strictly 50-minute segments. Dana did not waste any time with explaining about the music. The only instructions she gave were simple and reinforced with large cards she held. On one card was “mirroring” and the other, “travelling”. The “mirroring” instruction meant that students were to be in a pair and mirror each other’s movements until she held up the “travelling” card. The “travelling” card meant that they moved individually around the space in any way they wished, to the music, until she again held up the “mirroring” card. When this occurred, they quickly faced a partner and began mirroring each other again. There was no discussion or negotiation regarding partners, as the music did not stop, and the action kept on going.

Not stopping and continuing action is an aspect of time-pressure that realistically occurs in music. The repertoire does not wait for you to be ready to participate. Improvisation and participation are “in the musical moment”. Dana’s pedagogy prepared students for thinking about, and responding to music, in real-time. The pressure of time also sped up negotiation for leadership, as there was no time to discuss who was leading the pair.

Cognition work is extended into the world and cognition is for action and Sensorimotor integration

A feature of this lesson is how Dana developed cognition through grounding the learning in perception / action processes. Her lesson fulfilled all the claims for embodied cognition, but this section will particularly focus on how cognition extended into the world, showing that “cognition is for action” (Wilson, 2002, p. 626), and these together formed strong sensorimotor integration. This is a circular process. Knowledge and cognition are developed through the world exerting pressure for action on the individual. The individual acts, developing sensorimotor integration, and this action makes a change in the world that then creates more action opportunities.

Perception, action and cognition develop reciprocally

The music lesson opened with the development of music cognition through moving to the music. Moving to the music quickly engaged the motor and auditory systems in these students. "Music perception is shaped by the human motor system and its actions" (Maes, Van Dyck, et al., 2014, p. 1). It was interesting to see the raw response of the students to the music. The students had not practised any specific movements to the music. Therefore, it was interesting to see that spontaneously, every student responded vigorously with movement. When I commented to Dana after the lesson on their willingness to move, she said that this was the first year level "that had experienced a very active, movement-based curriculum right through secondary" (Dana, personal communication, 10 October, 2016). She felt that because the students were used to responding with movement, they were able to respond without feeling embarrassed or inhibited.

Figure 4.15 - mirroring

At first, there was just lots of movement, seemingly unrelated to the music. Movements were fast, and for the partner who was copying (mirroring) (*Fig. 4.15*), this would have been difficult to copy at exactly the same time. Movements that are repetitive and predictable in a musical style are more easily copied, and as the activity progressed, repetition, and movements that looked more connected to the music started to appear. There were some movements that were cooperative movements, that needed the participation between the pair, such as a meeting of hands on the beat. This required joint attention and coordinated action (Sebanz et al., 2006; Vesper et al., 2017). It was clear by this time that the students had started to listen and sense aspects of the music and respond to the music rather than just move.

Dana's pedagogy also created dynamic interaction amongst many in just a few minutes. The students "mirrored" in pairs for just short periods, such as 40 seconds, before they "travelled" individually, moving in any way they wished, before combining actions in a pair again. This process resulted in accelerated patterns of learning as the student experienced many different actions related to the music in a short period of time.

Perception guides action and action influences what is perceived (Vernon, Lowe, Thill, & Ziemke, 2015). Hearing the music would guide how to move, and when students see other students moving, that would influence what they heard in the music. Social interaction is a powerful mechanism for learning. Moving together creates a feeling of cohesion and shared perspective-taking through joint action (Pacherie, 2014). In social interaction, shared mental states pool collective cognition and bring actions into alignment (Gallotti & Huebner, 2017). As students see each other move, they are influencing each other's perception of the music and co-constructing musical meaning (Maes, Van Dyck, et al., 2014).

Vesper et al (2017, p. 2) outlines coordination mechanisms that allow us to successfully coordinate movement through joint attention. In the case of copying someone else's movements to musical repertoire, the type of mechanisms involved would be:

- *Joint action goal* – to move appropriately to the music;
- *Task representation and sensorimotor prediction* – understanding of the type of movements that might occur to this type of

repertoire, what movements might follow one from another (e.g. if a leg tapped to the right, one might predict the next action would be tapping to the left);

- *Sensorimotor communication* – understanding how the movement fits with the repertoire (e.g. to the beat, with the contour of the melody and so on);
- *Multisensory processing* – integrating information from multiple senses (e.g. sight, hearing, haptic, proprioceptive senses);
- *Conventions and culture* – appreciating rules about who carries the lead.

Joint action goals can influence the acquisition of new skills. When people learn and act together in joint action, their mental representations incorporate the other's actions. This joint action constructs knowledge from both participants and transfers between them. Social interaction in joint action "can shape our most basic action, perception, and cognitive processes" (Loehr & Vesper, 2016, p. 546). Classroom music activities such as "mirroring" incorporate this type of learning, where the knowledge and skill of each participant in the joint activity transfers and helps construct musical cognition.

The creation of perception and action networks results in skilful sensorimotor integration. The development of perception action networks occurs over time as experiences are reiterated, rehearsed and practised in many different ways. This repetition process develops cognition that is shaped by skilled sensorimotor capacities in tightly coupled cognition, action, perception systems (Garbarini & Adenzato, 2004; Rizzolatti & Fadiga, 2007). In the instance of Dana's lesson, the perception of the music "spurs action tendencies" (Maes, Leman, Palmer, & Wanderley, 2014, p. 1) which in turn shape cognition. As the music activity in Dana's lesson was a highly socially-mediated activity, between pairs and within a group of students, the process was also mediated by social interaction, all strong markers for developing powerful memories.

Extending cognition through use of an affordance – the drumsticks

In the next part of the lesson, Dana gave all students a pair of drumsticks. Providing the students with a new tool offered new possible interactions with the music, the space and things in the space, and other students. The only difference in the activity was the addition of using drumsticks, and a third card, the "drumsticks" card, was added to the "mirroring" and "travelling" cards. When the "drumsticks" card was held up, the students were to find ways of making sounds with the drumsticks. When the "mirroring" card was held up, they were to use their sticks in pairs in some way.

The music was started, and the movement began with "travelling", but this time they had drumsticks in their hands. The movement was qualitatively different, even if they were not moving the sticks around. The students were much more constrained when "travelling" with the sticks. Some were more flowing in their movements, as if with extended arms, and finding long durations in the music to synchronise with. Using the drumsticks afforded different types of movement and interaction with the repertoire and other students, and thinking was extended into using the tool (Clark & Chalmers, 1998; Krueger, 2014). The use of the sticks guided the students' attention to different aspects of the music. When the "drumsticks" card was held up, there was initially much action in finding sounds that could be made using the drumsticks, hitting objects in the space such as walls, furniture, air-conditioning ducts and so on. This sound-making seemed to not relate to the music. Initial activity was entirely about exploration of the tone colour of the sticks, and the sticks in relation to other materials (*Fig. 4.16*). However, as the activity progressed, some students returned to the place where they had explored the sound previously and began making rhythm patterns that related to the music. The "travelling" with sticks engendered relationships with longer durations in the music, such as phrases, but the drumsticks prompted relationships with the rhythm patterns in the music. Structure and Duration are concepts that students engaged with because of the tool, and is a good argument for using tools to develop musical skills.

Figure 4.16 - Exploration with drumsticks

The affordances of the drumsticks developed deeper engagement with, and discoveries about the music, without Dana making this explicit in her teaching. The tools created a drive in the students to explore and become more skilled in their interaction. "Spontaneous exploratory activities are firstly focussed on directing attention outward toward events, objects and their properties" (Menin & Schiavio, 2012, p. 211), then gradually this manipulation leads to discoveries about musical elements. Students make connections between musical context and intentional, musically-directed actions through affordances (Menin & Schiavio, 2012); in this case, the drumsticks. Kreuger describes this process as "drawing novel experiences out of us" (2014, p. 1) through extending thinking into the musical affordance of the tool.

Extending cognition through use of an affordance – melodic percussion instruments and ostinato

Drumsticks and the body were the initial musical tools that Dana used in her pedagogy to engage the students with the repertoire, and provide skilful ways of musical interaction. Tools change perception and behaviour (Anderson et al., 2012) and "play an active role in driving various cognitive processes" (Krueger, 2014, p. 5).

The next musical tools that students used were melodic percussion instruments. Coupled with this was the use of the conceptual tool, ostinato. Ostinato is a repeated pattern in music. It can be melodic or rhythmic or both. The ostinato was from the piece of repertoire that the students had moved to, so they had already developed a "feel" for how it fitted with the style of the music. Additionally, they had moved and played with the sticks to it, so they had developed a "feel" for patterns that would fit with it.

Dana taught the students the ostinato on the melodic percussion instruments. The students learnt this very quickly as they had heard it multiple times while they were moving. The sound was already "in their bodies and in their ears". Then, while half the class played the ostinato, the other half explored sounds to create their own ostinato that would fit with the existing one (*Fig. 4.17*). It is interesting to note that while students were very active and used big movements continually while moving throughout the previous activities, when sitting using the instruments, they were very focussed and managed in their movements. This focussed behaviour could have been a result of having satisfied a need for movement, as

Figure 4.17 - Ostinato and improvisation

well as being ready and prepared through the previous activities to perform on the instruments. Physical activity is very important in the development of memory (Bekinschtein, Cammarota, & Medina, 2014; Donnelly & Lambourne, 2011), learning (Glenberg, 1997) and music cognition (Gruhn et al., 2012).

Understanding how an ostinato would fit with the existing ostinato required active exploration. There was a specific goal and thinking was extended into using the instrument to solve the problem of fitting one ostinato with another. Without the instrument, solving this problem would not be available to them. The intrinsic properties of the instrument as a tool in providing pitch meant that the students did not need the ability to imagine this complex task. They could think as they were exploring. In this way, thinking is active exploration. Musical thinking emerges from dynamic, embodied interactions between the brain, the body and the world (Menin & Schiavio, 2012).


Figure 4.18 - Composed ostinato

After some exploration time, students performed their ostinato to the class. The first student's ostinato used a rhythmic pattern that was complementary to the existing ostinato in the repertoire. The second ostinato had the same pattern but with a complementary melodic pattern. The third student's ostinato had rests (spaces with no sound) to complement the existing pattern that had no rests. The fourth ostinato was a combination of all of these ideas. The fourth student's ostinato had a complementary rhythm pattern, melody and rests. It was also longer. What was also interesting about this ostinato was in the way the student played it. Because of the rests, to keep the ostinato in "place" in time, his whole body was moving. His body helped him keep the "place" but also, it helped the observers understand the "place" (*Fig. 4.18*). Body movement conveys much information to others as they perceive and predict how the movement matches the music (Demos, Chaffin, & Logan, 2017). The student was using his body as a tool for delineating time and assisting his overall performance.

Cognition is for action and action shapes cognition – student reflections

Repeated explorations with movement and the drumsticks, synchronised with the music, developed internal associations between actions and sound (Maes, Leman, Palmer, Wanderley, et al., 2014). The students' movements and use of drumsticks shaped their musical cognition, so that after the activity, students were able to reflect on this.

Dana asked the students, "Did anyone find what happened in that [activity] particularly interesting?". Without specifically suggesting any particular aspect, this focussed the students on recalling their actions and consciously thinking about their response to this. One student immediately answered with, "I feel like the stick noises, like, there was such, there was such variation, like get some <u>grooving parts that were crashy and punky out there</u>" (moving the sticks around on the underlined words).

Another said, "Yeah the stick bit. It sounded really cool". These comments revealed that the students had made connections between what they did and what they heard, between action and perception.

Affordances as pedagogical tools

Dana used the cards with the words "mirroring" and another with "travelling" printed on them to tell students when to change action. This was a skilful use of a pedagogical tool. It afforded change in student behaviour without Dana interrupting either the sound or the flow of the activity.

Dana's reflections after the lesson

Dana reported that apart from two of the students, most could not read music and were self-taught, "natural" musicians. For this reason, she really wanted the students to feel and move to the music before they did anything that required more theoretical knowledge.

Having the first activity, where students moved to the music in pairs, individually, then with the sticks, was designed to get them "in tune" with the music. She thought that they were then aurally prepared for music making on the instruments and improvisation with the musical elements, starting with ostinato.

Dana said that she finds if she does not do embodied musical activities first, if she tries to do anything else, they just look at her blankly and say, "Well why am I doing this?". Now, she just naturally does this first, embodies the musical ideas in some way before going into more theoretical ideas. Her focus for what the students will learn through this repertoire is bitonality, but before she gets to this point in the learning, there will be many steps of embodiment before they have internalised the understanding of this.

Steve's secondary music classroom - Multimodal embodiment and joint action to experience chord progression

In an independent school in Singapore, a Year 7 class was experiencing chord progressions multimodally, through the body.
Steve, the teacher, was a participant in the last Neuropedagogy course in Singapore and immediately was inspired to embed embodiment in his music pedagogy.

"Chord Dancing", or moving to show chord progressions

Year 7 learnt a simple two chord song, then were given a large card with one note of a chord written on the card e.g. C, E or G for the C chord, and G, B or D for the G chord. The students had to sing the note on their card. When students heard their chord, if their note was in that chord, they had to step and move around the room. When their chord was not being played, they stood still, as the other chord notes moved around them. The common note in both chords, the G, was the only note that could keep moving. The teacher was playing the ukulele and sometimes did not play the chords predictably, so students listening was tested.

The purpose of Steve's activity was to teach the students to "hear" chords in musical repertoire. Students who had the same card at first moved and sang their note as a group when their chord played. Performing as a group allowed socially developed cognition to occur. When the group all sang the pitch and moved whenever the chord occurred in the repertoire, this reinforced to all in the group how the pitch fitted into the chord and what happened in the repertoire (what it sounded like) when the chords changed. This is another example of how social interaction in joint action assists in the acquisition of a skill (Loehr & Vesper, 2016). As students became more confident, Steve instructed them to move individually, not in a group, but still acknowledging chord changes and singing their notes. Without telling students the answer, Steve's pedagogy allowed the development of musical skills and concepts in the authentic context of the repertoire.

The note cards were then scattered all over the room and as the teacher played chords, the students had to move to a note of the chord being played and sing it. The activity kept on evolving with different movements and students singing the notes, until by the end of the lesson, the class could sing chords to accompany a song. The following lesson, what had been learnt about chords was then transferred to melodic percussion instruments where they explored improvising melodies with the chords.

In the course of this lesson, Steve's class used multiple modes of being musical. They used:
Physical tools – musical instruments, Note Cards, gestures and movements
Conceptual tools – song, symbols (notes), language (musical terminology), chords
Cultural tools – ensembles, dance
Social tools – other students.

All the students were moving and responding to the repertoire and the responses were visible, audible and kinaesthetic. These actions provided an integrated, multisensory, multimodal representation of learning about chords in music, so that there were many ways of developing memory of this concept.

When concepts and skills are practised across modes, multimodally, information in one modality reinforces understanding in another, and the memory and mental schema become multimodal. "Cross-modal perception is a form of multi-modal [sensory] perception that leverages the information obtained in one modality to facilitate the interpretation of another modality" (Martin-Martin & Brock, 2017, p. 1).

Summary

The music pedagogy of Dana and Steve reflect a focus on immersion in embodied musical experiences to develop music cognition. Dana used terms such as "in tune" with the music, "get the feel of", terms that suggest an embodied approach to learning, and in a later communication, said that the students now "effectively problem solve with their bodies" (Dana, personal communication, 1 November 2016). In both Steve and Dana's lessons, the cognitive load was lightened by extended thinking into the body and tools. "Learning is primed by what we perceive, and what we expect in the world as we move about it, in addition to how we interact with objects and situations discovered" (Johnson-Glenberg et al., 2016, p. 3). The way Steve and Dana used the body and tools, supported and strengthened students' musical learning.

Joint action was a strong feature in both classrooms. Social interaction enhanced and assisted skill and conceptual development in the students. Joint actions are "useful to not only gather information about other people but to actively provide others with information about one's own actions" (Vesper et al., 2017, p. 5).

Overall, the importance of movement in shaping cognition (Maes, Leman, Palmer, & Wanderley, 2014; Phillips-Silver & Trainor, 2005) was underlying all activities in the secondary classrooms.

4.4 The primary setting – Complexity through simplicity

The Primary setting has a Kindergarten and Year 4 class, both taught by Lauren.

The primary education classroom - Kindergarten

This first primary education setting is a Kindergarten class of twenty-four students, all girls. The outstanding feature of this lesson was how complexity arose from simplicity. Simplicity was provided in the form of simple speech rhyme. Complexity arose from how the speech rhyme, as a tool, was used to afford musical behaviour and thinking.

Introducing Lauren

Lauren is forty-eight years old and is a Kindergarten to Year 12 teacher at an independent school for girls. She is a graduate of Level 4 of the Orff Schulwerk Teacher Training course and has been highly sought after for her expertise in teaching music. Lauren is a mentor-teacher in the Richard Gill music teacher mentoring program and has gained high praise from many teachers throughout Australia for her ability in facilitating confidence and skill in their music teaching.

Lauren's Professional Background

Lauren has a Bachelor of Music Education and Master of Music.

Classroom Setting

This lesson was with a Kindergarten class of twenty-four students, all girls. They have two 40-minute lessons per week. Lauren's classroom is a music room. It looks, sounds and feels like a music room. It is a large classroom with an abundance of musical and other equipment, and lots of space for flexibility of use. Lauren has a large array of melodic and non-melodic percussion instruments which can be seen on shelves and set up at the side of the classroom; an interactive whiteboard and quality sound system; medium-sized, stackable chairs, suitable for primary students; small whiteboards for students to use for symbols and notation, write upon, and use in group activities; stools for sitting with correct body posture at melodic percussion instruments; a piano; and a storeroom for books, scores, and other music literature.

Kindergarten classroom – complexity through simplicity

The six claims of embodied cognition *(Wilson, 2002, p. 626).*

This section will focus on the 1st and 2nd claim of embodied cognition.

1. Cognition is situated - Use of space where learning takes place

The majority of the space is empty so that it can be used for any sort of movement activities. During this lesson, this space was used with everyone in a circle (*Fig. 4.19*); walking anywhere in the space (*Fig. 4.20*) (to the beat); performing in pairs anywhere in the space, but had to change partners quickly, so lots of space needed; back to sitting on the floor in a group in front of Lauren (*Fig. 4.21*); to working in small groups, distributed through the space (*Fig. 4.22*).

Figure 4.19 – Sitting in a circle

Figure 4.20 - Walking to the beat anywhere in the room

Figure 4.21 - Class in front of teacher

Figure 4.22 - Groups of students distributed through the space

2. Cognition is time-pressured

Learning in real-time in the real world is time-pressured. Music occurs in real-time and time has passed as the next sound occurs. To bring attention to how time-pressured music is, Lauren devised a game to play with the rhyme. To the beat, she taught a movement pattern to use with a partner (*Fig. 4.23*) while the students recited the rhyme. Still maintaining the beat when the rhyme was finished, the students had four beats to find a new partner and begin the rhyme and movements with a new partner (*Fig. 4.24*). The pressure to find a new partner within the four beats caused a great deal of speed, fun and laughter, but also achieved their understanding of time, duration and structure.

Figure 4.24 – Four beats to find a new partner

Figure 4.23 - Saying the rhyme with partner

Lauren's use of language and the mirror neuron system as a pedagogical tool

Lauren used very little instructional language in this lesson. The lesson opened with her asking the students if they had ever had a fright. Immediately, this engendered lots of facial expressions and gestures to do with fright, such as a quick, inward gasp and short, high-pitched vocal sound, hands up to face, eyes wide, fearful expression, and arms shielding body. Lauren also modelled a fearful expression.

Asking the students if they had ever had a fright was a very clever introduction to the expressive qualities of this speech rhyme, and expression generally in music. As soon as Lauren mentioned "fright", embodied memories of fear and fright were expressed through their bodies. Words and language are grounded in physical experience and link action and cognition (Arbib, 2011; Cartmill et al., 2012). The mirror mechanism would fire in response to Lauren's facial expression and would map back to their past experiences of "fright" (Foroni & Semin, 2009; Kraft & Pressman, 2012). Three aspects would fire the mirror mechanism in response to this:

1. The word "fright" and its link to the action of fear and fright;
2. Seeing Lauren's facial expression and gestures;
3. Their personal, embodied action plans that would signify fear and fright.

The feeling of the embodied memory of fear and fright enhances understanding of the energy used in expression of these, and that understanding is directly transferrable to expressions when playing music. The fast intake of breath, the short sharp sounds of fear, can all be emulated when making music that suggests this expression. Lauren did not have to describe something abstract and expect the students to understand. In responding to that simple question, much valuable personal knowledge and understanding was engendered and physically experienced. "Fright" was a deeply embodied memory. The mirror mechanism produces motor representations, actions and gestures, that make us feel certain emotions and also reflect upon the emotions and actions of others (Rizzolatti & Fabbri-Destro, 2010, p. 240).

Lauren continued to get students to embody other words in the poem, such as night, ghost and so on. As students suggested movements, Lauren copied them and, in turn, all the students performed the movements. The gestures and movements were constructed using the students' embodied memories that the words evoked. Vocal sounds also accompanied the gestures and actions, coupling sound, facial expressions and action to create meaning. "Saw a ghost" was said in a long, wobbly, rising and falling pitched sound, accompanied by ghost-like waving arms and "ghostly" facial expressions (*Fig. 4.25*).

Figure 4.25 - "Saw a ghost"

Lauren told the students that this all happened to a lady called Miss White. Someone immediately called out, "I know her". Again, this is an example that shows how words map back to memory, meaning, place and action. Without instructing the students to copy her, Lauren said the whole poem, accompanied by the actions devised together, and the students all performed the actions. They were imitating Lauren's movements and facial expressions, processed by the mirror mechanism.

Tools, Affordances and Extended Mind

The use of a tool and how it afforded musical learning was the outstanding feature of this lesson. The major tool that Lauren used was the rhyme. It provided the means for learning about musical expression and all the musical concepts, as well as synchronising multiple musical modes.

The rhyme as a tool

Tools engage us with the world and "play an active role in driving various cognitive processes" (Krueger, 2014, p. 5). Tools with musical affordances develop musical thinking and enhance musical behaviour. When using a tool, the mirror and peripersonal mechanisms in the brain include the tool into the body schema as if it is part of the body (Rademaker, Wu, Bloem, & Sack, 2014). With repetition, the brain develops strong sensorimotor representations, resulting in skilled musical understanding and behaviour with the tool (Mathias et al., 2015).

This lesson very simply used a short speech rhyme as a tool for learning (the original version has "Mrs" White, but Lauren changed it to "Miss":

Miss White had a fright
In the middle of the night.
Saw a ghost, eating toast,
Halfway up a lamp-post!
(Ellis, 2001)

The tool, the rhyme, afforded action and expression and afforded opportunities for acknowledging and performing the beat. The students first learnt movement, gestures, vocal and facial expression to perform while saying the rhyme (described below). When the students knew the words well, Lauren then replaced the actions with body percussion, patsch (patting knees) and clap, to the beat. The rhyme afforded opportunities for acknowledging and performing the beat.

The rhyme as a tool for practising musical concepts

Lauren used this simple rhyme to practise all the musical concepts in a meaningful way. When conceptual development in music is actively generated through personal engagement, meaning is connected to the concept. Conceptual development provides strength and depth to musical understanding.

The first part of the lesson was learning the poem, making movements and gestures that enhanced the expressive qualities of the poem, and provided physical structure to the overall form of the poem. The second part of the lesson developed understanding about musical concepts.

The students echoed Lauren phrase by phrase, keeping the beat with body percussion. However, the words were not just spoken. In every phrase, the words were spoken differently. The 1st phrase Lauren said from soft to loud, the 2nd from loud to soft, 3rd phrase whispered, and 4th phrase whispered except for the last word, "post", which she said very loudly. Lauren was using the rhyme as a tool for practising musical concepts, synchronised with keeping the beat. Practising performing in this way was authentic, because the phrases represented the structure of the repertoire, not just speaking loudly and softly in any time. It kept intact the metrical structure, form structure, beat and rhythm patterns of the rhyme. Lauren went on to practise all the musical concepts simply by using this one tool, the rhyme. She practised:
Duration – through getting faster and slower;
Pitch – by saying it in a high voice, and a low voice and fluctuations between;
Dynamics – through using a soft voice, loud voice, and volumes in between;
Tone Colour – by using expressiveness to make voices different, such as an angry voice, a frightened voice, and later in the lesson, by transferring voice to playing instruments;
Structure – through performing the rhyme in its logical structure, phrase by phrase.

The rhyme as a tool for developing audiation

Musical memory, or audiation was practised through using this tool. Audiation is imagining or internally hearing sound without the actual presence of sound. Audiation is a very important musical skill, as it helps to develop musical memory and gives rise to understanding about music.

Lauren gave the simple instruction, “We’ll do the rhyme again, only in our heads”. She then started off whispering the first few words while performing the beat body percussion, indicating through facial expression and a few isolated, whispered words, where they were up to in the rhyme. To the outsider, it would look as if virtually nothing was happening. Knowing that their brains were very actively engaged, it was quite fascinating to watch such young children being focussed and quiet but knowing that they are hearing sound in their heads. Not all were able to do this instantly, and like all skill development, it will take repetition. However, because Lauren’s pedagogy scaffolded the development of this skill sequentially, logically and meaningfully, most students achieved the ability to hear the whole rhyme in their heads. For this part of the lesson, the rhyme as a tool afforded audiation.

The mirror mechanism benefits music pedagogy

The mirror mechanism allows understanding of the intention of others’ behaviour through observing their action (Rizzolatti & Fogassi, 2014). Lauren models musical behaviour, without explaining it, knowing that students will understand the intention of her actions, and they will see others imitating her behaviour. Her behaviour does not need explaining when students will gain an understanding through their own bodies. “Social experience exerts its effect through imitation; when the child imitates the way adults use tools and objects, she masters the very principle involved in a particular activity” (Vygotsky, 1978, p. 22). Embodied knowledge is acquired more quickly, efficiently, and more meaningfully when the learner acquires it through their own bodily efforts. Lauren does a lot of modelling in her teaching, understanding that the mirror mechanism is designed for learning through imitation and action understanding. This is not to say that imitation is the only way humans learn, but it is a very strong way that humans acquire learning.

When we perceive action, this is reflected in our own brains in motor regions where these action maps are stored. In the brain, as we perceive others' actions, it is as if we are doing it ourselves, and in some circumstances, it is difficult to over-ride this. For example, the game, "Steve says" shows how words are grounded in action and therefore, when we hear the word, especially action words such as verbs, it is difficult not to do the action. Additionally, if the leader is also doing the action, our brains are simulating both the words and the actions in our brains, and so it is doubly difficult to over-ride.

When playing the game, "Steve Says", a leader says an action, such as "stand up" and also performs the action. If the instruction is preceded by "Steve says…. (instruction)", then all must copy. If the instruction is not preceded by "Steve says", but the instruction is still said and performed by the leader, anyone who performs the action is "out". This type of imitation is automatic imitation and mediated by the mirror neuron system (Heyes, 2011). Imitation can be modulated by our ability to manage attention. Imitation can also be modulated by what we think the intention of the action is and inhibitory processes in the brain. However, imitation is also driven by long-term, sensorimotor associations. As these automatically fire during this response to stimuli, it can be difficult to resist (Heyes, 2011, p. 463), even when we notice discrepancies and know we should not act.

The action of the mirror mechanism can work to benefit music pedagogy. Lauren did not have to instruct students to copy her. This was intentional in her pedagogy, as she knew they would copy on seeing her doing the actions. In part, imitation by the students of the teacher's actions is due to past experience, but also a behaviour synonymous with the mirror mechanism. Imitation can increase the speed and depth of experience in learning. Without wasting time in issuing instructions and waiting to see if students understood, just doing it and having students copy mitigated the necessity for verbal instruction.

Without saying anything, and with no time in between, Lauren then began performing the beat through body percussion, which all students copied. Not waiting and without verbal instructions kept the students' attention and seamlessly introduced new learning. Lauren then gave a single word instruction, "Echo". The students know that they watch then copy, in time. No time is lost, which allows students to maintain attention and not be distracted.

Extended cognition

To understand how many sounds occurred on each beat, Lauren used body percussion as a way of extending the students' thinking into using their body as a tool. In this way, the body and the gesture became physical markers to identify what sounds occurred on the beat. Even though Chemero states that, "A cognitive system is extended whenever it is in part constituted by things outside of the biological body" (2016, p. 5), in this case, thinking was extended into the body and gesture as external tools.

Students kept the beat using body percussion and saying the rhyme. At first, Lauren tried to get them to only say the words that made one sound on the beat, so beats that had two sounds were silent. However, this proved to be too difficult and abstract and was unsuccessful.

Lauren then changed the process. While saying the rhyme, she used a gesture for one sound, and a different gesture for two sounds occurring on the beat. The beats with one sound were assigned to a clap. The beats that had two sounds were assigned to the knees (patsch). For example, both of the words "Miss" and "White" are said with one sound to the beat, so would be clapped. "In the", "mid-dle", and "of the" are all examples of two sounds to the beat, so were patsched. Instead of explaining what she was doing, Lauren performed the rhyme as described. Explaining would have been much more confusing than just demonstrating.

Lauren's pedagogy was physicalising abstract concepts. While she didn't have time to get to what this activity was preparing for, it was a pre-literacy activity. Using this rhyme, Lauren planned to build upon the embodied "feel" of how many sounds occurred on each beat, to *symbolising* how many sounds occurred on the beat. In order to symbolise, the students would need to have a physical experience in order to understand what to symbolise. Lauren had intended using big paper cups for the one sound, and smaller paper cups for two sounds to the beat. Size of cups would suggest that one sound takes up the same amount of space as the two smaller cups. The two smaller cups together equalled the one big cup. In this way, understanding about time, space, relative space and so on would be physically manipulated.

Sound is invisible, and these abstract concepts need to be physicalised and embodied through action in order to gain a deep understanding. Learning that is physically manipulated develops deep knowledge structures in the brain (Johnson-Glenberg et al., 2014)

The role of the musical world and principle of neural reuse

The Kindergarten lesson is a strong example of how the world that Lauren has created is in line with the principle of neural reuse (Anderson, 2014). The core to this principle is the idea that "individual neural elements… are used and reused for multiple cognitive and behavioural ends" (Anderson, 2016, p. 1). Lauren has achieved this through the use of one major tool for multiple layers of learning.

One of the principles of neural reuse is that "newly acquired capacities are generally supported by mixing and matching the same neural elements in new ways" (Anderson, 2016, p. 1). As described, Lauren used a poem as a tool to develop musical cognition. She used the tool in multiple ways so that students could learn many musical skills, strategies for understanding how musical concepts work, and practise making deep cognitive connections between these.

Using the same tool saves cognitive load (Clark, 2017). The students did not have to learn new repertoire for each new aspect of the learning. Using the same piece of repertoire meant that the cognitive load was used for applying the concept, developing skills, and strategy development.

Another principle of neural reuse is that it supports and encourages both procedural and behavioural aspects of cognition (Anderson, 2014). Understanding what musical behaviour is and how it develops musical cognition was embedded in Lauren's pedagogy through many opportunities for perception and action. The perception and action opportunities developed skilled multisensory integration. For example, keeping the beat while saying the rhyme integrates sensory ways of detecting the beat, haptic and proprioceptive understanding of what the beat feels like and the body action to demonstrate this. In other words, students were developing the "how to" (the incremental steps of action) with "which" musical behaviour to practise "what" musical cognition. Sensing and acting in this musical world was developing skilled sensorimotor integration, ready to transfer to the next musical context and reuse of the same circuits to make new connections.

Musical learning that integrates the brain, the body and the world to develop cognition through embodiment favours neural reuse (Anderson, 2010). The more neural activity that is involved in learning, the more widely connected the neural connections and circuits become. Embodied memory engenders these circuits in later reflective and abstract thought, and maps to procedural, episodic and behavioural ways of understanding concepts.

The experiences that the students in Lauren's class developed will drive musical understanding to the next time they keep a beat to a piece of repertoire, the next time they analyse how many sounds occurred on the beat, how to demonstrate a rhythm pattern, express their musical ideas, and how to move to show the structure of repertoire. Repetition of procedure and behaviour involving interaction with new tools will develop deeper understanding and usable knowledge, surely the most important tenet of education in general, and for this thesis, music education.

Reflection by Lauren after the lesson

Lauren said that the aspects of the research that she felt had the most impact on her pedagogy were use of tools with affordances for being musical, understanding the effect of the mirror neuron system, and especially, embodiment.

Lauren talked to her students about the research underpinning what they did. She described how mirror neurons enabled them to learn through imitation, recognise actions and understand intentions, and that these all helped them be musical together. She also talked to the students about how all the different ways they were performing (singing, playing, using speech, notation etc) were connecting the same ideas in different ways. Lauren found that the students started to talk about what was happening in their brains and how moving helps them learn (embodiment).

The primary education classroom – Year 4

This primary education context is Year 4. The outstanding feature of this lesson was the use of gesture in the teacher's pedagogy, and how embodiment developed abstract thought. The lesson was based around a Macedonian dance, Rada Pere. Once again, Lauren has used one main tool, the dance, to create a lesson involving many deep and varied musical memories using the same piece of repertoire. The class has 28 students and Year 4 have 1 x 50-minute lesson each week.

The six claims of embodied cognition *(Wilson, 2002, p. 626).*

Cognition is for action

This discussion will focus on how Lauren utilises the action of gesture to convey meaning instead of using language in many instances. Gesture is a useful pedagogical tool as it conveys meaning quickly and does not disturb or distract from the sonic "musical space"[18] of the music classroom. Gesture directly maps onto the motor and mirror mechanisms in the brains of the students so that meaning is conveyed through action understanding, without the need for words.

Three types of gesture will be outlined to show how the musical space can be preserved but meaning can be understood, and musical information can be conveyed. The three types of gesture are deictic, conventional and representational. Deictic gesture, such as pointing and gaze, draws attention to objects.

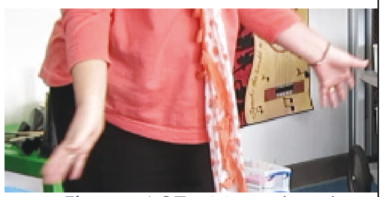
Conventional gestures use standardised forms to convey cultural meaning, such as nodding the head for "yes" (in some but not all

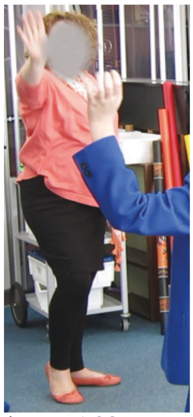
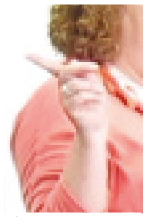
[18] When "musical space" is mentioned in this section, it is referring to the musical atmosphere of the classroom. As music is the language of sound, other sounds, such as language, can interfere with the "sound space" by introducing sounds that are not musical. If the teacher is introducing a melody, for example, if there is spoken language or other sound interrupting the memory of the melody, this will erode the memory of the melody.

cultures). Representational gesture captures aspects of an action; iconically (demonstrating how to play drum) or metaphorically (moving 2 open hands up in the air to signify maintaining a sustained sound while keeping the volume up) (Cartmill et al., 2012), and spatially (capturing aspects of relative space).

Use of gesture and how it contributed to the pedagogy

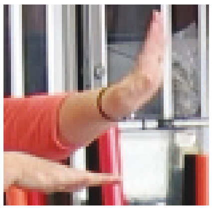
(Note: Dei = Deictic; Con = Conventional; Rep = representational; Met = metaphorical; icon = iconical)

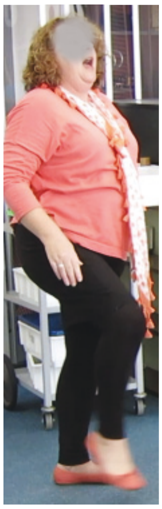
Description of gesture and contribution to pedagogy	**Type of gesture**
Learning the dance	
<u>Pointing</u> – to indicate where and which students should go where.  *Figure 4.26 - Pointing for where and which* *<u>Both hands sweeping away from her body</u> accompanied by the words, "further back" – to indicate that the rows of students should move back*  *Figure 4.27 - Move back* *<u>Arms raising with upward movement and upward facing hands</u> – stand up*  *Figure 4.28 - Stand up*	Dei

Description of gesture and contribution to pedagogy	**Type of gesture**
Learning the dance	
<u>Raised hand and slightly raised same side leg</u> – to bring attention to which side, left or right, and which corresponding foot. These gestures quickly and quietly brought attention to what students were to do.  *Figure 4.29 - which side, which foot* *<u>Pointing to side</u> – to indicate direction* Cuing direction just prior to moving ensures that the whole group move in the same direction, in time.  *Figure 4.30 - Direction* *<u>Touching hand to leg that will start the movement pattern</u>* – notice that students are copying and  *Figure 4.31- Copying to create a touch memory* creating a touch memory to remind them which leg to start on.	
<u>Flat hands in front of body, very deliberately moving in a specific direction, with a crossover</u> – to indicate stepping, and a specific number of steps, to the left, including crossover steps; *pattern of "steps" – (L=left; R=right)*	Rep (icon)

Description of gesture and contribution to pedagogy	Type of gesture
Learning the dance	
Lstep, Rcross, Lstep, Rcross, Lstep, Rcross, Lstep, Rclose. *Rstep, Lcross, Rstep, Lcross, Rstep, Lcross, Rstep, Lclose.* This was performed silently, with Lauren looking at the students with an encouraging expression that suggested that she was doing something they needed to take notice of.  *Figure 4.32 - Lstep*  *Figure 4.33 - Rcross*  *Figure 4.34 - Rclose* These gestures represented what the body would be doing. They prepared the students for understanding which hand to use, which direction, and what action (stepping, crossing or closing). Additionally, Lauren used a mirroring teaching technique to make it easier for students to understand which direction. Mirroring technique involves the teacher moving in the direction she wants the students to move in, however, to do so, she will actually start on the opposite foot or side e.g. if she wants the students to move to the left, starting on the left foot, the teacher would actually demonstrate using her right foot to the right. This technique is easier for the observer to interpret direction and which body part, than if the observer tried to analyse the opposite foot, direction and so on. It is especially useful for when a body part crosses another body part, as this is visually confusing.	

Description of gesture and contribution to pedagogy	**Type of gesture**
Learning the dance	
Points to feet to indicate the movement is transferring from hands to feet (same movement as hands but with feet)  *Figure 4.35 – Transfer from hands*  *Figure 4.36 – Transfer to feet* These gestures suggested the idea that instead of demonstrating the movements in the hands, this time it would be in the feet. This transferred the movement from being represented in the hands to directly using the whole body. The advantage of demonstrating in this way is that in observing the movement, the students gain a lot of information and understanding of the intention of the action through the mirror mechanism. The students then did the movement themselves, building upon the information already gained, making it a personal motor memory. Lauren continued to model the movements as the students copied. She also hummed the dance music that these movements belonged to, further preparing students for when they would move with the music. Hearing the music also synchronises what they do with what they see and feel; the melody, seeing Lauren, themselves and others doing the movements, and feeling their body doing the movement with the music.	Dei + icon

Description of gesture and contribution to pedagogy	Type of gesture
Learning the dance	
<u>Hands moving away from body in stepping motion</u> – to indicate moving forward *<u>Hands moving back toward body in stepping motion</u> – to indicate moving backward*  *Figure 4.37 - Forward and backward* *<u>One hand flat (to represent the foot that stays on the ground) while the other hand, palm facing forward and sweeping up</u> – to represent resting foot while other foot sweeps up*  *Figure 4.38 - Representing resting foot and sweeping foot* As Lauren demonstrated these gestures, students copied in real-time, as they understood the intention. When she finished performing the movement sequence, she asked the students what they thought the movement would look like if the movement was in the feet. A student offered to demonstrate and performed all the steps correctly. For the heel rest, the student did a kick, which the gesture could also have indicated, not being a perfect representation. Lauren acknowledged this and said that it could have been that step (kick), but was "this" (heel rest).  *Figure 4.39 - Kick step*  *Figure 4.40 - Heel rest*	Rep (icon)

Description of gesture and contribution to pedagogy	Type of gesture
Learning the dance	
Asking the students to show what they thought the movement would be, provided an opportunity for Lauren to assess what the students were understanding about symbolising (as the gestures symbolised movement), and what fitted with the genre, or style of movement. It also stimulates students to use thinking strategies to make predictions. Making predictions delves into their conceptual networks to strengthen and grow new connections (neuroplasticity). Rote learning inputs information, but offering opportunities for linking information to practice and new solutions makes deeper connections, "reflecting a path of knowledge change" (Roth, 2001, p. 373).	
<u>Inward breath synchronised with patting knee and moving foot forward</u> – inward breath to indicate to begin, patting knee to indicate which foot to start on and foot doing actual movement. The inward breath as a gesture is common to ensemble and choral groups. Without saying, "go", it symbolises the preparation the body does in starting a movement. Using this gesture in pedagogy is practising this musical skill for future musical engagement in joint actions.  *Figure 4.41 - Breath as a metaphoric gesture*	Rep (met)

Description of gesture and contribution to pedagogy	Type of gesture
Learning the dance	
<u>*Gesture, moving feet in stepping movement and saying words*</u> *- to associate with the action* – to bring attention to refining the movements.  *Figure 4.42 - Gesture, movement and words* Lauren was using all three communicative elements, gesture, movement and language concurrently, to provide understanding to the movement idea that she was performing. They formed an integrated system "in which effort expended in one modality can lighten the load on the system as a whole" through shifting the cognitive load from verbal processing to motor processing (Goldin-Meadow et al., 2001, p. 521).	
After learning the basic steps, Lauren then asked students what hand movements they thought would fit with the movement patterns. While moving, the student said and gestured her suggestion.  *Figure 4.43 - Student using words and gestures*	Rep (Icon) +

Description of gesture and contribution to pedagogy	Type of gesture
Learning the dance	
The student who proposed a solution described what she was doing as she was doing it. She said, "for the side one you could go, um, a [snapped fingers] ...., like, ... then, a ...clap?" Doing it while she was verbalising it gave a better representation than description alone. When gesture reinforces the idea expressed in the verbal description, students are likely to solve the problem using a strategy compatible with the idea (Roth, 2001, p. 373). In this way, the student provided a visual representation that was easier to follow for her fellow students, and easier for Lauren to ascertain her evolving understanding. When the whole class then practised this solution, Lauren sang  *Figure 4.44 - finger snapping on the crossover*  *Figure 4.45 - Clapping on the closing step* the actions and performed them with the students, therefore adding a verbal label to the action, assisting them in thinking about the movements. This had become quite a complex task, as there were added gestures (clap and snap) with movement, melody and the words to denote the movements. "Gesture actively brings action into a speaker's mental representations, and those mental representations affect behaviour" (Goldin-Meadow & Beilock, 2010, p. 1).	

Description of gesture and contribution to pedagogy	**Type of gesture**
Learning the dance	
<u>Moving hands out from body in swaying movement around body</u> – to indicate how to move with steps  *Figure 4.46 - Student suggesting arm movement* The student who suggested this solution did not verbalise. She just moved, demonstrating the stepping pattern and the hand and arm movements solution. Lauren described it "as if elegantly moving with big ball gowns perhaps", giving a metaphorical idea to the movement.  *Figure 4.47 - Singing melody, performing movements*	Rep (icon + met)

Description of gesture and contribution to pedagogy	**Type of gesture**
Learning to play	
Lauren had the melodic percussion instruments (xylophones and metallophones of varying sizes) set up on one side of the room. Facing the students is a Xyloglock, a teaching tool for showing students playing techniques such as using one mallet after another, showing the melody and which notes to play. The tool is set up to mirror the students' instruments, so they can easily copy and conceptualise melodic ideas.	
<ins>*Pointing fingers to note names on the Xyloglock*</ins> *– to indicate and bring attention to which notes to play with which hands (left or right).*  Lauren simplified the process of learning the melody by playing just two notes that occurred often in the melody. She sang the melody and every time those notes occurred, she gestured playing those notes on the xyloglock. This coupled the gesture pointing to the notes on the xyloglock with the sound of the melody. Gesture and sound informed students' thinking about the specific two sounds within the melodic form of the repertoire. There was no explicit teaching. The students embodied this understanding through doing it, singing and playing. After	Diec

Description of gesture and contribution to pedagogy	Type of gesture
Learning to play	
just two times, they could sing the whole melody and play those two notes every time they occurred in the music.	

Lauren's pedagogy embedded embodied information through gesture, movement and language, coupled to create strong musical meaning. Gesture is a powerful pedagogical tool as it embodies meaning, in this case, about where, how, what and when, and about musical behaviour through deictic gesture. The action embodies meaning (Anderson, 2003; Glenberg et al., 2013; Niedenthal, 2007). Gesture also facilitates attention to specific content amongst a sometimes confusing background (Roth, 2001). In music, isolating elements takes meaning away from how the element functions, such as when students are asked to practise a rhythm pattern but never hear how it fits into repertoire.
"Gesture and speech form an integrated and … synergistic system in which effort expended in one modality can lighten the load on the system as a whole" through shifting the cognitive load from verbal processing to motor processing (Goldin-Meadow et al., 2001, p. 521).

Abstract cognition is body based

Pedagogy that uses movement as a thinking tool provides body-based grounding for abstract thinking. Musical meaning is action-based (Fortuna, 2017, p. 121) and actions can modulate auditory experience (Maes & Leman, 2013a, p. 1). In other words, what we do when listening to music has an effect on how we hear it (Phillips-Silver & Trainor, 2007).

Students' perception of the music was shaped by their actions. Their musical understanding was embodied and the integration between sensory and motor representations led to internal models of the structure of the repertoire. This musical understanding was engendered without explicit teaching.

Learning the dance with Lauren developed patterns that were coded between the brain and the body, and made connections and associations between perception and action. All the senses entwined to develop a rich conceptual object (Purves et al., 2013, p. 575) that included vision (seeing the movements), auditory information (the sung melody and the recording), haptic (the feeling of the movements) and proprioceptive (the feeling of the body parts involved, and self in space). Coupled with the motor response, these memories become entwined in a Hebbian process[19] (Shatz, 1992) with the musical environment to develop skilled musical cognition.

Thinking through movement

After the students had learnt the dance with Lauren singing the melody, she then put the recorded music on with the verbal instructions, "When we do the dance with the music, think about how many sections there are". The students were familiar with the musical idea of sections, which are complete musical ideas within the structure of a piece of repertoire. Section types include introduction, coda, verse, chorus and so on. In order for students to be able to do this, Lauren had provided an embodied model of the structure of the repertoire, through the movement patterns they had already practised.

The students and Lauren performed the movements once with the music. After this, Lauren guided their thinking by saying, "If I call these movements section A [while gesturing the steps to the side], what would we call these movements [gesturing the forward stepping movements]?"

[19] Neurons that fire together, wire together (Doidge, 2007, p. 63).

There was swift response from students saying, “B” (the correct answer) and confirming nods from other students.

Lauren then guided their thinking by asking, “How many different sections were there?” Again, confident answers of “2” were the replies.

Lauren: “What happened with those 2 sections?”
Students: “They kept on repeating”
Lauren: “They kept on repeating, yes, and we call that in music, structure, where composers and performers have a sort of organisation. I want to see if you can work out the organisation of that music, so you need to work out, how many times we had the A section, the B section, the A section, the B section. How are we going to do that? I saw some people sometimes use this thing [pointing finger along a line in the air] in different subjects to see how things are moving”
Student: You could put things down like every time the section happens.
Lauren: “yes, yes you could. What about, not just in music but in other subjects you have this thing called a timeline, where, as the piece progresses, we can see what’s happening in the different sections. So, in your groups, group 1, group 2, group 3, group 4 [indicating groups], I want you to use a whiteboard and a pen and together, while the music is playing, we’ll plot the different sections [drawing a line on her whiteboard on the wall to demonstrate].

Notating – grounding symbols in action

The four groups gathered in different parts of the room and Lauren instructed them to not let anyone else to see their board. "You're all cracking the code. Maybe you will use the letter "A" or "B", or you might have your own way". Already the students had started to plot the sections on the timeline before the music was played again[20] (*Fig. 4.51*).

Figure 4.51 - Already notating before hearing the music

Figure 4.52 - Students notating and pointing while teacher moves structure

It was surprising how accurate students were. Lauren assisted by moving the structure and humming quietly while students notated (*Fig. 4.52*). The students also noticed where there was a pattern that changed. One student said, "Sometimes the sections repeated and sometimes not" (*Fig. 4.52*). Lauren then told them they were to put their boards aside to do the dance again and see if they could notice the pattern.

Action-based problem-solving

The pedagogical strategy of solving the problem through the body again stimulated their efforts to connect what the body was doing during the music. Before the students performed the dance again, Lauren asked them to notice an additional aspect in the music. "What changes in the music?"

Student: "I realised the beat got a tiny bit faster".

Another student: "We had that on our board".

---

[20] I, as the researcher, realised as I watched the students confidently symbolising the structure, that I did not know the structure of the dance because I had not moved. I had not embodied the structure through movement.

Lauren: "Did you? Well my question is, what did you notice about the beginning?'

Discussion followed with lots of points made by the students. Lauren did not give any answers. Her questioning guided them to think back to what they did and how this linked to the structure of the music, so all language was grounded in the action that created the memory.

When the students had performed movements to the music, their understanding of the music was guided by those actions. The actions sorted and categorised sound.

Reflection by Lauren after the lesson

Lauren said that the aspects of the research that she felt had the most impact on her pedagogy were use of tools with affordances for being musical, understanding the effect of the mirror neuron system, and especially, embodiment and movement.

The primary classroom and music pedagogy informed by embodied cognition and cognitive neuroscience

The outstanding feature of this lesson was the use of gesture in Lauren's pedagogy, and how embodiment developed abstract thought. Once again, Lauren used one main tool, the dance, to create a lesson involving many deep and varied musical memories using the same piece of repertoire.

Using gesture achieves many strong musical pedagogical outcomes. First, when the teacher uses gesture in their pedagogy, students have an image before them that strongly relates to the meaning of the message. Secondly, sometimes gesture can couple with other sensory and motor aspects, such as dance and song. When Lauren was teaching the movements to the dance, she accompanied the gestures with the melody. This allowed the students to learn the melody without even realising it, as they associated the movements with the sound. Thirdly, using gesture preserved the musical space by not having unmusical sound distract from connecting sound and movement.

The other way that Lauren coupled gesture was with language, when she sang the movements while gesturing. This allowed gesture, melody and speech to form an integrated system and lighten the cognitive load (Goldin-Meadow et al., 2001, p. 521). Fourthly, gesture can focus attention on salient features and assist in problem-solving. This is especially pertinent in music, as the unified whole in repertoire can have many overlapping layers of musical elements. Gesture can bring to the foreground where the teacher wants the focus to be.

Another strong feature of Lauren's pedagogy was in embodying learning to develop abstract thought and problem-solving skills. From the outside, when one looks into an active classroom, it can look like everyone is just "playing" and having fun, but that playing is the serious business of developing cognition, which can be fun. When knowledge is embodied through doing it, repeated actions in response to ongoing and overlapping experiences in the world develops internal models that capture the relationships between action and sound. Those internal models are the foundation upon which musical thinking and cognition grows (Maes, Van Dyck, et al., 2014).

Overall, the theme in these two classes is complexity through simplicity. Lauren exemplifies how a simple tool can achieve complex thinking. She used just one poem in the Kindergarten class, and just one dance in the Year 4 class, but demonstrated how one musical tool, used many different ways, results in deep knowledge development and musical behaviour. This is in line with the principles of neural reuse, that "newly acquired capacities are generally supported by mixing and matching the same neural elements in new ways" (Anderson, 2016, p. 1).

4.5 The special education setting – Joyous, rapturous, exuberant embodiment

This section discusses two special education contexts; one primary, where Bonny teaches, and the other secondary, where Merryn teaches. The outstanding feature of the special education contexts is the way the music pedagogy engenders open joy and exuberance in the students through being musically active in learning. There was much learning through imitation, indicative of the brain's mirror mechanism (Rizzolatti & Sinigaglia, 2016), use of tools with musical affordances (Krueger, 2014; Windsor & de Bézenac, 2012), and joint action, movement together in being musical (D'Ausilio, Novembre, Fadiga, & Keller, 2015; Scholtens, 2019).

The special education classroom - primary

This special education context is in Brisbane at a state school for children with mild to moderate intellectual disabilities. Bonny is the music teacher and had taught in the special school for two terms on a contract basis. When teaching in this school, the teachers and aides also assisted in managing the students (*Fig. 4.53*). The class is an upper primary class.

Figure 4.53 - Teachers and teacher aides assist in lesson

Introducing Bonny

Bonny is a highly-experienced classroom music educator. Specific aspects of her lesson with students in a special school are highlighted to capture how cognitive neuroscience and embodiment can be applied in music pedagogy. The strongest impression from these captured moments is the joy, exuberance, spontaneity and action in learning that the students and Bonny displayed (*Fig. 4.54*).

Figure 4.54 - Joyful learning

Bonny's Professional Background

Qualifications: B.A., Grad.C.E., Orff level 4.

Bonny started teaching music in primary school settings in Brisbane in 1989, but prior to that, had been teaching Afrikaans and Drama in high schools in Zimbabwe for six years. In 1997, she started teaching in a special school for students with intellectual impairments up to 18 years old, and subsequently taught in various special settings: students with behavioural difficulties, severe physical impairments, and special units within a primary school. Bonny is now working in a state high school which is an intensive English language school for migrant and refugee students, ranging in age from 10-18 years. The school prepares these students for mainstream settings. The students at this school represent diverse cultures.

Bonny's work with the Australian Orff Association since 1995 has involved teaching adults, usually classroom music teachers, in workshops and training courses and she has presented numerous professional development sessions for generalist teachers, as well as mentoring of individual teachers. Since 2005, Bonny has taught a weekly adult folk dance class and Israeli dance group.

Like all the participants in this thesis, Bonny is a graduate of Level 4 of the Orff Schulwerk Teacher Training courses. Additionally, she is also a qualified presenter in the subjects of Movement and Dance and Pedagogy in the Orff Schulwerk teacher training courses.

Classroom Setting

Bonny does not have a classroom in this school. She was working on a contract for two terms only. The school had sought a music teacher through "The Song Room", an organisation that produces resources and assists schools with music programs. Knowing her experience teaching in special settings, Bonny was approached by The Song Room to teach at this school, to assist them in setting up a music program, and demonstrating how to implement active music pedagogy.

Bonny's lesson was held in a semi-covered area outside a classroom, where fifteen upper primary students gathered from a number of classes. This was to be the 2nd last lesson of her contracted period with the students, and they were preparing for a performance later in the week, where parents, other students and teachers would be the audience.

It was very clear that Bonny's lesson was a very special event for these students. One particularly tall body spotted Bonny from across the playground and with glee and excitement on his face, he bounded toward her, miming playing the guitar. Bonny had not yet taken out her guitar, so without words, he demonstrated everything that Bonny represented to him – being musical. Throughout the lesson, he was completely engaged, happy, joyous in participation and was very musical. Everything that Bonny did, he did. He moved in time with the music, performed actions to the beat without being instructed to do so. When they sang some songs, he signed the words, which Bonny had not taught him to do, but of course they all learn sign language to assist in communication.

Bonny was quite minimal with her language. While it is important for these students to learn to communicate with language, processing of language is complex, therefore, in a music lesson, it is useful to focus on musical communication. She said, "Just copy my hands". In terms of neuroscience, as soon as she says, "hands", we know that this area in the motor cortex will be "on alert"; mirror neurons will be ready to fire because hands and face have special significance for mirror neurons (Rizzolatti & Fadiga, 2007).

A most joyous and active part of this lesson was during the performing of the repertoire, Can-Can by Offenbach. The recording began and Bonny moved to the music in front of the students. They were all synchronously engaged with Bonny's movements. Teachers and aides came from other rooms to join in. The joy was infectious and irresistible, as evident from the exuberance of movement from everyone and the spontaneous smiles as the music began, and for the duration of the movement and music. At the end of the recording, children and teachers clapped and smiled at each other, having shared the joy of an experience in joint action. This involved shared movements, shared attention and intention, shared social harmony, to create a feeling of community, closeness, cohesiveness and security (Pacherie, 2014).

The Primary Special Education classroom - primary

The six claims of embodied cognition *(Wilson, 2002, p. 626)*.
This section will discuss how music learning was embodied in Bonny's lesson.

Cognition is situated

Everything, everyone, and the place all become entwined in the memory of what happened in Bonny's music lesson. "The world" and all the components of that world have varying degrees of significance and strength to the memory of that music lesson. "Neurons that fire together, wire together" (Doidge, 2007, p. 63; Shatz, 1992). Bonny represents being musical to those students, as demonstrated when one of the students gleefully bounded toward her when she arrived, playing an "air" guitar. To those students, Bonny belongs to that place and they know that when she and the place are together, musical "things" happen. Bonny is the one leading. She sings, moves, uses lots of facial expressions to indicate aspects of the music and her body also reflects this. The place where musical behaviour and thinking happens for those students is where Bonny is. The students immediately display musical behaviours when they see her, such as copying her actions and expressions during the music, responding in echoing phrases in the music without being instructed to do so.

The space is used in a special way. Even though many of these students have motor challenges, they all moved around in the space. Sometimes they sat and moved, doing actions to music or while they were singing. At other times, they used the more open space to dance, play musical games, and act out a story. Sometimes they were arranged so there was a place for characters in the story[21], a place for instrumental players, and a place for moving characters. Bonny was not always in the same place leading the activities. Sometimes she was facing one way toward the group, sometimes from a different direction. Other times she moved amongst the children, participating in a game, dancing with the students or taking part in the story. Even though the space was challenging to use, being outside and not set up as a music space, Bonny used the space to create multiple places of musical action and situations for learning. This created a stimulating and enriched environment (Radin, 2009; van Praag et al., 2000).

[21] The students were rehearsing a story performance of "Bunyips Don't" (Odgers, 2005).

Cognition is time-pressured

Music is time-pressured; it occurs in and through time and does not stop to wait for one to think about it. It is therefore meaningful to experience music "in time" but also to do things "in time" that assist in making sense of music as a multisensory activity. Bonny used "echo songs" to help achieve this. Echo songs are songs where the leader sings a phrase and then others copy. Echoing is a form of musical turn-taking, like the turn-taking in language conversation, and indicates musical joint action and action of the mirror mechanism for auditory and motor processing (Bangert et al., 2006; Phillips-Silver & Keller, 2012). Interestingly, one of the students "conducted" while Bonny was singing, most were bobbing in time to the music, and many were smiling spontaneously whenever they were performing. At the end of the song, Bonny sang "oh yeah" in a sustained sound, and one of the students immediately responded with "shimmy hands", arms and hands outstretched and "shimmying", understanding that this was an appropriate gesture for this moment in the music. Bonny was not performing this action, as she was playing the guitar, so this indicates that the student understands the genre and mapped this back to his past experience of this type of music.

During the rehearsal of the story, one of the students who had the hanging chimes to play to depict a specific aspect of the story, had difficulty in holding the instrument. He had motor management issues, so it was quite amazing to see him predict and manage to play his instrument at the correct time. Time-pressure drives thinking at speed.

Cognition work is extended into the world

In preparation for the presentation for parents later in the week, the students were rehearsing a story performance of "Bunyips Don't" (Odgers, 2005). The characters in the story were tools for extending thinking into the world. When the students were acting in each of the character roles, they were developing their expressive capacities and skills. One student who was non-verbal, kept coming into the story rehearsal carrying instrument boxes. It was clear that she wanted to be where the students were who were using scarves, as this was the place where she kept bringing things. Bonny gave her a scarf to move with as some of the others were doing and immediately, she was part of the group. The scarf enabled her to move like the others and demonstrate her understanding of her place in the story (*Fig. 4.55*). Having wandered during all the previous time in the lesson, immediately she had a "tool" to extend and demonstrate her intention and understanding and she was together with the other students in the story. Using the scarves is not only an example of tool use and extended cognition, but also joint action and attention. She was part of the group.

Figure 4.55 - Scarf as tool for expressing action

The world is part of the cognitive system

Every person, object and the place were part of the cognitive system operating in this lesson. Hearing the story, having characters do and say their part in the story order, seeing the costumes and illustrations, hearing the sounds of characters, both vocal and instrumental, seeing and making the movements, and finally dancing at the "bunyip" party all became part of the embodied personal experience of everyone there. The story became a very strong and important aspect of the embodied cognitive system of each student. It represented a whole sequence of related embodied activity in speech, sound, movement and meaning, and all in a shared experience of jointness of intention and attention. The mirror neuron system is "intimately connected to the body and... the brain has evolved to interact with and understand other brains" through this system (Overy & Molnar-Szakacs, 2009, p. 492).

Probably the most joyous aspect of watching this lesson was in witnessing how expressive and verbal the student was who played the young bunyip. After only one rehearsal previous to this lesson, he remembered his part mostly word for word (though his words were sometimes difficult to understand). His gestures, facial expressions and actions all told the story strongly. His teachers were amazed that he could be so verbal and expressive and that he remembered the words. This story and the music lesson allowed him to develop his expressive abilities. It was also time-pressured which served to accelerate his performance abilities.

Figure 4.56 - Improvising singing and dancing

During part of the story, the young bunyip had to sing like the birds. The bird sound had been played on a whistle instrument, but the young bunyip (student) had to sing. In the moment, he improvised, not just a sound, but a series of song-like sounds, and he also moved to express his song (*Fig. 4.56*). Later he had to look disappointed, and his body bent, he turned away and had an exaggerated disappointed look on his face (*Fig. 4.57*). The story and the ideas provided the structure for him to do this. He embodied the story, and this became part of his cognitive system.

Figure 4.57 - Embodying disappointment

Cognition is for action

It was quite fascinating to watch the students respond to Bonny's actions to Offenbach's "Can Can". This piece of repertoire was quite fast, and while they had heard and responded to this music before, to be able to keep in time and understand how the actions were related to the music was evident in the way they performed. Even though some could not exactly copy the actions, it was clear that they were synchronised with the music as they did not stop moving (*Fig. 4.58*). Hearing the music and seeing Bonny drove them to move. Interestingly, many of them were also vocalising sounds that were clearly related to the music. It was interesting that these vocalisations also reflected not just melodic features, but also tempo and rhythmic features. The music and watching Bonny drove their actions and vocalisations.

Figure 7.58 - Synchronising actions with music

Overy and Molnar-Szakacs (2009) propose that imitation, synchronisation and shared experience, implicated through the mirror mechanism, are powerful tools in learning, and especially implicated in musical learning. "Music provides not just a pleasant auditory signal, but a strong sense of an agent or agents – one is not alone when one listens to music" (Overy & Molnar-Szakacs, 2009, p. 499). When humans learn through imitation, it is a complex neural process, but efficient, fast and how humans have evolved to learn. It involves a hierarchical process from cognitive to motor levels, beginning with intention (understanding the goal of the action), goal (understanding the sequence of short-term goals to achieve the end goal), the kinematic level (identifying which body parts are involved, even down to hand shape and movement through time and space), and muscles (the pattern of required muscle of activity to achieve the goal) (2009, p. 493). Through the mirror mechanism, the observer predicts, based on the past experience of the individual, what the intention of the action is and minimises error through comparing past experience to the observed action in that moment. This complex process becomes more powerfully incorporated into the sensorimotor system when dynamically updated by the individual through doing it, though moving and acting. It then becomes the individual's personal, embodied knowledge and evolves in a deeply unified and overlapping manner. There is much debate over how the brain achieves this. Andy Clark describes action recognition as much less "top-down" and more like "active perception" (2017, p. 732), in the moment. He states that, "brains like ours, wherever possible, exploit simple strategies that rely heavily on world-engaging action, delivering new sensory stimulations just-in-time to support behavioural success" (Clark, 2017, p. 736). In line with Anthony Chemero's view of radical embodied cognition (Chemero, 2013), I ascribe to the view somewhere between all these, that sometimes we imagine and act (top-down), and sometimes we do not, but common to these views is the dynamic power brought to cognition through action, just as these students experienced. Action shapes cognition, builds their knowledge and allows them to apply predictions to make meaning from the world.

It was also interesting to note the students' facial expressions while moving to the Can-Can. Some of the students were not very expressive with their faces while some were exuberant, however, all students were actively engaged whenever music was happening, through song or recording.

Abstract cognition is body based

With this special class, Bonny used the story book, "Bunyips Don't" (Odgers, 2005), to practise expression, an important aspect of being musical. The enactment of this story was to be presented to the parents later in the week. The students all had roles and actions to perform and had practised it only once before. As soon as Bonny mentioned the story, one boy immediately stood up with a great big smile. Bonny smiled at him, and asked the class, "Who was our young bunyip?" They all named this student and he strode over to where he had stood previously to play this part. Apparently, Bonny was told that this student would not be suitable as he might not remember the words, nor be able to verbalise. This was not the case. Bonny then asked the class, "Who were…." and held up props; more students jumped up, demonstrating evidence of past associations. As Bonny handed out instruments, she asked the students what these sounds were associated with and for the students to motion how to play them. These are all aspects of embodiment, recalling what the body did in relation to ideas. The actions synchronised with all the ideas associated with this musical event.

While students waited to receive their instrument, others were playing and those who did not have instruments, were moving in preparation for their character. When the young bunyip was given his material props, he immediately began moving in character. Even though this student could not walk smoothly, he performed beautifully flowing movements while holding the scarves, an example of extending thinking into using the tool, and sensorimotor integration. The quality of the material or tool, the scarf, allowed an interaction between his body and the tool, and this facilitated his expression of the bunyip character.

Tools and Affordances

Tools with musical affordances enable the body to extend into the environment to allow direct musical experiences that would not be possible without the tool (Leman et al. 2010, 203-223). Bonny provided many experiences for active tool use through using the body to be musical. For example:

Figure 4.59 - Tool for playing and associating with character

- Scarves afforded flowing movements which were then associated with flowing movements of the birds in the story.
- The heavy tail of the young bunyip changed the qualities of the student's movements and fed back into his body how he should move, keeping the character in his mind.
- Instruments afforded sound-making to represent story ideas e.g. the drum represented whenever the grumpy old bunyip was talking (*Fig. 4.16*). The student who played this instrument never missed his cue. The associations in his mind were clearly demonstrated through the instrument.

Extended Mind

Extending thinking into the world through performing physical actions on external objects simplifies mental actions (thinking) (Kirsh & Maglio, 1994). This means that with a light cognitive load, the brain can focus on other layers of understanding. In Bonny's lesson, thinking was extended into:

- using the scarves, so that the student could create their character;
- using musical instruments, so that the student could represent how they thought the book characters' movements "sounded".

Both of these examples develop musical skills. Creating a character develops musical expressive skills and exploring the sound possibilities of instruments to represent an idea develops understanding about tone colours that are available through sound sources such as musical instruments, and other sound sources.

Joint Action

Part of the story had a birthday party in which there was a dance. Bonny put on the music, "You make me feel like dancing" (Sayer & Poncia, 1976) and the students copied her simple movements. What was not simple was that they had to change direction, turn around, move up, move down, point and all in time to the music. Once again, the teachers were amazed that students who had difficulty smoothly managing their movements at other times could move basically in time with the music, and change movements when the music changed. There was a particularly astounding moment when this occurred in the music, where the lyrics say, "Feel like dancing, Whoa! Dancing. Whoa! Dance the night away" and on the "Whoa!", everyone has to jump. To do this in time, one has to anticipate that this is coming (*Fig. 4.60*). Most of these students jumped or moved up at exactly the right time. When others around them were doing the same thing, this assisted through joint action. Again, mirror neurons and peripersonal neurons are at play here, guiding and developing movement intentions and predictions and a sense of self in space.

Figure 4.60 - Predicting and anticipating

Joint Attention

The class were all involved equally in the story. They were in character, moved as part of the whole group, contributed to the whole group, and worked in ensemble. There was, however, one student who displayed little expression on his face and did not seemingly involve himself in the story, until someone came in too early in one instance, at which he became quite agitated and insisted that everything stop. The teachers gently encouraged everyone to quieten while he settled down and showed what he wanted to happen, and the play continued. This demonstrated that while he was not showing how he was involved, he was keenly aware in his own way and there was a way for him to actively take part.

Mirror Neurons

Bonny's pedagogy reflected a deep understanding of how the mirror neuron system engages learning through imitation and action understanding (Rizzolatti et al., 1996; Sinigaglia, 2013). This was achieved with very little need for language instruction or explanation, which is appropriate for special education contexts, but also, for learning at all levels. When the learner's own brain and body makes sense of what is happening in the world, it is deeply connected to all the neural and physical structures that developed that understanding, providing a rich retrieval system for the next time that understanding is applied.

Bonny's body and facial expressions provided a model and clues for how the body and sound synchronise. She did this through:
<u>Gestures</u> – for sitting, pointing (to focus on who, what, where), soft, loud, looking for turn-taking, stop, we, you, rise, on your feet, thumbs up (good work), nodding (to indicate positive, correct, encourage), cuing (direction, about to start, stop);
<u>Body</u> – posture for singing, moving to the beat, moving to suggest style of music, turning to focus attention, action for playing the guitar and other instruments and body percussion;
<u>Intention</u> – Bonny sometimes does not explain what students are about to do. She will put on music and start moving, and students analyse her intentions e.g. to move a certain way, move to the beat and so on. In this way, students ascertain themselves what to do, either by working it out themselves, or getting cues from others;

Imitation – movements to songs and recordings, facial expressions, rhythm patterns, skills – body percussion, movements, how to play instruments;
Language – accompanying words with gesture to enhance meaning e.g. "your hands (holding up hands) are going to do what my hands do"., Verbs that resonate in the motor cortex (Ackeren, Casasanto, Bekkering, Hagoort, & Ruschemeyer, 2012; Bedny & Caramazza, 2011);
Joint action – performing movement, gesture, dance and games together with others.

Peripersonal Neurons

In Bonny's lesson, students learnt to manage the physical and musical social space around them through singing, moving, acting, playing games and musical instruments together. Peripersonal neurons affect how we interact with objects and people around us (Graziano & Campbell, 2018, p. 3).

It was clear that some of the students had a sense of place and self in relation to others. This was evident through understanding where to be during the enactment of the story. However, some did not, and at any time might just walk through the performance, unaware of a sense of place or time in relation to self. They were gently guided to focus on the story, where everyone was, where they thought they should be and so on, assisting them in developing social cognition and use of peripersonal space.

Multimodal Integration

There were many modes of musical behaviour practised in this lesson. Multimodal refers to the "mode" of behaviour and delivery of information; for example, in music, if you are singing, you in singing mode. The other musical modes used in this lesson are vocalising (as well as singing, vocalising includes speech, scat and vocables), moving, dancing, playing (instruments, sound sources or body percussion), improvising, composing, expressing, and listening (actively).

Bonny asked students to recall a song they had practised previously, but all she did was say and clap, "Go go". Immediately students started to sing the song. They sang and clapped on the word "go". This as a more complex activity then just clapping to the beat. They combined singing and body percussion modes of musical behaviour. They then got into pairs and instead of clapping just their own hands, they had to synchronise the song, the movement with their partner by clapping the partner's hands instead of their own. Bonny then asked them to put in a movement that they wanted as well as the clapping. Instantly a pair added a turn on a long sound. This demonstrated deep musical understanding, that their movement took the amount of time that a long note took and that they could do it together. They performed this to the rest of the group and then all had to do this added movement when performing the song the next time. Most students performed this at the correct time. Bonny then added another challenge into the game by turning to change partners. Much laughing and happiness ensued as students fairly successfully achieved this. Time pressure achieves and drives action, as evidenced by what these students could achieve. The other interesting and unexpected aspect one could observe was the joy on the children's faces as they faced one another. They all greeted each other, and this achieved social cognition through playing the game and being musical. Mirror and peripersonal neurons would be activated also in performing these joint actions.

Multisensory Integration

The activities that the students were engaged with were multisensory and synchronised with song, gesture, words, and sound. Because the whole body was engaged, rather than just watching, reading or seeing others perform, each student developed rich, multisensory understanding. Our brains have evolved to learn and operate in a multisensory world, and the brain develops a larger and more knowledgeable set of memories when they are integrated through the senses (Shams & Seitz, 2008).

One of the teachers and one of the students are deaf. They participated in time with the "Gogo" song, smiling and seeming to enjoy the rhythm pattern of the words and the actions by exuberantly joining in with the others. Even without the auditory sense, the activity was still multisensory, as they could perceive the rhythm through seeing the actions, feeling their own bodies doing the actions in joint action with others (*Fig. 4.16*), move and have a sense of self in space through proprioceptive and haptic senses. Additionally, they participated with others, so also perceived the "jointness" of being in a musical ensemble activity.

Figure 4.61 - Complex movement in joint action event

Sensorimotor Integration

As this was such an active lesson, with lots of variety of musical behaviours, there was great opportunity for developing the ability to integrate sensory perception and the corresponding motor response. Sensorimotor integration is developed through integrated, dynamic, sensorimotor interactions with the world (Held & Hein, 1963).

An example of sensorimotor integrations occurred when Bonny put on a recorded piece called, "Beebop, Shake it up". The lyrics "tell" the body what to do, so the students were responding to the action words (mirror neurons and language), keeping in time with the music, moving the actions in time, and singing the lyrics as well. This was quite a complex activity to do in time (time pressured), but all the children were fully engaged, active and clearly enjoying it. They perceived the action visually, aurally and through the haptic and proprioceptive sensory systems. This integrated with motor patterns and synchronised with decoding language and being in time with the music; a highly complex activity that practised sensorimotor skills in real-time.

Enriched Environments and Neuroplasticity

Deep musical cognitive development is a result of richly complex interacting elements in an enriched environment. Bonny presented challenge and choice, active engagement, socialisation and lots of variations in the many activities in her pedagogy. They sang and moved, played and sang, danced and sang, acted and expressed story and sequence, chose movements to fit the music and so on. When there was an activity where the "jazzy" style music lyrics gave movement ideas, such as "climb the tree", the students all created their own movements as they thought the idea could be expressed, then when the music stopped unexpectedly for a moment, they all had to freeze (*Fig. 4.62*). You could see that the students were anticipating when the music would stop and when it would start again. At one point, the "freeze" part when the music stopped lasted for quite a long time, and they all started to laugh. Nothing was said, but they all jointly understood and felt that this was funny. That is very musical, as their anticipation and prediction are evidence of musical thinking skills, and understanding humour is a sophisticated way of thinking. These quick responses were very interesting to watch, and a clear indication of their listening skills. The students' chosen movements were a delight, as even those children who had

Figure 4.62 - Synchronising movements with music

difficulty moving fluidly at other times, were smoothly dancing to the music. The two non-hearing people, a teacher's aide and a student, equally enjoyed this activity. They were in time, stopped appropriately, and were guided visually by the actions of the others. By the expression on their faces, they were enjoying the challenge just as much as those who could hear. Bonny creates an enriched environment in her music classes through lots of challenge, choice and active engagement.

Language

Spoken language was used in meaningful ways in this lesson and related to movement. Language is grounded in our interaction with the world and maps back to the experience and meaning derived through the words (Barsalou, Santos, Simmons, & Wilson, 2008; Glenberg, 2015; Glenberg et al., 2011), especially action words (verbs) (Bedny & Caramazza, 2011; Sidhu, Kwan, Pexman, & Siakaluk, 2014).

Bonny's instructions were about what to do. Lyrics in the songs were action words. At the end of the lesson, the student who had been the young bunyip in the story came up to Bonny and said some of his lines. These musical activities were strengthening the students' abilities with understanding language. Action words are processed through the mirror neuron system and the structure of the story assisted students in embodying their understanding and synchronising this with language.

Observations by teacher at the school

Bonny was contracted to the school to help establish a music program. I interviewed the teacher whose class Bonny was working with. Her discussion focused on how Bonny achieved learning and engagement, commenting more on how learning occurred rather than just about music.

Her overall strongest observation was that it was the action in learning, actually physically doing the learning, not just listening, that created the strongest and most powerful learning. “Making everything physical makes it stronger. I can see it makes learning more personal”. Along with this, she said that “everything is experienced in many different ways and links to other ways”. She gave the example of one of the students who is autistic and who at first was not interested in using the musical instrument (the guiro). When dancing, he was also not interested until Bonny did a dance where everyone linked through putting their hands on the shoulders of the person in front of them while they stepped to the beat. At first, he seemed unaware of what was happening, until he felt the momentum of the person in front and the person behind, which impelled his body to move also. The teacher said that he suddenly beamed and started moving in time with the music. It was as if “he had had the body woken up a bit”, she said, and he had a sudden awareness of being in sync with the music and others. He was delighted with the sensation.

This is an example of embodying the music, and it was created through feeling the movement with others in joint action and shared sensorimotor integration (Glenberg, 2010, p. 445; Maes & Leman, 2013b). This assisted him in developing the feeling of synchronising his own body with the music, and he demonstrated through his successful movements and joy that this was a positive experience for him. Following this experience, he then wanted to play the guiro. The teacher described that it was as if his body “had switched on”.

The teacher noted that Bonny repeated activities, but always added new things, and the students “don’t sit around too much”. She said that repetition is good, but always doing things the same way creates boredom and loses attention. Variety and change promotes neuroplasticity (Bengoetxea et al., 2012).

An interesting comment from this teacher, a specialist in special education, was that "With these kids, there is a big focus on Visuals, but taking out too much visuals helps focus on other senses". Bonny deliberately made activities highly sensory. In music this is going to include auditory sensations, but to synchronise this with visual, kinaesthetic, haptic and proprioceptive senses through physically engaging with people and objects creates a much richer and deeper neural "object". The whole sensory system provides the best representation of the world when sensory information is combined to create a unified, perceptual object (Purves et al., 2013, p. 575).

Along with all this, the teacher said she had learnt to take risks in teaching. She viewed all the action in learning as risky, but conceded that actually, it engaged the students more. Also, she felt that if she was prepared to take the risk, she would learn what does not work, but almost certainly, learn something new about her students.

Reflection by Bonny, two years later, on the impact of the neuroscience and embodiment research in the Neuropedagogy course.

Bonny said that learning about embodiment and neuroscience had been the most meaningful professional development that she had ever done. It had lent validity to what she does in the classroom and how she achieves this. Having knowledge of the research to inform and support her approaches to learning gave her "professional self-assurance" that she had previously lacked.

The most powerful and exciting information for Bonny was about mirror neurons. "It made me super-aware of the impression that my demeanour can make, right down to the expression of my eyes". She felt that while the neuroscience research presented in the course informs much of the way she was teaching with an active approach, knowing more about what is happening in the brain has proved valuable in the teaching and mentoring sessions that she does with adults and teachers.

As with all the participant-researchers in this thesis, Bonny is a long-standing Orff practitioner. She has always felt as if it was a "common sense" approach and it had worked for her across the many settings of her work, and had always been "great fun". "For many years, the fun factor seemed to work against me in the more serious music education world". Bonny now feels that her pedagogical practice has academic rigour and she feels proud that the students she teaches give "whoops of delight" when they see her and know that they will be DOING music.

The special education classroom - secondary

This special education context is in Perth at a state secondary school for children with mild to moderate intellectual disabilities. Merryn is the music teacher and was teaching in the school for just that year. As with Bonny's school, when teaching in this school, the teachers and aides also assisted in managing the students. The class is a middle years secondary class.

Introducing Merryn

Mary has been a primary classroom specialist, flute studio teacher, pre-school music specialist, and special education music specialist. She is currently about to open her own independent primary school, specialising in Creative Arts, in Western Australia.

Professional Background

Qualifications: Dip. Mus., Advanced Studies in Orff Schulwerk (Austria), Level 4 Orff Schulwerk Teacher Training.

Sensorimotor integration: a powerful moment shared between teacher and student

One of the most touching moments in Merryn's lesson was to do with a student who is non-verbal, has vision difficulties, is non-mobile, and confined to a wheelchair. Lily (not her real name) has little voluntary control of her body. While Merryn was playing the guitar and singing, Lily was still and attentive. Seeing this, Merryn approached her and put the guitar on her lap and asked her if she would like to play the guitar. Lily's hands carefully came to the guitar, a beautiful, calm smile on her face, then she put her own hand on Merryn's as she played (*Fig. 4.63 & 4.64*). Merryn had made available a touch experience of not only the feeling of what it felt like to play the guitar, but the shape of the hand, the rhythm and beat of the movement with the singing, the weight of the guitar and the vibrations the sound makes as it resonates with the wood and strings of the guitar. For a full three minutes, Lily was focussed intently on the guitar. During that time, it was if time stood still for the rest of the group. No-one moved or made a sound as Lily explored playing the strings and listening to the sounds she made. Merryn then started the song again and this is when a most miraculous thing occurred. Lily was, for a few moments, brushing her fingers over the strings in time with the song. To be able to manage her movements to do this was extraordinary. There

Figure 4.63 - Smile and hand on hand

Figure 4.64 - Touching the playing hand

Figure 4.65 - Focus

were no great sounds of glee; it was an intensely beautiful moment, and Lily's face had an expression of rapturous focus (*Fig. 4.65*).

This was an example of what could be termed, **shared sensorimotor integration**. It is shared because both Merryn and Lily were sharing and coordinating their movements and the song and playing the guitar. This coordinated movement together was also an example of **joint action**. Merryn made this opportunity to feel joined in action with others through coupling her body with Lily's in playing the guitar.

Extending into the musical environment

When Lily reached out to play the guitar, this was also a special moment of musically extended cognition. "Embodied cognition …puts the emphasis on the role of the human body as a mediator for meaning formation" and is a "special case of extended cognition (when humans use technology to "reach out" into the musical environment)" (Leman & Maes, 2015, p. 236), technology being the guitar. Lily reached out to extend her musical thinking into the guitar. What she could not express through her body on its own, she was able to express through her intentioned movements on the guitar, a tool that offered affordances for her musicality to be revealed.

Getting attention to focus on learning


Figure 4.66 - Joy in the sensory, musical tool

The active body, engaged with learning through tools, sound and the repertoire is how Merryn engaged these students so strongly. Getting attention is vital in learning. When attention is sustained and focussed, the brain has time to make, connect and retrieve memories. This memory process is achieved most strongly through active learning and results in neuroplastic change (Rocha et al., 2018).

Lily seemed particularly attracted and responsive to tools that allowed strong sensory interaction. Merryn handed out plastic bags and invited the students to find and make sounds with the bags. All the students showed a great deal of pleasure in doing this, with excited sounds and smiles and giggles. Lily again was particularly anxious to play with the bag. She seemed to relish the highly sensory aspects, such as the sound, feel, and the tool's availability for her body to manage. Her face expressed joy and focus (*Fig. 4.66*). Lily's teacher's aide, sitting next to her, commented that it was rare to get Lily to smile so widely. Lily explored sounds differently to the other students. She did not have as much control over her movements and hands as the others, so she used her face and her left hand to move the bag to make sounds.

Repertoire and play for exploring and developing musical thinking and neuroplasticity

Repertoire is a tool for learning. Merryn used a simple hand play game as her repertoire. The game gave purpose and structure to using the plastic bag and its affordances for creating movement and sound.

She taught the students a movement pattern to a speech rhyme, then she went to each student and asked them to invent their own movements (*Fig. 4.67*). Later, these movements and gestures were transferred to using the plastic bags. "Can you do it [the rhyme and actions] a different way?" Merryn asked.

Figure 4.67 - Students inventing new gestures; teacher copying

Each student offered their own actions, and they were interesting, varied and appropriate to the game. Merryn quickly adopted their movements and gestures, sometimes refashioning them to fit with the structure, but showing that she valued their individual choices, inventions and musicality. Merryn's pedagogy gave both feedback for how to do the task plus acknowledgement of their efforts. Attention, effort and active learning was achieved through using repertoire and the plastic bags as tools. The embodied learning and the tool made this learning accessible, active, strong and personalised. Because the learning feels like a game, the effort is sustained and repeated, which reinforces the processes of memory and neuroplasticity (Niland, 2009). Active, musical, memory-making shapes musical cognition and changes knowledge structures in the brain (Herholz & Zatorre, 2012; Wan & Schlaug, 2010).

Maintaining attention through use of tools and touch

As stated previously, getting and maintaining attention is important in making memories. Because Lily can gain limited visual stimulation, Merryn provided another way of getting and maintaining her attention, through touch. When it was Lily's turn to show her invented actions to the game, Merryn put her hands on Lily's lap, and Lily guided Merryn's hands to show her her own movements to the game. As Merryn sang the song, Lily's movements demonstrated not only her inventions, but her understanding of the musical structure of the song and her ability to keep the tempo. Touching of the hands (*Fig. 4.68*) and singing the song created another instance of the power of shared sensorimotor integration for this student to demonstrate her understanding and learning through action and personal engagement.

Figure 4.68 - Touch demonstrating musical understanding

The tools that Merryn used also engaged Lily's and all the other students' attention. The scarves that she used were brightly coloured, so for Lily, with limited vision, they stood out from the background, and were as foregrounded for her as much as the other students.

Merryn sang and played a peekaboo game/song with the students. They used the brightly coloured scarves to "hide" behind, though the material was transparent. The bright colours, combined with being able to see through them, provided inviting sensory experience. When they played the game and sang the song, they had to "peep" from behind the scarf at exactly the right time. Three of the students were quite capable of doing this and still enjoyed the game, but Lily and another had challenges with this. One had verbal processing challenges but managed to say "boo" at exactly the right time, and Lily managed to pull her scarf down and "peep" at exactly the right moment.

Active musical experiences drive musical cognition

Music drives us to move, and when listening to music, movement drives our understanding about music (Leman & Maes, 2015; Phillips-Silver &

Keller, 2012; Phillips-Silver & Trainor, 2007; Schiavio & van der Schyff, 2018). When people are engaged in musical joint action they demonstrate a shared sense of rhythmic and affective state (Phillips-Silver & Keller, 2012). Sharing understanding with others builds attentiveness and learning as they anticipate their own and others' actions to the music. Moving together supports their "in time" movements to the song with Merryn.


Figure 4.69 - Falling pitch using tools

Merryn used tools with musical affordances to learn about pitch in a very strong and active way for the students. Each student was given a scarf. The scarf was thrown high into the air and as it floated down, it was accompanied by the students making a descending pitched vocal sound, with them each inventing a sound for when it hit the ground, such as "plop". The exertion and action of reaching, throwing, watching and making the sound integrated into a conceptual understanding of pitch, binding together the look, feel and sound of highness to lowness in pitch (*Fig. 4.69*). The conceptual strength was that it was self-generated by the student, there was invention and choice, it was active, it was social, and it was play-like. Every student demonstrated a sense of joy and fun. Using tools changes perception and behaviour (Anderson et al., 2012), and using these tools allowed these students to practise and show their understanding of pitch, and extend their thinking into the tool (Leman et al. 2010, 203-223). The scarf was a tool with musical affordances for each student, that allowed meaningfulness to unfold in the action of using it, and promoted musical skill development.

The activity continued into a song with rising and descending pitch with actions for in, out, up, down, and roundabout, their actions helping the students learn about language as well. These words were accompanied by actions to match the words, creating meaningful, grounded, language connections. To reinforce the pitch aspects, Merryn again used tools with musical affordances. This time, the small scarves were thrown into a larger piece of material, held by all students and teachers together. Everyone holding the one piece of material allowed a shared sensorimotor experience, reinforcing the language and music pitch ideas. Time-pressure being an aspect of real-time, embodied learning (Wilson, 2002), drives faster, efficient processing and relevance between parts and meaningful wholes of conceptual information (Gülpinar, 2005; Kitchen, 2017). Using the singing mode of being musical is an ideal way of creating this type of learning, as the teacher can adjust the tempo according to how the group is managing the task, all participants are coupling ways of being musical to action. Because it is a playful activity, it lends itself to repetition, which reinforces learning.

Figure 4.70 - Shared sensorimotor representation of pitch

The other aspect that reinforces and strengthens memory during these types of activities is that the experiences are deeply sensorial and create a strongly binding conceptual understanding through embodiment. The activity uses not just peripheral sensory apparatus of vision and hearing, but also the deeper sensory apparatus of touch and internal understanding of what it feels like, the haptic and proprioceptive senses (Rozzi et al., 2008). During this activity, students gained understanding of what it feels like for pitch to be high and low, and this binds with what it sounds and looks like (*Fig. 4.70*). Should it be appropriate, this experience directly leads to symbolising through graphic notation, and eventually, conventional notation to represent sounds. Already, these students were symbolising using the scarf, but also through their bodies. Their bodies became a tool for representing pitch.

Conclusion: the impact of embodiment and neuroscience on music pedagogy in the special classroom

This section has discussed two special education contexts; one primary and one secondary. Bonny and Merryn are very active and expressive in their own musical behaviour and this is reflected in their music pedagogy. They provide models of what we look like when we are being musical. Models such as these feedback and map onto the mirror mechanisms of students so that they understand what it is to be musical (Livingstone & Thompson, 2009; Overy & Molnar-Szakacs, 2009). Their classrooms look and sound like music classrooms, as there is song, dance and movement, recorded music, musical instruments and other tools with affordances for being musical. Teachers and students are all active in their learning.

Musical embodiment

Bonny's and Merryn's pedagogy reflects musical embodiment and the neuroscience that supports learning in this way. As all activities engendered action by all students, learning was through the whole body. This achieved deeply sensorial activation attached to conceptual memories. These students were learning how it "feels" to be musical, and their perceptions and knowledge about music are informed by what they did, developing integrated multisensory knowledge. The human brain has evolved to learn in a multisensory world, and learning is stronger because of the richness and complexity of sensory interactions (Shams & Seitz, 2008).

Actions were linked to sound and the musical context. As students explored the feel and sound of the plastic bags in Merryn's session, they put these actions into a speech game, integrating the sensory and motor systems to develop skilled sensorimotor integration.

Similarly, in Bonny's lesson, when students copied her movements to the Can Can, they were learning to associate musical concepts with sound. This association was achieved through relating what their bodies were doing synchronously with the music, practising relating parts to conceptual whole simultaneously. When the students made their own movements related to the music, this demonstrated that their previous experiences and developed understanding could be shown through making predictions about what to do. "Active sensorimotor experience plays a key role in musical skill acquisition" (Schiavio & Timmers, 2014, p. 21).

Tools with musical affordances

The use of tools with affordances for developing musicality were a strong feature of both classrooms. The tools enhanced students' thinking capacities and became active components in shaping neural organisation (Bruner & Iriki, 2016, p. 99) and understanding in music. In Bonny's classroom, the students used musical instruments, recorded music and story. In both classrooms, they used material (scarves), props (costumes), bodies (as musical instruments – body percussion; as movement to express musical ideas), games, songs, speech, and dances. This provided opportunities for the students to develop musical skills and extend their thinking into the tool. Physical actions on external objects in these cases simplify mental actions (thinking) (Kirsh & Maglio, 1994).

The mirror mechanisms and peripersonal systems were involved in tool use. The mirror mechanism enables recognition of how to use and choose tools that fit with the body's musical capacities (Krueger, 2014; Mooney, 2010). Managing, using and developing neural "space" for the tool is processed through peripersonal neurons (Graziano, 2018; Noel et al., 2015). Peripersonal neurons are also active during social experiences, giving understanding for how to interact appropriately with others. All the activities in these classrooms involved social experiences, giving important musically social cues, such as how to interact with others musically, and how to synchronise musical behaviour. In terms of the tools used, these become neurally integrated to provide an abstract model of the sound and action associated with the musical tool and/or its affordances.

Summary

The pedagogy of both Bonny and Merryn reflected active, meaningful, embodied and neuroscientifically sound principles for learning. Their classrooms were examples of enriched environments that promote neuroplasticity through a combination of complex social stimulation and environmental interaction (van Praag et al., 2000). There was invention, exploration, variety, change, choice and challenge in their pedagogy. The learning was holistic, multisensory, relaxed alert, complex but authentic, skilful and positive.

4.6 The embodied music classroom: principles for enriched music pedagogy

This section discusses how the insights gained from the Instrumental, Secondary, Primary and Special Education settings, were used to create principles for music pedagogy, embedded with embodiment and neuroscience. These were enacted by the researcher in a lesson series in the tertiary music classroom. Students were Bachelor of Education (Primary) students and participated in a music education subject in how to teach music and dance.

The tertiary setting was used to practise all the aspects of embodiment and neuroscience that had been features of the observed classrooms. In the development of the tertiary lesson series, the researcher developed principles to guide planning for enriched environments where musical learning and behaviour can occur. These principles will guide pedagogy for music teachers who wish to incorporate embodiment and neuroscience practices in their teaching.

A description of those important aspects follows, with the principles outlined in the final chapter, Chapter 5, Conclusions and Future Directions.

The role of the world in embodied musical cognition

"The world" in embodied cognition is the setting in which interaction between the brain, the body and the world occurs. Embodied cognition asserts that knowledge is grounded in sensorimotor systems that engage with the world (Barsalou, 2008; Glenberg et al., 2008; Glenberg et al., 2013; Wilson, 2002). As we encounter and sense the world, neural motor systems respond and develop skilled behaviours for managing in that world. The world constitutes the physical materials, objects and social opportunities that are available.

What caught the researcher's attention in all the settings where observation lessons occurred was *how* the "world" was captured in each setting. All the contexts had rich worlds to engage with, and each had special features. In the special education context, the special feature of the world was the interaction with sound and objects; the exuberance in response to music with Bonny, and the rapture in response to sharing the sensorimotor integration with the instruments and tools with Merryn. In the instrumental context, the special feature of the world was the social engagement that was fostered and supported the learning, and the multimodal interactions that were created and available in that world. The primary context had ever-changing sites of musical engagement in the world, with just one major tool, used multiple ways. The secondary context used sound and action with the world to harness and focus attention, through lively, active musical behaviour and joint attention.

Creation and features of a musical world

The world, in all the settings, was created by the teacher. The features that contributed to the world were the teacher and their musical embodiment, the embodied musical action, objects and tools in the world, the physical space used for the lesson, and other people.

- **The teacher and their musical embodiment**

  The embodiment of music in the teacher's body is a very important part of music pedagogy, and a feature of the musical world. The teacher's body is a model of musical behaviour. They engage in being musical with the students and share in the feeling of being musical with students. The teacher uses face and hands to enhance musical ideas and convey inclusion, and they develop understanding of musical concepts by embodying them.

- **Teacher as model of musical embodiment:** The teachers in each of the observed settings looked and sounded like they belonged to a musical world by the way they embodied being musical. The teachers all demonstrated musical behaviour. They used expressive voices, sang, moved, gestured, and played. Through the teacher's model, students know what musical behaviour looks like because the teacher is the embodiment of music.

- **Teacher engaged in the world with students:** Another noticeable feature in each setting was how much the teacher was musically engaged in the world <u>*with*</u> the students. None of the teachers stood back and watched, or told students what to do, or only taught from the front of the room. The teachers modelled all the musical behaviour and participated in music-making activities.

- **Teacher and shared embodied experience:** In the instrumental setting, Phil, the teacher, shared embodied experience. He adjusted student's posture and playing position, very subtly, as he moved around the students while they were playing. He did not give lots of verbal instructions. He acted on their body by a touch to adjust hand position, a lift to put the student's body into a better posture, so it was the student's body that felt the effect of the adjustment and embodied the playing position.

  In the special education setting, the desire to feel and embody what it felt like to play the guitar was initiated by the student. She reached out to touch the teacher's hand to feel the strumming hand on the guitar. If the teacher, Merryn, had not been embodying this musical behaviour, the student would not have been able to enter the shared embodied experience of what it felt like to strum the guitar strings. The student then took the place of Merryn's hand strumming and demonstrated that amazing moment of playing the strings in time with the song, from a body that had very little controlled movement.

- **Teacher-to-student embodied social and musical engagement:** The teachers all looked at their students, as an invitation to join in the musical world. They had expressive facial expressions and used hands in gesture and demonstration of procedures, to bring attention to place, direction, and to represent ideas (Goldin-Meadow, 2015). Hands and face have special significance in the mirror mechanism (Rizzolatti & Craighero, 2004). Humans are hard-wired to recognise and take special note of facial expressions. Expressions enhance understanding of language and give meaning to actions, express emotion, affirm, engage, include and encourage. Hands use gesture and embody meaning in action.

  It is a very special design in music pedagogy to be able to look at students, and include them personally, while embodying musical behaviour. The face of the teacher tells the student that they are included, they belong, "I mean you". Students stay engaged when they feel included, and a facial expression by the teacher conveys this. If the teacher is reading music while teaching, or watching a screen or otherwise looking elsewhere, the students can become disengaged. It can convey the message, "I don't mean you".

- **Teacher – expressions of the face to suggest musical embodiment:** Facial expressions enhance the message, and this is not just the social message. Facial expressions also embody the musical message. The lift of the brow to reach a high note looks like how it feels to reach up high. The intake of breath looks like the feeling of beginning something. This is embodied musical expression, and embodiment of musical action.

- **Teacher – expressions of the body to suggest musical embodiment:** The body also enhances meaning about the music. When the body gets into a position to prepare for the beginning of action, we usually draw in the breath, ready to begin. The mirror mechanisms in the brains of the observers are assessing the intention of the goal of this preparation and making predictions about what sort of action will emerge (Anderson, 2016; Friston, 2005; Park & Friston, 2013). For example, if the teacher wants to embody making a soft sound, the body would be very managed and make small, little soft movements. Small, managed movements embody how to make soft sounds. If the teacher wants to embody rhythm patterns with different sounds, they might use body percussion on different body parts. Body percussion is hitting the body to make sound. Different body parts elicit different tones, so a hit on the chest would sound different to a hit on the knee. When a teacher embodies a variety of body percussion sounds in a rhythm pattern, they are embodying the concepts of tone colour and duration.

  The embodiment of music in the teacher's body is an integral part and very important feature of the world in the music classroom. If there were no instruments and musical tools, no music room or space, no recorded music to listen to, the embodiment of music in the teacher's body can still make the musical world.

Objects and tools in the world that drive musical thinking

Each of the observed settings provided interaction with tools that afforded musical behaviour. They were either <u>physical musical tools</u> such as musical instruments, materials and objects, movements, gestures, games or technology; <u>conceptual musical tools</u>, such as musical structures, scales, repertoire, symbols, poems, stories; <u>cultural musical tools</u>, such as dances and ensembles or <u>social musical tools</u> such as ensembles, groups or whole class. Tools afford extending thinking into the world. For example, extending thinking into a melodic musical instrument provides an opportunity to play with melody. Without the musical instrument, this capacity might not be available. The musical instrument provides extended musical capacities.

Using tools that have affordances for being musical increases musical capacities and skills and music cognition. Tool use changes perception and behaviour (Anderson et al., 2012) and "play(s) an active role in driving various cognitive processes" (Krueger, 2014, p. 5). When we develop strong sensorimotor maps with tools through lots of practice, the tool becomes part of our neural structure and provides a mental tool for thinking musically. These mental tools give rise to abstract thought, audiation (the ability to "hear" or imagine sound without the physical presence of sound), problem-solving and other mental skills for approaching musical learning and meaning-making.

- **Physical, conceptual, cultural and social tools:** Tools that afforded musical behaviour in the observed settings were:
  - Physical:
    - musical instruments, "other" sound sources;
    - objects that assisted use of instruments, such as stools for instruments to sit on;
    - stools for students to sit on, but stackable so that space could easily be cleared for other musical action;
    - materials – floaty scarves to help express musical ideas, large floaty materials to that the whole class could hold onto it, and feel the combined, joint movements made upon the material;
    - technology and sound equipment - interactive boards, computers for teachers and students to view and work on together;

- Conceptual:
    - writing materials – small whiteboards for group work, so that a group of students could experiment with symbols, jointly record group ideas, create big symbols, etc.
    - repertoire – songs, dances, music recordings, poems, story;
    - gestures – solfa[22], handsigns to represent chords, gesture to represent motor actions;
    - symbols – conventional and graphic notation;
    - language – musical terminology, direction;
- Cultural:
    - Gestures for direction (procedural; orientation, left and right etc), cues, confirmation;
    - Procedures for making music;
- Social:
    - Whole class, groups, pairs, teacher-student, student-student; parent/carer-student.

What defines the physical space of the world?

The size of the space to move in, the acoustics for sound, the flooring, furniture, all physical things in the space, or that are perceived outside or around the space, have an effect on the embodiment of music in the space. For example, the floor surface can enhance or impede movement; how the sound resonates in the space can enhance or diminish the quality of sound; how much space is around the body and what can be seen and heard in the space affects musical embodiment. These are important considerations in music pedagogy.

---

[22] Solfa – a system that ascribes syllables and handsigns to degrees of the diatonic scale. The tonal centre, designated as "doh" is movable, so all other notes of the scale are related to where the "doh" is situated. It is used as a teaching tool for sight-singing and reading.

- **The way the space is used:** Both Merryn and Bonny created a musical world in the space where their lessons occurred, even though they were not in a music room. They did this through embodying musical behaviour, using musical tools and engaging the students in being musical. That space became a musical space through the way they used it.

  In the special education setting, neither Bonny nor Merryn had their own dedicated, music classroom. In some states in Australia, they are called, "itinerant" teachers, "extras", "casuals", "extra-curricular" teachers, "release-from-face-to-face" teachers, or in Bonny's case, "contract" teachers. These titles all suggest an uncertainty of value, role, or entitlements, as the role, except in the case of a contract role, is not "the music teacher".

  These titles mean that usually there is no dedicated space that is the "music room", or special equipment. The result of not having a music title and no dedicated space is that the teachers usually "bring and carry" all the equipment they need, cannot leave their equipment in a safe place in the school, set up and pack up every lesson or visit, and cannot prepare the space permanently to suit a music world. It also means that the equipment used for teaching music and for the students to use is often the teachers' own equipment.

  As mentioned, the observed lesson by Bonny was the second last of the two terms she had been employed. In Merryn's case, the school decided to devote some unallocated funds toward music. As Merryn had taught in the school for a short, set period of time the year before and had made a very positive impact on teachers and students, the school decided to fund more time for the students to be musical with Merryn.

Merryn and Bonny created the musical world in the space they used through embodying musical behaviour, using musical tools and engaging the students in being musical.

In the instrumental setting, Phil's use of physical space was very interesting. As described in section 4.2, the pianos were around the walls of the room with a chair in between each piano for the carer to sit. There was a big space in the middle of the room where movement activities, using small percussion instruments and games were held, and at the "front" of the room was a baby grand piano, whiteboard and computer screen. This arrangement of the room allowed many different ways of engaging students in musically embodied behaviour.

In the primary setting, Lauren was very fortunate to have a dedicated music room that was quite large. She, therefore, had room to have melodic percussion set up ready to use, open storage for easy access to small percussion instruments, open space for movement, whiteboards on two walls, effectively changing "front" of room, and stackable stools. On the walls were lots of musical images, such as pictures of ensembles, instruments, composers, musical words and symbols, posters and also photographs of the students doing musical activities. Any musical behaviour was possible in that room and everything about the room looked, sounded and felt like a place where music happens. This was also very similar for the secondary classes.

Consideration of the physical space is very important for being musical. All the classrooms in this thesis created a physical setting for varied musical engagement, even though some spaces were not music rooms. Overall, the space should be used to serve musical activity, and prime the musical brain.

Other people and social affordances

All the music settings in this thesis were group settings. Group settings provide great opportunities for social engagement, which affords ensemble understanding and communication, group work, play and conceptual construction through group problem-solving and creative opportunities. The interplay between individuals and groups can provide some of the richest affordances for interaction in the world (J. J. Gibson, 1986a, p. 135). Students can feel comfortable in group settings as they are not individually always the focus of attention. Being part of a group provides some personal space for watching and learning from others, practising on one's own, or joining with others.

In the instrumental setting, Phil used the parents and carers in a very special, social way. The students developed their conventional and musical social skills by greeting other adults, performing to them, playing games with them, talking to them and being assisted by the adults. The adults become an integral part of the musical setting by supporting the students, encouraging and assisting them in performance, developing their own musical behaviour through interacting musically, and being part of this world, understanding the embodied musical behaviour. The parents and carers also became the link between home and the music lesson, a link that often is missing from the instrumental setting and can be the cause of disengagement with the instrument.

The role of the body in embodied musical cognition

Embodied musical action

Lots of embodied musical action took place in all the music lessons observed. No-one was a spectator to learning[23]. None of the rooms had everyone sitting at computers, though sometimes, in the instrumental context, a computer was used[24]. To anyone who might have looked into the rooms or into the space in which the lesson was taking place, there was no doubt about what subject was being practised in the space. The bodies, sound, the activities, the teacher, the tools that afforded musical behaviour all together made it abundantly clear that this was a musical world. Everyone was actively immersed in the making of embodied musical memories.

The type of actions that are musically embodied action are:

- Vocalising – expressive speech, singing, scat singing, vocables, singing in solfa (pitch names with related hand signs);
- Moving – dance movement, expressive movements, gestures;
- Playing – using instruments, bodies and other sound sources to make sounds;
- Improvising – inventing and creating musical ideas in the moment;
- Composing – inventing and creating musical ideas, and refining to formalise musical ideas;
- Listening – active listening, where musical thinking interprets, understands and decodes sound (not passive);
- Speaking – using specific musical terminology and language to capture musical ideas and concepts, conveying and delving more deeply into musical understanding;

---

[23] This of course does not mean that one cannot be learning about music while watching or listening, but in the music learning context, students should, most of the time, be actively engaged with learning about being musical.

[24] Again, there is a time to be on computers when learning music.

- Conducting – leading and keeping a group of players or singers or dancers together and jointly perceiving musical intention.
- Joint action – being musical jointly with others, in a class group, in pairs, in ensemble, in time and musical place with others.

The act of making music involves deep immersion in embodied musical action.

The role of the brain in embodied musical cognition

The brain is complex and the behaviour that results in deep learning is set in complex, multisensory worlds. The brain is equipped and in fact works better in rich environments where action and perception are challenged to fire and build strong connections and networks in the brain. "Cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks" (Bressler & Menon, 2010).

The way to create strong brain networks in the music classroom is to incorporate a wide variety of richly sensory activities so that students understand what it *feels* like to be musical, what it *feels* like to produce pitch, volume, and dynamics with the voice, body and on musical instruments; what it *feels* like in the body when a deep sound resonates from the vibration of the instrument through the body; what it *feels* like to yearn for resolution in melody and chords; what it *feels* like to draw toward the end of a song. It is only when the full range of senses activate through personal engagement with being musical that strong representations and memory are developed.

Strongly networked musical memories and knowledge are developed through multiple modes of being musical. Information in one mode facilitates interpretation in another, and cross-references and strengthens memory (Martin-Martin & Brock, 2017, p. 1). Just singing, or just playing is not enough to develop these deeply networked knowledge structures. Teachers need to incorporate many modes of musical behaviour in their pedagogy.

Engagement with tools with musical affordances develops skilful capacities in students. When the tool, such as a musical instrument, is repeatedly used, strong sensorimotor integration occurs, resulting in skilled performance and understanding. Tools become part of the body schema in the brain (Iriki, 2006) and thinking is extended into using the tool (Leman et al., 2010). The peripersonal and mirror mechanisms are involved in this process.

The mirror mechanism is important for music teachers to understand. Joint action and attention, essential for skilled ensemble behaviour and musical social cognition, are actioned through the mirror mechanism (Keller et al., 2014). The mirror mechanism is designed to understand the behaviour of others through imitation and prediction of intention of actions. Imitation and allowing students to predict and develop knowledge through action and perception are features of music pedagogy that reflect understanding of the mirror mechanism's functions (Overy & Molnar-Szakacs, 2009).

Neuroplasticity is the change that takes place in the brain as a result of experience (Martin, 2015). The more the brain is challenged through enriched environments, the more neuroplastic change takes place and the brain gets stronger. Everything that is involved in the experience becomes intertwined in the memory through a Hebbian process (Hebb, 1949). This means that all the neuronal networks develop connections amongst one another, so that retrieval of memory can be activated from many different networks (Merzenich et al., 2014).

Enriched environments promote neuroplasticity and a fast, efficient, learning brain (Radin, 2009; van Praag et al., 2000). Enriched musical environments provide great opportunities for challenge, options, reward, novelty, social stimulation and collaboration, through active, embodied engagement in a richly musical world.

All of these neuroscience aspects were incorporated into the pedagogy in the Instrumental, Secondary, Primary and Special Education settings.

4.7 Principles for embedding embodiment and neuroscience in music pedagogy

As a result of the insights gained from all the settings in this thesis, a set of principles for developing enriched musical worlds through music pedagogy have been devised. Principles to do with "the world" and "the body" incorporate embodied cognition research in multimodality, tool-use and affordances, joint action, extended cognition. "The brain" principles reflect the research aspects of multisensory integration, sensorimotor integration, peripersonal and mirror mechanisms, neuroplasticity and enriched environments. These principles will be outlined in the final chapter, Chapter 5, Conclusions and Future Directions.

Chapter 5 – Conclusions and future directions

This thesis has investigated how embodiment, underpinned by relevant aspects of neuroscience, can be embedded in music pedagogy in four music education settings. Firstly, it showed how a group of experienced teachers conceptualised and embedded embodiment theory in their music pedagogy. Secondly, it illustrated how these conceptualisations and practices form new perspectives on how embodiment can be embedded in different settings. Chapter 1 provided a background for the thesis, the significance of the main question, and an overview of the methodology. This chapter also presented an outline of the significance of embodied cognition to music pedagogy, and of the neuroscience that supports it. Chapter 2 located music pedagogy in an embodied cognition framework and argued its key aspects in relation to how neuroscience explains these phenomena. Chapter 3 detailed the design-based methodology process to explore ways that embodied cognition could be enacted in an authentic setting, the classroom. It described the selection criteria for participant-researchers and the approach to analysing the data. Chapter 4 presented four distinct settings in which conceptualisations of embodied cognition were applied in the classroom in the teachers' music pedagogy. The chapter closed with a description of insights gained from the settings that form principles for embodied music pedagogy.

This final chapter draws together the main findings, with implications for music pedagogical practice in each specific setting and the wider music education field, and a set of principles for embodied music pedagogy, with connections made to the research literature.

The central question of this thesis was:

> ***How do music teachers embed embodiment, informed by neuroscience, in music pedagogy?***

The two associated questions were:

> ***What does music pedagogy informed by embodied cognition and neuroscience look like?***
>
> ***What future directions does this research offer to specific music settings and wider music education field?***

The following is a summary of the results of investigating these questions, with conclusions and future directions presented.

5.1 Summary of results and conclusions

The thesis has four distinctive features. Firstly, it links key aspects of neuroscience that are pertinent to musical behaviour, to embodied cognition theory. Secondly, it provides four different music education settings where experienced teachers have embedded embodiment in their music pedagogy. Thirdly, it fills the gap in the literature about what music pedagogy would look like in practice, informed by embodied cognition theory and neuroscience. Fourthly, it proposes principles for developing embodied music pedagogy.

The analyses of the settings were designed around interacting aspects of embodied cognition and neuroscience, with focus on the most salient features in each setting. All aspects are overlapping and interweaving, but in description, reveal practices that engender musical behaviour.

This thesis built upon research by others who established knowledge about embodied cognition and neuroscience. However, this thesis also connected these ideas and applied them to the field of music pedagogy, resulting in musical pedagogical practices supported by research. The concepts from embodied cognition are "the world", "the body" and "the brain". In each of the settings, "the body" was epitomised with high levels of action, which developed and shaped music cognition. This confirms that "The finding that music perception is shaped by the human motor system and its action suggests that the musical mind is highly embodied" (Maes, Leman, Palmer, & Wanderley, 2014, p. 1). The world in each case was rich with opportunity for interaction with people, places and things, reinforcing that cognition "arises from bodily interactions with the world and is continually meshed with them" (Thelen, 2000, p. 5). Cognition was extended into the world through tools with musical affordances and social engagement. The classroom setting afforded socially-mediated musical engagement (Bowman, 2004) which develops and constructs musical capacities for sharing mental states and shaping social music cognition (Gallotti & Huebner, 2017; Schiavio & Høffding, 2015). Finally, each setting provided an enriched environment that afforded rich engagement through a combination of complex social stimulation and environmental interaction (van Praag et al., 2000).

5.2 Implications of the thesis for music education settings

This thesis has examined how embodied cognition, underpinned by neuroscience research, has been implemented in the pedagogy of music teachers in four specific music education settings. Each setting has yielded rich data that demonstrates what embodied music pedagogy looks like in practice. The implications of this data are discussed with a particular emphasis on how they can be further elaborated in the wider field of music education.

Instrumental setting – Multimodal embodiment

The instrumental setting exemplified active, embodied music neuropedagogy. The main ways it was achieved was through use of space (the world), social cognition (the world), use of tools, affordances and extended cognition (the body) and multimodal learning (the body). The implications of each of these will be discussed further.

Use of space (the world)

Flexible use of space can engage students actively in diverse, musical, modes of action. This was a feature of all settings but is not usually associated with the instrumental setting. In the National Review of Music Education, Pascoe et al (2005) stated that current instrumental pedagogy had "a narrow focus on micro skills, (and) while important, should not be the only focus…Instrumental music must connect with and support the broad aims of music education" (Pascoe et al., 2005, p. 126). He went on to say that instrumental pedagogy needs to be open to "innovation, change and development" (p. 126)

Results in the instrumental setting demonstrated a wide variety of ways that space can be used in the instrumental setting. Having a large space allows flexibility of use and different sites of learning and engagement, for example, a site for:

- direction instruction – so there might be a whiteboard to draw and write on;
- technology use – to view musical samples, or use musical tools;
- instrumental play – not just the instrument of direct instruction, but other instruments, such as melodic and non-melodic percussion;
- social engagement – this site had a chair for carers to sit upon between pianos. This meant that carers could engage with the musical learning with their child, other students and the teacher. The space also allowed for the teacher-and- students, and

students-and-students to engage socially, both musically and culturally;

- Movement - movements could include gestures to indicate musical understanding, such as wide sweeping arms to show length of phrasing; dance, pre-organised movement, which develops understanding of such concepts as genre and structure. Gesture emphasises and enhances meaning and grounds understanding in action (Beilock & Goldin-Meadow, 2010). Movement could also include dance, which creates understanding of genre, structure, metre, rhythm patterns and so on.
- Being an audience – enhancing active perception (Windsor, 2016)
- Different perspectives – lying on the floor to observe closely, at the instrument watching the teacher play, watching others, being watched, playing with others;

This instrumental setting demonstrates how having a flexible use of space contributes to innovative practice and allows for connections to the broad aims of music education. The use of space in this setting provides an enriched environment, through variety, change, options, choice, key aspects of enriched environments for developing neuroplasticity (Gülpinar, 2005).

Social Cognition

When students engage socially in musical activities, they are developing key musical performance skills. This contributes to creating social cohesion, "co-pathy (the social function of empathy), communication, coordination of actions", cooperation, and a sense of belonging for all (Koelsch, 2013, p. 204). Conventional and musical social cognition is a function of the mirror mechanism (Rizzolatti & Fabbri-Destro, 2008) and peripersonal neural systems (Teneggi et al., 2013).

The results from this thesis demonstrated innovative ways to engage in musical social cognition that has implications for the wider instrumental setting. These include:

- Parent/cares in partnership in the lesson – this can give confidence and assurance, especially to the younger student, provide enjoyable interaction, create links between home and the instrumental lesson, facilitate understanding and unity, strengthening through sustaining musical action between home and the lesson;
- Student-to-student - when students play together, they develop their musicality through understanding of the intention of others' musical movements and facial expressions, use of breath, gesture and so on. They also learn about how to listen to inform musical judgements, such as how to play as a soloist, in a duet, or as the background. They learn through watching others (vicarious learning) who are engaged in the same activity. This engagement is processed through the mirror and peripersonal systems.
- Types of musical social engagement – singing, playing instruments, hand play, games, problem-solving tasks, dancing and moving.

Tools, affordances and extended cognition

One would think that the obvious tool that would be used in an instrumental lesson would be the instrument of focus itself. However, this setting demonstrated that many tools can be used to develop a depth of musical understanding beyond just the instrument being learnt. Musical tools such as musical instruments afford the development of technical and musical skills on that instrument. Multiple tools afford more musical learning that maps back to understanding of musicality on the target instrument. For example, when body percussion is used as a tool for performing a rhythm pattern, and the student then plays the pattern on the piano, they will already have played it using another tool. This enhances their understanding of what the pattern feels and sounds like, in a crossmodal, cross-reference (Spence & Parise, 2012).

Through results from the instrumental and other settings, this study proposes four categories of musical tools that have affordances for musical behaviour. This list is a guide and there could be others considered.

- **Physical** – musical instruments, materials (to manipulate to express musicality), movements, gestures, games, technology;
- **Conceptual** – Scales, forms (e.g. rondo, sonata etc), repertoire, symbols, scores, language, songs, poems;
- **Cultural** – dances, choirs, ensembles, events;
- **Social** – the interplay between individuals and groups. (Gibson (1986a, p. 135) considered that other people provide the richest and most elaborate affordances for interaction in the world).

Tools can also be used to extend thinking into using the tool and thus, lighten the cognitive load. When using a musical instrument, a student does not have to imagine what pitches sound like. It is under their fingers, into their bodies and develops cognition. Problem-solving, composing, improvising, feeling the music and other musical functions can all be achieved through extending thinking into using the instrument. Ultimately, this creates the musically independent musician (autopoiesis) through the emerging understandings that arise from extending thinking into using the tool. Examples of this are creating melodies using a restricted number of pitches, or playing repertoire a bit differently and so on.

Multimodal – multiple ways of musical engagement to develop musicality

The instrumental setting in this thesis used many modes of musical behaviour to enrich musical understanding and performance. When students practise being musical in many different ways (modes), they leverage "the information obtained in one modality to facilitate the interpretation of another modality" (Martin-Martin & Brock, 2017, p. 1).

This thesis proposes that multimodal refers to the multiple "modes" or ways of expressing musicality through the body. The modes require action with an affordance to make them exist. Improvising and composing can use any tool with musical affordances.

The musical modes of behaviour are: vocalising (singing, speaking, using vocables, scat singing), moving, dancing, playing, improvising, composing, notating, gesturing, reading (decoding symbols), describing (using language), listening (active), jointly acting, extending thinking. The table in Chapter 2, *Table 2.1 Multimodal uses of tools with musical affordances,* identifies musical tools that engender such behaviour. For example, when in "singing" mode, *a song (the tool) affords singing*. If the song was accompanied by movement to acknowledge the beat, *the song and movement afford singing and playing the beat*.

Implications for instrumental music pedagogy

The overarching implication for the instrumental setting is that action leads to musical behaviour and cognition. Action in instrumental pedagogy can involve flexibility in use of space (the world), opportunities for developing social cognition (the world), using of tools, affordances and extending cognition (the body) and using multimodal ways of musical learning (the body).

All of these aspects interweave and overlap. The use of space allows many modes of musical action. Social musical interaction develops musical ensemble skills and joint action. Use of tools with musical affordances invites action to become more skilful in being musical. Extending cognition into the tool is the action of musical thinking skills and independence. Multimodal action provides a cross-referencing of musical understanding, creating depth and richness to musical cognition.

Secondary setting – problem solving with the body

The Secondary setting used action through extending thinking into the body and use of musical tools. This was achieved through keeping the repertoire in real-time (time-pressured), using perception and action to develop skilled sensorimotor integration and cognition, using tools with musical affordances and multimodal learning.

Time-pressure – the pressure of real time

A key aspect of embodiment is "the lived experience" (Hermans & Bremmer, 2015), the experience as it is practised in the moment. Music in its authentic context is in real-time, in the moment. To perceive features of the music in real-time is complex meaning-making cognitive task. However, when extended into the body through moving, perception of the music guides action and influences what is perceived. "How we move will influence what we hear" (Phillips-Silver & Trainor, 2007, p. 535).

The secondary setting demonstrated that immediate immersion in real-time repertoire, with purposeful movement "suggestions", engendered direct, meaning-making movements in the students.

Extending cognition through use of an affordance

This setting demonstrated that tools allow skilful capacities to emerge that would not be available without the tool. Use of external tools affirmed that they enhance sensory and thinking capacities and become active components in shaping neural organisation. When students use tools with musical affordances, their capacities to demonstrate their musical capacities increase. Through direct engagement with tools such as drumsticks, students develop strong sensorimotor networks to make meaning from musical experiences. "Active sensorimotor experience plays a key role in musical skill acquisition" (Schiavio & Timmers, 2014, p. 21). Students make connections between musical context and intentional, musically-directed actions through tools with musical affordances.

Problem-solving through the body through multimodal learning

As with the instrumental setting, when problem-solving is practised through the body in a variety of ways, perceptions are cross referenced across modes. Offering multiple ways of practising musical concepts is attractive to the secondary student. They are most engaged when actively experiencing their learning and this folds into skilled engagement. Active engagement with moving, playing, improvising and composing focusses attention because it is completely embodied. Embodied learning maps back to the neural structures in stronger ways than just passive learning, where information is delivered instead of explored and discovered. Musical cognition becomes action as they engage with instruments, others and repertoire. The mirror mechanism processes engagement with using the tool and social engagement (Rizzolatti & Sinigaglia, 2016). The peripersonal neuron system is engaged in social cognition and through using tools to help manage the space around the body (Graziano & Campbell, 2018).

Implications for secondary music pedagogy

Pedagogy that engages the secondary student through active engagement with tools, movement and repertoire, directly relates to musical meaning-making and cognition. When students are fully engaged with many ways of being musical, they are primed for noticing aspects of the repertoire, problem-solving through active exploration and playing, and making it their own lived experience.

Primary setting – complexity through simplicity

The primary setting was a perfect example of how the complexity in music could be simplified through carefully prepared pedagogy. Teachers do not need to use lots of repertoire for students to learn about musical ideas. Repertoire is a tool for learning about musical ideas and concepts. Skill development is in the embodied experience of doing activities with the repertoire. This setting used one tool for many purposes, to experience complexity through simplicity.

Aspects that have previously been described, such as flexible use of space, time-pressure, tools, affordances and extended cognition, problem-solving through the body are also aspects of the primary setting. The aspects that will be discussed further are simple tools for multiple purposes, the mirror mechanism and how it benefits music pedagogy, use of gesture and grounding symbols through action.

One tool, many purposes

One simple tool with Kindergarten, a speech rhyme, and one simple tool with Year 4, a dance, resulted in deep and complex musical learning. All the musical concepts and many musical skills were actively practised through the rhyme, including audiation, the ability to think about sound without the physical presence of sound. Many musical concepts and abstract memory were shaped by use of the dance with Year 4. Both examples of use of simple tools for learning resulted in richly networked perceptual objects that included visual, auditory, haptic and proprioceptive memory. Together these develop skilled musical cognition in line with the principle of neural reuse. Core to this principle is the idea that "individual neural elements… are used and reused for multiple cognitive and behavioural ends" (Anderson, 2016, p. 1).

Using the same tool saves cognitive load. In practical terms, when time is short, learning new repertoire unnecessarily takes up the time that could have been spent developing cognitive capacities. Opportunities for perception and action to develop sensorimotor integration were all folded into using one tool. This skilled learning could then be transferred to the next learning context for reuse of the same circuits to make new connections.

Mirror mechanism and how it benefits music pedagogy

Skilled pedagogy uses efficient ways of communicating and for learning to be enacted. The mirror mechanism, the neural system that enables learning through imitation, benefits music pedagogy. Musical behaviour can be modelled, without explicit instruction and students learn through imitation. This saves time in explaining through language, which can be easily misunderstood and takes time. However, when learning is enacted through imitation, the learning is embodied and embedded in the sensory and motor systems of the observer. This grounds understanding through the body and personalises memory.

Use of gesture

Gesture is a strong pedagogical tool. It conveys meaning quickly through action understanding and does not distract from the "musical space" (sound that is occurring). Deictic gesture, such as pointing and gaze, draws attention to objects. Conventional gestures use standardised forms to convey cultural meaning, such as nodding the head for "yes" in some but not all cultures. Representational gesture captures aspects of an action; iconically (demonstrating how to play drum) or metaphorically (moving two open hands up in the air to signify maintaining a sustained sound while keeping the volume up) (Cartmill et al., 2012), and spatially (capturing aspects of relative space). This was very effectively used to convey how to do a dance, (direction, cuing for left and right, crossing the midline, and so on) as well as learning to play an instrument (pointing to notes while playing sounds, demonstrating how to play while singing and so on). Gesture is usually associated with hands, but also the whole body. Breath, for example, can indicate when to start moving or about to start a new movement. This is a very important musical skill to understand, as ensembles and dance use breath, gesture and fine movement to convey musical meaning. This enables people to perform in joint action and understand the meaning through social cognition.

Grounding symbols through action

Action-based problem-solving is body based. The action in learning can be used to solve problems. What looks like musical play and games is actually the work of internalising musical understanding. Knowledge that is grounded in bodily action captures abstract relationships between action and sound. Those internal models are the foundation upon which musical thinking and cognition grows (Maes, Van Dyck, et al., 2014).

Implications for primary music pedagogy

Using pedagogical tools economically enables the real learning to be enacted through use of one tool. This is using a principle of neural reuse, that "newly acquired capacities are generally supported by mixing and matching the same neural elements in new ways" (Anderson, 2016, p. 1); one tool, many purposes.

Modelling is an efficient pedagogical tool. It takes advantage of the mirror mechanism which enables understanding through imitation.

Gesture as a pedagogical tool conveys information efficiently and meaningfully. When a teacher uses gesture, students receive a visual representation of meaning. This can be a very useful pedagogical tool when teaching complex movements, such as left and right directions and crossover movements. Gesture preserves the sound environment, where speech might interfere with the sound. Gesture and speech can also be coupled to create meaning, such as singing note names or singing movements. "Gesture and speech form an integrated and … synergistic system in which effort expended in one modality can lighten the load on the system as a whole" through shifting the cognitive load from verbal processing to motor processing (Goldin-Meadow et al., 2001, p. 521). Finally, gestures bring concepts to the foreground of attention.

Knowledge that is grounded in physical interaction creates abstract connections between action and sound, and provides useful cognitive tools for problem-solving.

Special Education setting – Joyous, rapturous, exuberant action

This setting presented action-based, joyful musical learning. Embodied music pedagogy has a unique and irresistible way of opening the mind and inspiring the body to respond. Learning and responding through imitation, the use of tools and joint action, and multisensory integration allowed all to be fully musically engaged and active.

Modelling and imitation

Clear models of what it is to be musical conveys musical meaning to everyone and is essential in special education settings. Grounding musical understanding in action means that every student is able to demonstrate their musicality without explicit instruction, use of language, or processing of confusing messages. Musical expression is conveyed through hands, face and related vocal tone. Body language and facial expressions are quickly processed through the mirror mechanism (Rizzolatti & Fadiga, 2007), so pedagogy that uses body and face for teaching enables strong learning in these settings.

Joint attention and musical social cognition are also enabled through this system, so important musical lessons are conveyed through imitation and understanding of motor actions. “Music provides not just a pleasant auditory signal, but a strong sense of an agent or agents – one is not alone when one listens to music” (Overy & Molnar-Szakacs, 2009, p. 499).

Use of tools to extend thinking and create structure

Once again, the use of a simple tool to process complex activity and musicality was presented. In this setting, it was a story book, providing a rich context for musical expression, structure, sequence, vocalising, memory formation, and character development. Sub-tools within this framework, such as costume and musical instruments, provided more ways to extend thinking into the tool. Characters in the story enabled embodiment and expression through movement, costume and words. The intention and attention to the story line created a jointness in focus and coordinated engagement. The use of these tools exploits the way the brain can use strategies, such as story, costume and character, for supporting behavioural success in the simplest possible way (Clark, 2017, p. 736).

Multisensory and sensorimotor integration

Our brains have evolved to learn and operate in a multisensory world, and the brain develops a larger and more knowledgeable set of memories when they are integrated through the senses (Shams & Seitz, 2008). Synchronising musical modes of behaviour results in knowledge understood in one domain giving understanding in another. Singing while playing a game, dancing to recorded music, saying words and playing the rhythm patterns, singing note names and playing the notes are all examples of synchronised musical behaviour that creates meaning in both. Additionally, this musical action gives the "feeling" of keeping the beat, the feeling of playing loudly, the feeling of stepping softly. These sensory experiences then coordinate with motor actions to enact them, to develop skilled sensorimotor integration. Shared sensorimotor integration can couple people together in musical action. This can be particularly important in a context where motor management may be impaired, but when coupled with another, full embodied understanding is engendered.

Implications for special education music pedagogy

Music pedagogy that uses imitation as a learning tool does not need explicit instruction. Thinking and understanding is body-based and internalised through action. It takes advantage of the sensory system to create meaning. When teachers model musical behaviour, this sends a strong message to students about what being musical is.

Creative use of tools such as story provides musical learning as well as memory development. When students "hook" their thinking to a story, meaningful sequence increases cognitive storage, and expression demonstrates their understanding.

Music pedagogy can couple people together to create a stronger sensory and sensorimotor experience. When students have motor support through shared engagement, they can benefit from the full sensorimotor integrated experience.

Embodied music classrooms – Principles for music pedagogy

Combining all the findings from the settings and applying them into one setting created an enriched environment for musical development. "The world" was created in the space through making it meaningful to the theme of the lesson. Things, people and the space helped to create musical meaning. "The body" engaged with multiple ways of being musical, creating multisensory understanding of what it feels like to be musical, and these were integrated with motor networks to create skilled sensorimotor networks. "The brain" utilised the peripersonal and mirror mechanism to engage through social cognition with others, and successfully developed skilled capacities through tool use. While this description separates functions and processes, this all works so seamlessly that the interwoven and multilayered process is unconscious. However, music pedagogy that engenders this deep learning in an enriched environment considers how this can all be captured in all its complexity, but simply.

This last phase of the thesis involved combining all of the aspects of embodiment and neuroscience into a lesson series in the tertiary setting. In the spirit of Hebbian learning (Hebb, 1949), where all the things that happen in the same place and time become entwined in a neural assembly that fires together, this supports enriched environments. Action is key to enabling this process through the combination of complex social stimulation and environmental interaction.

Implications for embodied music pedagogy

The combination of findings from all the settings have resulted in a set of principles to guide the design of music pedagogy for teachers. The principles are framed by embodied cognition, the interaction of the brain, the body and the world, and informed by neuroscience.

The world of the music classroom should look, feel and sound like a musical world. Social engagement, use of tools and music-making are integral to active learning in the musical world. The teacher creates the musical world and is important in modelling musical behaviour.

The embodiment of knowledge and development of music cognition is shaped, strengthened and enhanced by what the body does. Skilled musical behaviour is the result of rich experiences in multiple ways of being musical. When embodied knowledge is developed in many ways, this facilitates connected and usable knowledge.

The brain creates integrated, highly networked musical knowledge through enriched musical environments. These involve action, personal engagement, authentic contexts, complexity, attention, novelty, reward, and meaning.

Put simply, when one looks into a music classroom, it should look different to other classrooms. It should be full of musical sounds, behaviour, action, things that enable musical behaviour. Every *body* should be acting musically, even if sometimes, musical behaviour is abstract. When performing musically, behaviour should be musical, so gesture, breath, face, hands, energy are all communicating musical "language". Just as in other subjects, there should be problem-solving, skill development, creation and exploration, and above all, excitement and joy.

The following are principles for the design of embodied music pedagogy. “The world” and “the body” incorporate embodied cognition research in multimodality, tool-use and affordances, joint action, extended cognition. “The brain” principles reflect the research aspects of multisensory integration, sensorimotor integration, peripersonal and mirror mechanisms, neuroplasticity and enriched environments.

5.3 Principles for the design of Embodied Music Pedagogy

1. **THE WORLD – People, places and things**

The world where the musical activity takes place should look, feel, sound musical, and immerse students in experiences and ideas that contribute to being musical. This includes:

- **Social engagement** to develop and construct knowledge, support and scaffold learning, create music “ensemble”;
- **Tools with musical affordances** and other artefacts and objects that enhance musical learning;
- **Sound** – music in authentic contexts (recordings, songs, instrumental works, dances and so on).

2. **THE BODY – The teacher and the student**

The body should engage in multiple modes of being musical, use tools with musical affordances, extend thinking into using tools and interactions with others, and practise being musical jointly with others.

- **The teacher’s body** should be a model of musical behaviour;
- **The student’s body** should always be actively engaged with being musical, making music, actively listening to music, symbolising musical ideas, using language that describes music, moves musically and so on.

3. **THE BRAIN**

The brain develops cognition through a challenging enriched environment. This involves:

- **Cognition** - Action, movement;
- **Autopoiesis**[25] - Personal engagement, social engagement, reflection, negotiation;
- **Complexity** - Choice, challenge, change, novelty;
- **Strengthening** - Repetition, goals, assessment, authentic knowledge;
- **Thinking** - Invention, experimentation, exploration, problem-solving, pattern finding and making, prediction, extending thinking into tools
- **Attention** - Joy, focus, reward, meaning, effort.

5.4 Limitations

Sample size and selection

The participant-researchers were a convenience sample. They had all completed Level 4 of the Orff Schulwerk Teacher Training courses and were available to me as the coordinator of the Orff courses. As Level 4 was the final course in the Teacher Training courses, some had expressed an interest in further courses, so information was sent to them about the "Neuropedagogy in Music" course.

The Orff Schulwerk approach to teaching music emphasises an active approach to music pedagogy, so this also could have formed a bias. As all participants had completed all 4 of the levels in the Orff courses, it suggests that they favour an active approach to teaching music.

[25] Autopoiesis – the development of unique cognitive structures that emerge over a lifetime of personal experiences; the creation of the autonomous self (Maturana & Varela, 1980).

However, doing all 4 levels of the courses also demonstrates a commitment to improving their practice. The courses are rigorous, each are 36 face-to-face hours with assessment tasks, and participants give up a week of holidays to do each level. Most of the participants completed the courses before there was a requirement for teachers to fulfil professional development hours, either through NESA (NSW Educational Standards Authority), AIS (Association of Independent Schools), or their states. This also suggests a commitment to developing their practice, as attendance at professional development courses was voluntary. The instrumental participant-researcher is not a school music teacher, so his professional development is by his own choice. It is interesting that he seeks training in teaching practice and pedagogy rather than the instrument that he teaches.

All of the participant-researchers are highly experienced teachers and therefore their expertise was valuable for this research. A number present regularly at national and international conferences, and others are sought after for their pedagogical expertise. As experienced teachers, they knew their subject content well (not the focus of this thesis), knew their students well and how to manage them, so they could devote the lesson to developing how they perceived embodiment could be embedded in their pedagogy.

This research was not seeking to find *whether* teachers could implement embodied practices in their pedagogy. It was seeking to find out *what it looked like*, so it was appropriate to use this sample of teachers who already had action-based learning in their pedagogy. The distinction was in how they practised the embodied cognition and neuroscience in their pedagogy and in their musical setting.

The size of the sample of participant-researchers was small owing to the scope of this thesis. Having at least one participant-researcher in each setting provided enough data to elicit rich findings, however, more participants would reveal more generalisable findings.

Future studies could focus more on teachers who are new in their practice, to see if an embodied pedagogy would assist them with teaching subject content. As the instrumental setting had group lessons, teachers could be sought who teach one-on-one lessons to see what the pedagogy would look like. Different settings of the same year groups could be compared to see if embodied pedagogy is more suited to specific settings. The same teacher on different days and different or same year groups could be used for comparison to find if specific year groups suit an embodied pedagogy, see how the pedagogy changes with different music topics or skills.

Lack of available data

Observations were performed only on one day that the researcher was invited to view. On any other day, different results would have been observed due to many factors, such as the dynamics of the students in the class, year levels, different focus lessons, topics and skills and so on. This could limit the variety of ways that the embodiment and neuroscience research could be applied.

Another limitation due to lack of data was in collection of interview data. In Phase 1, in the Reflection phase, six months after the initial Neuropedagogy course and after some lessons had been videoed, those participant-researchers who lived in the same state gathered to discuss focussed questions. Not all could attend due to not being available or living interstate. They were sent the questions, but only two replied. During the meeting, not all the questions were answered, but certain aspects were discussed more deeply because they were responding to each other’s comments.

Lack of research studies on the topic

The researcher could not locate any other studies on how embodied cognition, underpinned by neuroscience, was implemented in music pedagogy, therefore, there was no specific guide as to how this thesis compared to others or could be implemented. However, this is also a strength, as new knowledge was generated by this thesis.

Measures used to collect the data

Video was the principle way data was collected. For the participants in different states, the researcher was able to visit and video the lesson, but the other video was performed by another teacher. This may have meant that the camera was not capturing the important information for identification by the researcher.

In order to become "invisible" in the classroom and not distract attention, the researcher tried not move or adjust the video camera during the lesson. In the larger classes, again this could have meant that important information was not captured. A 360-degree camera hung from the ceiling would be more useful and less invasive in collecting data. People tend to forget that it is there, and it captures everything that occurs, though an additional microphone ensures that sound is clearly recorded.

The focus was on the participant-researcher's pedagogy, not on what the students were doing. However, inevitably, as there is a reciprocal process inherent in teaching between the teacher and the student, the focus included what the students were doing to identify the effect of the pedagogy. Future studies could capture the reciprocal effects to identify different aspects of embodiment.

The video data were interpreted by the researcher as an informed observer. As a music teacher, and understanding the embodied cognition and neuroscience research, this informed the interpretation of the data by the researcher. This could also have formed a bias toward looking for evidence of these aspects. Future research could have the data analysed by someone who did not have a background in music education, but understood the embodied cognition and neuroscience research, to see if the practices could be identified. It would also be interesting to see if they could identify any practices that could be applied to another subject's pedagogy, such as Mathematics.

Self-reported data not verified through other sources

The significance of actions that occurred in the videoed lessons could have been biased. At times, the researcher interpreted such things as emotions through the behaviour that is generally ascribed to that emotion. This was particularly so in the special education lessons, where students do not always have expected responses to activities or actions, so interpretation is left to the researcher, based on all the factors evident in that moment. These may have been due to other events or experiences beyond the knowledge of the researcher. Further visits to the same classroom and students could improve reliability of interpretation.

The researcher can only report on behaviour that indicates the neuroscientific underpinnings. There may be other processes occurring that are not identifiable by the researcher and the interpretation of an expert in neuroscience could be valuable in cross-referencing explanations.

5.5 Future research and directions

A number of possible future research suggestions were offered in the limitations section. As participants from the Neuropedagogy courses have given feedback on their learning, it is clear that there needs to be *more* embodied, practical activities with the introduction of each topic in the course. From the first course in July 2016 to the most recent in November 2019, there has been a reduction in the amount of research presented, an increase in use of specific terminology to allow participants to speak knowledgeably about the research, and increase in presentation of short bursts of knowledge, practical application then discussion relating the two. These changes have resulted in more declarations of the "ah ha" moment, indicating understanding. The test of course will be to see if the teachers can apply it in their pedagogy.

It will be inevitable that there will be a call for a comparison between embodied music pedagogy and other music pedagogy, to see if embodiment produces better results, or practices. Mina Johnson-Glenberg conducted research with students studying centripetal force. She compared the learning gains of students in activities that involved high levels of embodiment, and low levels of embodiment. In testing immediately after activities, all participants demonstrated the same learning gains. However, results one week later revealed that "only the high-embodied learning condition continued to show gains in generative physical knowledge, whereas the low-embodied group decreased in their knowledge" (Lindgren & Johnson-Glenberg, 2013, p. 446).

Johnson-Glenberg asserts that it is in the encoding phase of learning, the initial actions that were involved that were directly related to the content, that gave strength to memory and facilitated recall. "More muscular movement engages more sensorimotor systems and this translates to larger areas in the sensorimotor cortex being activated" (Johnson-Glenberg et al., 2016, p. 5). She proposes that if the content suits embodied learning, that this be embedded in pedagogy and in the testing methods. Assessments based on embodied knowledge could actually involve creative problem-solving, as the gestures, movements and actions that generated the knowledge in the first place are available to explore solutions. Just as in Johnson-Glenberg's experiments, I expect that it will be in the long-term results that the strength of embodied learning will be demonstrated in music students. Designing experiments to assess long-term results of embodied learning in music could be a future direction for research.

The participants in this thesis have been instrumental in new understandings emerging from complex and dense research. Nothing about human cognition and behaviour is simple and it will be a never-ending journey exploring embodiment and insights that can be gained from neuroscience to enhance teaching and learning in music. However, when people such as the teachers who participated in this study, so love their work, their students, their subject, and have the courage, determination, intellect and creativity to keep exploring, real and rich developments occur. It is a privilege to be included in such collaborations.

I look forward to teachers testing the model proposed from this thesis for designing embodied music pedagogy. Based on the vigour and creativity of the participants in this thesis, I have "great expectations" that they will contribute rich insights into its continual development.

Many of the participants in the Neuropedagogy courses continue to email and contact me to discuss new ideas and realisations they have come across as they experiment with new approaches in embedding embodiment into their pedagogy. I am hopeful that the research presented inspires and motivates teachers to “bravely” forge new practices, test how it fits with their personalities, their students, and they notice the effects on musical behaviour and learning. “I am on fire with being jolted into multimodal action. The last 2 doubles (2 hours with year 7) that I usually dread have been magical…I am loving life in the year 7 classroom again!” (Steve, personal communication, 13 November 2019).

Reference List

Abrahamson, D., & Sánchez-García, R. (2016). Learning is moving in new ways: The ecological dynamics of mathematics education. *Journal of the Learning Sciences, 25*(2), 203-239. doi:10.1080/10508406.2016.1143370

Ackeren, M. J. v., Casasanto, D., Bekkering, H., Hagoort, P., & Ruschemeyer, S. A. (2012). Pragmatics in action: Indirect requests engage theory of mind areas and the cortical motor network. *Journal of Cognitive Neuroscience, 24*, 2237-2247.

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences, 21*(2), 247-286. doi:10.1080/10508406.2011.611446

Anderson, M. L. (2003). Embodied cognition: A field guide. *Artificial Intelligence, 149*, 91-130. doi:10.1016/S0004-3702(03)00054-7

Anderson, M. L. (2010). Neural reuse: A fundamental organizational principle of the brain. *Behavioral and Brain Sciences, 33*(4), 245-313. doi:http://dx.doi.org.ezproxy.lib.uts.edu.au/10.1017/S0140525X10000853

Anderson, M. L. (2014). *After phrenology : Neural reuse and the interactive brain*. Cambridge, UNITED STATES: MIT Press.

Anderson, M. L. (2016). Précis of after phrenology: Neural reuse and the interactive brain. *Behavioral and Brain Sciences, 39*, 1-45.

Anderson, M. L., Richardson, M. J., & Chemero, A. (2012). Eroding the boundaries of cognition: Implications of embodiment1. *Topics in Cognitive Science, 4*(4), 717-730. doi:10.1111/j.1756-8765.2012.01211.x

Ansari, D., & Coch, D. (2006). Bridges over troubled waters: Education and cognitive neuroscience. *Trends in cognitive sciences, 10*(4), 146-151. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.tics.2006.02.007

Ansari, D., De Smedt, B., & Grabner, R. H. (2012). Neuroeducation - a critical overview of an emerging field. *Neuroethics, 5*(2), 105-117. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1007/s12152-011-9119-3
Arbib, M. A. (2005). From monkey-like action recognition to human language: An evolutionary framework for neurolinguistics. *Behavioral and Brain Sciences, 28*(2), 105-124. doi:10.1017/S0140525X05000038
Arbib, M. A. (2008). From grasp to language: Embodied concepts and the challenge of abstraction. *Journal of physiology - Paris., 102*(1 - 3), 4-20. doi:10.1016/j.jphysparis.2008.03.001
Arbib, M. A. (2011). From mirror neurons to complex imitation in the evolution of language and tool use. *Annual Review of Anthropology, 40*, 257-273.
Arbib, M. A. (2017). Toward the language-ready brain: Biological evolution and primate comparisons. *Psychonomic Bulletin & Review, 24*(1), 142-150. doi:10.3758/s13423-016-1098-2
Bach, P., Nicholson, T., & Hudson, M. (2014). The affordance-matching hypothesis: How objects guide action understanding and prediction. *Frontiers in human neuroscience, 8*, 254-254. doi:10.3389/fnhum.2014.00254
Bach-y-Rita, P., & Kercel, W. S. (2003). Sensory substitution and the human–machine interface. *Trends in cognitive sciences, 7*(12), 541-546. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.tics.2003.10.013
Banai, K., & Ahissar, M. (2013). Musical experience, auditory perception and reading-related skills in children. In.
Bangert, M., & Altenmuller, E. O. (2003). Mapping perception to action in piano practice: A longitudinal dc-eeg study. *BMC Neuroscience, 4*(1), 26. doi:10.1186/1471-2202-4-26
Bangert, M., Peschel, T., Schlaug, G., Rotte, M., Drescher, D., Hinrichs, H., . . . Altenmüller, E. (2006). Shared networks for auditory and motor processing in professional pianists: Evidence from fmri conjunction. *NeuroImage, 30*(3), 917-926. doi:http://dx.doi.org/10.1016/j.neuroimage.2005.10.044
Bannan, N. (2014). Music, play and darwin's children: Pedagogical reflections of and on the ontogeny/phylogeny relationship. *International Journal of Music Education, 32*(1), 98-118. doi:10.1177/0255761413491173
Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*(4), 577-660. doi:undefined
Barsalou, L. W. (2008). Grounded cognition. *Annual review of psychology, 59*(1), 617-645. doi:10.1146/annurev.psych.59.103006.093639
Barsalou, L. W. (2010). Grounded cognition: Past, present, and future. *Topics in Cognitive Science, 2*(4), 716-724. doi:10.1111/j.1756-8765.2010.01115.x

Barsalou, L. W., Santos, A., Simmons, W. K., & Wilson, C. D. (2008). Language and simulation in conceptual processing. In A. M. G. M. de Vega, A.C. Graesser (Ed.), *Symbols, embodiment, and meaning.* (pp. 245-283). Oxford: Oxford University Press.
Bassett, D. S., & Sporns, O. (2017). Network neuroscience. *Nature Neuroscience, 20*(3), 353-364. doi:10.1038/nn.4502
Bedny, M., & Caramazza, A. (2011). Perception, action, and word meanings in the human brain: The case from action verbs. *Annals of the New York Academy of Sciences, 1224*(1), 81-95. doi:10.1111/j.1749-6632.2011.06013.x
Behne, K.-E., & Wöllner, C. (2011). Seeing or hearing the pianists? A synopsis of an early audiovisual perception experiment and a replication. *Musicae Scientiae, 15*(3), 324-342. doi:10.1177/1029864911410955
Beilock, S. L., & Goldin-Meadow, S. (2010). Gesture changes thought by grounding it in action. *Psychological Science, 21*(11), 1605-1610. doi:10.1177/0956797610385353
Bekinschtein, P., Cammarota, M., & Medina, J. H. (2014). Bdnf and memory processing. *Neuropharmacology, 76*, 677-683. doi:https://doi.org/10.1016/j.neuropharm.2013.04.024
Bengoetxea, H., Ortuzar, N., Bulnes, S., Rico-Barrio, I., Lafuente, J. V., & Argandoña, E. G. (2012). Enriched and deprived sensory experience induces structural changes and rewires connectivity during the postnatal development of the brain. *Neural plasticity, 2012*, 1-10. doi:10.1155/2012/305693
Bläsing, B., Calvo-Merino, B., Cross, E. S., Jola, C., Honisch, J., & Stevens, C. J. (2012). Neurocognitive control in dance perception and performance. *Acta Psychologica, 139*(2), 300-308. doi:https://doi.org/10.1016/j.actpsy.2011.12.005
Blikstad-Balas, M. (2017). Key challenges of using video when investigating social practices in education: Contextualization, magnification, and representation. *International Journal of Research & Method in Education, 40*(5), 511-523. doi:10.1080/1743727X.2016.1181162
Bowman, W. D. (2004). Cognition and the body: Perspectives from music education. In L. Bresler (Ed.), *Knowing bodies, moving minds: Toward embodied teaching and learning* (pp. 29-50). Netherlands: Kluwer Academic Press.
Bresler, L. (2004). *Knowing bodies, moving minds : Towards embodied teaching and learning*. Dordrecht [Netherlands] ;: Kluwer Academic Publishers.
Bresler, L. (2006). Embodied narrative inquiry: A methodology of connection. *Research Studies in Music Education, 27*(1), 21-43. doi:10.1177/1321103X060270010201
Bressler, S. L., & Kelso, J. A. S. (2001). Cortical coordination dynamics and cognition. *Trends in Cognitive Sciences, 5*(1), 26. doi:10.1016/S1364-6613(00)01564-3

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences, 14*(6), 277-290. doi:10.1016/j.tics.2010.04.004
Bridges, D. (1978). Recent theses on music education. *Australian Journal of Music Education, 22*, 50.
Brooks, R. A. (1991). Intelligence without representation. *Artificial Intelligence, 47*(1), 139-159. doi:10.1016/0004-3702(91)90053-M
Brown, A., & Danaher, P. A. (2019). Che principles: Facilitating authentic and dialogical semi-structured interviews in educational research. *International Journal of Research & Method in Education, 42*(1), 76-90. doi:10.1080/1743727X.2017.1379987
Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*(2), 141-178. doi:10.1207/s15327809jls0202_2
Bruner, E., & Iriki, A. (2016). Extending mind, visuospatial integration, and the evolution of the parietal lobes in the human genus. *Quaternary International, 405*, 98-110. doi:https://doi.org/10.1016/j.quaint.2015.05.019
Caine, R. N., & Caine, G. (1997). *Unleashing the power of perceptual change: The potential of brain-based teaching*: Association for Supervision and Curriculum Development.
Caine, R. N., & Caine, G. (2005). 12 brain/mind natural learning principles. Retrieved from The Natural Learning Research Institute website: https://www.nlri.org
Calvo-Merino, B., Glaser, D. E., Gre` zes, J., Passingham, R. E., & Haggard, P. (2005). Action observation and acquired motor skills: An fmri study with expert dancers. *Cerebral Cortex, 15*, 1243-1249. doi:doi:10.1093/cercor/bhi007
Campbell (Producer). (2015, 28 October). *Interview with dr. Anthony chemero, co-author of phenomenology: An introduction.* [Retrieved from http://brainsciencepodcast.com/bsp/2015/123-phenomenology
Candidi, M., Aglioti, S., & Haggard, P. (2012). Embodying bodies and worlds. *Review of Philosophy and Psychology, 3*(1), 109-123. doi:10.1007/s13164-012-0091-6
Carman, T. (2008). *Merleau-ponty*. London: Routledge.
Carrasco, J. G., Serrano, M. J. H., & Garcia, A. V. M. (2015). Plasticity as a framing concept enabling transdisciplinary understanding and research in neuroscience and education. *Learning, Media and Technology, 40*(2), 152-167. doi:10.1080/17439884.2014.908907; 29
10.1080/17439884.2014.908907
Cartmill, E. A., Beilock, S., & Goldin-Meadow, S. (2012). A word in the hand: Action, gesture and mental representation in humans and non-human primates. *Philosophical Transactions: Biological Sciences, 367*(1585), 129-143. doi:10.1098/rstb.2011.0162

Catmur, C. (2013). Sensorimotor learning and the ontogeny of the mirror neuron system. *Neuroscience letters, 540*, 21-27. doi:10.1016/j.neulet.2012.10.001

Chandrasekaran, C. (2017). Computational principles and models of multisensory integration. *Current Opinion in Neurobiology, 43*, 25-34. doi:https://doi.org/10.1016/j.conb.2016.11.002

Chemero, A. (2003). An outline of a theory of affordances. *Ecological Psychology, 15*(2), 181.

Chemero, A. (2013). Radical embodied cognitive science. *Review of General Psychology, 17*(2), 145-150. doi:10.1037/a0032923

Chemero, A. (2016). Sensorimotor empathy. *Journal of consciousness studies, 23*(5-6), 138-152.

Chemero, A., & Kaufer, S. (2016). Pragmatism, phenomenology, and extended cognition. In R. Madzia & M. Jung (Eds.), *Pragmatism and embodied cognitive science* (pp. 55-70). Berlin: De Gruyer.

Chemin, B., Mouraux, A., & Nozaradan, S. (2014). Body movement selectively shapes the neural representation of musical rhythms. *Psychological Science, 25*(12), 2147-2159. doi:10.1177/0956797614551161

Chen, J. C. W. (2012). A pilot study mapping students' composing strategies: Implications for teaching computer-assisted composition. *Research Studies in Music Education, 34*(2), 157-171. doi:10.1177/1321103X12465515

Chen, J. L., Penhune, V. B., & Zatorre, R. J. (2008). Moving on time: Brain network for auditory--motor synchronization is modulated by rhythm complexity and musical training. *Journal of cognitive neuroscience, 20*(2), 226-239.

Chen, J. L., Zatorre, R. J., & Penhune, V. B. (2006). Interactions between auditory and dorsal premotor cortex during synchronization to musical rhythms. *Neuroimage, 32*(4), 1771-1781. doi:10.1016/j.neuroimage.2006.04.207

Cheng, L., & Leong, S. (2017). Educational affordances and learning design in music software development. *Technology, Pedagogy and Education, 26*(4), 395-407. doi:10.1080/1475939X.2016.1267037

Clark, A. (2005). Intrinsic content, active memory and the extended mind. *Analysis, 65*(285), 1-11. doi:10.1111/j.1467-8284.2005.00514.x

Clark, A. (2017). Busting out: Predictive brains, embodied minds, and the puzzle of the evidentiary veil. *Noûs, 51*(4), 727-753. doi:10.1111/nous.12140

Clark, A., & Chalmers, D. (1998). The extended mind. *Analysis, 58*(1), 7.

Clement, N. D., & Lovat, T. (2012). Neuroscience and education: Issues and challenges for curriculum. *Curriculum Inquiry, 42*(4), 534-557. doi:10.1111/j.1467-873X.2012.00602.x

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences, 13*(1), 15-42. doi:10.1207/s15327809jls1301_2

Congdon, E. L., Novack, M. A., Brooks, N., Hemani-Lopez, N., O'Keefe, L., & Goldin-Meadow, S. (2017). Better together: Simultaneous presentation of speech and gesture in math instruction supports generalization and retention. *Learning and Instruction, 50*, 65-74. doi:https://doi.org/10.1016/j.learninstruc.2017.03.005
Corballis, M. C. (2010). Mirror neurons and the evolution of language. *Brain and Language, 112*(1), 25-35. doi:10.1016/j.bandl.2009.02.002
Corsini, R. (2001). *The dictionary of psychology*. London, UNITED KINGDOM: Routledge.
Cottington, J. (2000). Descartes. In R. Monk & F. Raphael (Eds.), *The great philosophers* (pp. 77-112). London: Weidenfeld & Nicolson.
Csikszentmihalyi, M. (1997). Happiness and creativity: Going with the flow. *The Futurist, 31*(5), SR8+.
Csikszentmihalyi, M. (2015). *Systems model of creativity: The collected works of mihaly csikszentmihalyi*. Dordrecht, NETHERLANDS, THE: Springer.
D'Ausilio, A., Altenmüller, E., Olivetti Belardinelli, M., & Lotze, M. (2006). Cross-modal plasticity of the motor cortex while listening to a rehearsed musical piece. *European Journal of Neuroscience, 24*(3), 955-958. doi:10.1111/j.1460-9568.2006.04960.x
D'Ausilio, A., Novembre, G., Fadiga, L., & Keller, P. E. (2015). What can music tell us about social interaction? *Trends in Cognitive Sciences, 19*(3), 111-114. doi:https://doi.org/10.1016/j.tics.2015.01.005
Davis, J. I., Benforado, A., Esrock, E., Turner, A., Dalton, R. C., van Noorden, L., & Leman, M. (2012). Four applications of embodied cognition. *Topics in Cognitive Science, 4*(4), 786-793. doi:10.1111/j.1756-8765.2012.01225.x
De Jaegher, H., & Di Paolo, E. (2007). Participatory sense-making. *Phenomenology and the Cognitive Sciences, 6*(4), 485-507. doi:10.1007/s11097-007-9076-9
de Wit, M. M., de Vries, S., van der Kamp, J., & Withagen, R. (2017). Affordances and neuroscience: Steps towards a successful marriage. *Neuroscience & Biobehavioral Reviews, 80*, 622-629. doi:https://doi.org/10.1016/j.neubiorev.2017.07.008
Deak, G. O. (2014). Development of adaptive tool-use in early childhood: Senorimotor, social and conceptual factors. In J. B. Benson (Ed.), *Advances in child development and behavor* (Vol. 46, pp. 149-181). Burlington: Academic Press.
Dede, C. (2004). If design-based research is the answer, what is the question? A commentary on collins, joseph, and bielaczyc; disessa and cobb; and fishman, marx, blumenthal, krajcik, and soloway in the jls special issue on design-based research. *Journal of the Learning Sciences, 13*(1), 105-114. doi:10.1207/s15327809jls1301_5
Dekker, S., Lee, N., Howard-Jones, P., & Jolles, J. (2012). Neuromyths in education: Prevalence and predictors of misconceptions among teachers. *Frontiers in Psychology, 3*(429). doi:10.3389/fpsyg.2012.00429

della Gatta, F., Garbarini, F., Rabuffetti, M., Viganò, L., Butterfill, S. A., & Sinigaglia, C. (2017). Drawn together: When motor representations ground joint actions. *Cognition, 165*, 53-60. doi:https://doi.org/10.1016/j.cognition.2017.04.008

Demos, A. P., Chaffin, R., & Logan, T. (2017). Musicians body sway embodies musical structure and expression: A recurrence-based approach. *Musicae Scientiae, 22*(2), 244-263. doi:10.1177/1029864916685928

Dennis, E. L., & Thompson, P. M. (2013). Typical and atypical brain development: A review of neuroimaging studies. *Dialogues in clinical neuroscience, 15*(3), 359-384.

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., . . . Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences, 19*(1), 3-53. doi:10.1080/10508400903452884

Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*. New York: The Macmillan company.

Dewey, J. (2015). *Demoncracy and education*. In Project Gutenberg, D. Reed. & D. Widger (Eds.). Retrieved from http://www.gutenberg.org/ebooks/852

Di Paolo, E. A., & De Jaegher, H. (2012). The interactive brain hypothesis. *Frontiers in Human Neuroscience, 6*(163). doi:10.3389/fnhum.2012.00163

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental brain research, 91*(1), 176-180. doi:10.1007/BF00230027

A dictionary of physics. (2019). In R. Rennie & J. Law (Eds.), (8th ed.). Oxford UK: Oxford University Press.

Dionne-Dostie, E., Paquette, N., Lassonde, M., & Gallagher, A. (2015). Multisensory integration and child neurodevelopment. *Brain Sciences, 5*(1), 32-57. doi:10.3390/brainsci5010032

Doidge, N. (2007). *The brain that changes itself: Stories of personal triumph from the frontiers of brain science*. New York: Viking.

Donnelly, J. E., & Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. *Preventive Medicine, 52*, S36-S42. doi:https://doi.org/10.1016/j.ypmed.2011.01.021

Dotov, D., Nie, L., Wojcik, K., Jinks, A., Yu, X., & Chemero, A. (2017). Cognitive and movement measures reflect the transition to presence-at-hand. *New Ideas in Psychology, 45*, 1-10. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.newideapsych.2017.01.001

Drewal, H. J. (2016). Visual and sensorial aspects. In J. K. Olupona & R. O. Abiodun (Eds.), *Ifa divination, knowledge, power, and*

performance. (pp. 325-339). Bloomington, Indiana: Indiana University Press.
Düvel, N., Wolf, A., & Kopiez, R. (2017). Neuromyths in music education: Prevalence and predictors of misconceptions among teachers and students. *Frontiers in Psychology, 8*. doi:10.3389/fpsyg.2017.00629
Eagleman, D. (2015). *The brain: The story of you.* New York, NY: Pantheon Books.
El-Zanfaly, D. (2015). [i3] imitation, iteration and improvisation: Embodied interaction in making and learning. *Design Studies, 41*, 79-109. doi:https://doi.org/10.1016/j.destud.2015.09.002
Erickson, F. (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. In J. L. Green, G. Camilli, & P. B. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 177-205). Mahwah, NJ: Erlbaum.
Ernst, M. O., & Bülthoff, H. H. (2004). Merging the senses into a robust percept. *Trends in Cognitive Sciences, 8*(4), 162-169. doi:10.1016/j.tics.2004.02.002
Eysenck, M. W., & Brysbaert, M. (2018). *Fundamentals of cognition* (3rd ed.). Oxon UK: Taylor & Francis Group.
Fadiga, L., Craighero, L., & Olivier, E. (2005). Human motor cortex excitability during the perception of others' action. *Current opinion in neurobiology, 15*(2), 213-218.
Fields, R. D. (2011). Imaging learning: The search for a memory trace. *The Neuroscientist, 17*(2), 185-196. doi:10.1177/1073858410383696
Fink-Jensen, K. (2007). Attunement and bodily dialogues in music education. *Philosophy of Music Education Review, 15*(1), 53-68.
Fjeld, M., & Barendregt, W. (2009). Epistemic action: A measure for cognitive support in tangible user interfaces? *Behavior Research Methods, 41*(3), 876-881. doi:10.3758/BRM.41.3.876
Flohr, J. W. (2010). Best practices for young children's music education: Guidance from brain research. *General Music Today, 23*(2), 13-19. doi:10.1177/1048371309352344
Foroni, F., & Semin, G. R. (2009). Language that puts you in touch with your bodily feelings: The multimodal responsiveness of affective expressions. *Psychological Science, 20*(8), 974-980. doi:10.1111/j.1467-9280.2009.02400.x
Fortuna, S. (2017). Embodiment, sound and visualization: A multimodal perspective in music education. *Zbornik Radova Akademije Umetnosti, 5*, 120-131. doi:10.5937/ZbAkUm1705120F
Frazee, J. (1987). *Discovering orff: A curriculum for music teachers*. New York, US: Schott.
Freeman, W. J. (2004). How and why brains create meaning-t from sensory information. *International Journal of Bifurcation and Chaos, 14*(2), 515-530.
Frisoli, A., Solazzi, M., Reiner, M., & Bergamasco, M. (2011). The contribution of cutaneous and kinesthetic sensory modalities in

haptic perception of orientation. *Brain Research Bulletin, 85*(5), 260-266. doi:https://doi.org/10.1016/j.brainresbull.2010.11.011

Friston, K. (2005). A theory of cortical responses. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 360*(1456), 815-836. doi:10.1098/rstb.2005.1622

Froese, T., & Di Paolo, E. (2010). Modelling social interaction as perceptual crossing: An investigation into the dynamics of the interaction process. *Connection Science, 22*(1), 43-68. doi:10.1080/09540090903197928

Gall, M., & Breeze, N. (2005). Music composition lessons: The multimodal affordances of technology. *Educational Review, 57*(4), 415-433. doi:10.1080/00131910500278314

Gallagher, S. (2019). Precis: Enactivist interventions. . *Philosophical Studies (2019), 176*, 803-806.

Gallagher, S., Hutto, D. D., Slaby, J., & Cole, J. (2013). The brain as part of an enactive system. *Behavioral and Brain Sciences, 36*(4), 421-422. doi:10.1017/S0140525X12002105

Gallese, V. (2009a). Mirror neurons, embodied simulation, and the neural basis of social identification. *Psychoanalytic Dialogues, 19*(5), 519-536. doi:10.1080/10481880903231910

Gallese, V. (2009b). Motor abstraction: A neuroscientific account of how action goals and intentions are mapped and understood. *Psychological research, 73*(4), 486-498. doi:10.1007/s00426-009-0232-4

Gallese, V., & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology, 22*(3-4), 455-479. doi:10.1080/02643290442000310

Gallese, V., & Sinigaglia, C. (2011). What is so special about embodied simulation? *Trends in cognitive sciences, 15*(11), 512-519. doi://dx.doi.org/10.1016/j.tics.2011.09.003

Gallotti, M., & Huebner, B. (2017). Collective intentionality and socially extended minds. *Philosophical Psychology, 30*(3), 247-268. doi:10.1080/09515089.2017.1295629

Garbarini, F., & Adenzato, M. (2004). At the root of embodied cognition: Cognitive science meets neurophysiology. *Brain and Cognition*(56), 100-106. doi:10.1016/j.bandc.2004.06.003

Gardner, H. (1985). *Frames of mind: The theory of multiple intelligences*. London: Paladin.

Gardner, H., & Moran, S. (2006). The science of multiple intelligences theory: A response to lynn waterhouse. *Educational Psychologist, 41*(4), 227-232. doi:10.1207/s15326985ep4104_2

Gazzola, V., Aziz-Zadeh, L., & Keysers, C. (2006). Empathy and the somatotopic auditory mirror system in humans. *Current Biology, 16*(18), 1824-1829. doi:10.1016/j.cub.2006.07.072

Geake, J. (2008). Neuromythologies in education. *Educational Research, 50*(2), 123-133. doi:10.1080/00131880802082518

Gibson, E. (2000). Where is the information for affordances? *Ecological Psychology, 12*(1), 53.
Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting and knowing: Toward an ecological psychology* (pp. 67-82). Hillsdale, New Jersey: Lawrence Erlbaum Associates.
Gibson, J. J. (1986a). *The ecological approach to visual perception*. New York: Psychology Press.
Gibson, J. J. (1986b). *The ecological approach to visual perception*. New York: Psychology Press.
Gingras, B., Honing, H., Peretz, I., Trainor, L. J., & Fisher, S. E. (2015). Defining the biological bases of individual differences in musicality. *Philosophical Transactions of the Royal Society B: Biological Sciences, 370*(1664). doi:10.1098/rstb.2014.0092
Glenberg, A. M. (1997). What memory is for. *Behavioral and Brain Sciences, 20*(1), 1-19. doi:undefined
Glenberg, A. M. (2010). Embodiment as a unifying perspective for psychology. *Wiley interdisciplinary reviews. Cognitive science, 1*(4), n/a. doi:10.1002/wcs.55
Glenberg, A. M. (2015). Few believe the world is flat: How embodiment is changing the scientific understanding of cognition. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 69*(2), 165-171. doi:10.1037/cep0000056
Glenberg, A. M., Goldberg, A. B., & Zhu, X. (2011). Improving early reading comprehension using embodied cai. *Instructional Science, 39*(1), 27-39. doi:10.1007/s11251-009-9096-7
Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008). Processing abstract language modulates motor system activity. *The Quarterly Journal of Experimental Psychology, 61*(6), 905-919. doi:10.1080/17470210701625550
Glenberg, A. M., Witt, J. K., & Metcalfe, J. (2013). From the revolution to embodiment. *Perspectives on Psychological Science, 8*(5), 573-585. doi:10.1177/1745691613498098
Godoy, R. I. (2018). Motor constraints shaping musical experience. *Music Theory Online, 24*(3), 83-94.
Goldin-Meadow, S. (2015). From action to abstraction: Gesture as a mechanism of change. *Developmental Review, 38*, 167-184. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.dr.2015.07.007
Goldin-Meadow, S., & Beilock, S. L. (2010). Action's influence on thought: The case of gesture. *Perspectives on psychological science : a journal of the Association for Psychological Science, 5*(6), 664-674. doi:10.1177/1745691610388764
Goldin-Meadow, S., Nusbaum, H., Kelly, S. D., & Wagner, S. (2001). Explaining math: Gesturing lightens the load. *Psychological Science, 12*(6), 516-522. doi:10.1111/1467-9280.00395

Gooding, L., & Standley, J. M. (2011). Musical development and learning characteristics of students: A compilation of key points from the research literature organized by age. *Update: Applications of Research in Music Education, 30*(1), 32-45. doi:10.1177/8755123311418481

Goodwin, C. (1994). Professional vision. *American Anthropologist, 96*(3), 606-633.

Goswami, U. (2008). Principles of learning, implications for teaching: A cognitive neuroscience perspective. *Journal of Philosophy of Education, 42*(3), 381-399. doi:10.1111/j.1467-9752.2008.00639.x

Graziano, M. S. A. (2018). Our primal need for personal space; why do we need buffer zones? Over the decades, scientists have delved into the evolution, psychology and neuroscience of personal space. *Wall Street Journal Online*.

Campbell (Producer). (2018, 24 February, 2018). *Inteview with dr. Michael graziano, author of, the spaces between us: A story of neuroscience, evoution, and human nature.* [Podcast]. Retrieved from https://brainsciencepodcast.com/bsp/2018/142-graziano

Graziano, M. S. A., & Cooke, D. (2006). Parieto-frontal interactions, personal space, and defensive behavior. *Neuropsychologia, 44*(6), 845-859. doi:https://doi.org/10.1016/j.neuropsychologia.2005.09.009

Groussard, M., Viader, F., Landeau, B., Desgranges, B., Eustache, F., & Platel, H. (2014). The effects of musical practice on structural plasticity: The dynamics of grey matter changes. *Brain and cognition, 90*, 174-180. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.bandc.2014.06.013

Gruhn, W., Haussmann, M., Herb, U., Minkner, C., Röttger, K., & Gollhofer, A. (2012). The development of motor coordination and musical abilities in pre-school children. *Arts BioMechanics, 1*(2), 89-103.

Gulliksen, M. S. (2016a). Embodied making, creative cognition and memory. *FORMakademisk, 9*(1). doi:10.7577/formakademisk.1487

Gulliksen, M. S. (2016b). *Why making matters: Developing an interdisciplinary research project on how embodied making may contribute to learning*. Paper presented at the Proceedings of DRS 2016, Design Research Society 50th Anniversary Conference. Brighton, UK, 27–30 June 2016, Brighton, UK.

Gülpinar, M. A. (2005). The principles of brain-based learning and constructivist models in education. *Kuram ve Uygulamada Egitim Bilimleri, 5*(2), 299.

Gutierez, S. B., & Kim, H.-B. (2017). Becoming teacher-researchers: Teachers' reflections on collaborative professional development. *Educational Research, 59*(4), 444-459. doi:10.1080/00131881.2017.1347051

Haller, S., Kopel, R., Jhooti, P., Haas, T., Scharnowski, F., Lovblad, K.-O., . . . Van De Ville, D. (2013). Dynamic reconfiguration of human brain

functional networks through neurofeedback. *NeuroImage, 81*, 243-252. doi:10.1016/j.neuroimage.2013.05.019
Hannon, E. E., & Trehub, S. E. (2005). Tuning in to musical rhythms: Infants learn more readily than adults. *Proceedings of the National Academy of Sciences of the United States of America, 102*(35), 12639. doi:10.1073/pnas.0504254102
Harris, R., & de Jong, B. M. (2014). Cerebral activations related to audition-driven performance imagery in professional musicians. *PLoS ONE, 9*(4), e93681. doi:10.1371/journal.pone.0093681
Hartmann, C., Lazar, A., Nessler, B., & Triesch, J. (2015). Where's the noise? Key features of spontaneous activity and neural variability arise through learning in a deterministic network. *PLoS Computational Biology, 11*(12), e1004640. doi:10.1371/journal.pcbi.1004640
Hasson, U., Ghazanfar, A. A., Galantucci, B., Garrod, S., & Keysers, C. (2012). Brain-to-brain coupling: A mechanism for creating and sharing a social world. *Trends in cognitive sciences, 16*(2), 114-121. doi:10.1016/j.tics.2011.12.007
Haueisen, J., & Knosche, T. R. (2001). Involuntary motor activity in pianists evoked by music perception. *Journal of Cognitive Neuroscience, 13*(6), 786-792.
Hawkins, J., & Ahmad, S. (2016). Why neurons have thousands of synapses, a theory of sequence memory in neocortex. *Frontiers in Neural Circuits, 10*(23). doi:10.3389/fncir.2016.00023
Hayes, L. (2019). Beyond skill acquisition: Improvisation, interdisciplinarity, and enactive music cognition. *Contemporary Music Review, 38*(5), 446-462. doi:10.1080/07494467.2019.1684059
Hebb, D. O. (1949). *The organization of behavior: A neuropsychological theory*. New York: Wiley.
Held, R., & Hein, A. (1963). Movement-produced stimulation in the development of visually guided behavior. *Journal of comparative and physiological psychology, 56*(5), 872-876. doi:10.1037/h0040546
Herholz, S. C., & Zatorre, R. J. (2012). Musical training as a framework for brain plasticity: Behavior, function, and structure. *Neuron, 76*(3), 486-502. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.neuron.2012.10.011
Hermans, C., & Bremmer, M. (2015). *Embodiment in arts education teaching and learning with the body in the arts*. Paper presented at the Embodiment in Arts Education, Amsterdam University of the Arts. https://www.conservatoriumvanamsterdam.nl/fileadmin/download/conservatorium/lectoraat_Muziek/Embodiment/embodiment_in_arts_education.pdf
Heyes, C. (2011). Automatic imitation. *Psychological bulletin, 137*(3), 463-483. doi:10.1037/a0022288

Høffding, S., & Schiavio, A. (2019). Exploratory expertise and the dual intentionality of music-making. *Phenomenology and the Cognitive Sciences*. doi:10.1007/s11097-019-09626-5
Hohnen, B., & Murphy, T. (2016). The optimum context for learning; drawing on neuroscience to inform best practice in the classroom. *Educational & Child Psychology, 33*(1), 75-90.
Hollich, G., & Bahrick, L. (2008). Intermodal perception. In *Encyclopedia of Infant and Early Childhood Development* (Vol. 2, pp. 164-176).
Hostetter, A. B., & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review, 15*(3), 495-514. doi:10.3758/PBR.15.3.495
Huovinen, E., & Rautanen, H. (2019). Interaction affordances in traditional instruments and tablet computers: A study of children's musical group creativity. *Research Studies in Music Education*, 1321103X18809510. doi:10.1177/1321103X18809510
Hutto, D. (2005). Knowing what? Radical versus conservative enactivism. *Phenomenology and the Cognitive Sciences, 4*(4). doi:10.1007/s11097-005-9001-z
Hyde, K. L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A. C., & Schlaug, G. (2009). Musical training shapes structural brain development. *The Journal of neuroscience : the official journal of the Society for Neuroscience, 29*(10), 3019-3025. doi:10.1523/JNEUROSCI.5118-08.2009
Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, G., Mazziotta, J. C., & Rizzolatti, G. (2005). Grasping the intentions of others with one's own mirror neuron system. *PLoS Biology, 3*(3), e79. doi:10.1371/journal.pbio.0030079
Iriki, A. (2006). The neural origins and implications of imitation, mirror neurons and tool use. *Current Opinion in Neurobiology, 16*(6), 660-667. doi:https://doi.org/10.1016/j.conb.2006.10.008
Janata, P., Tomic, S. T., & Haberman, J. M. (2012). Sensorimotor coupling in music and the psychology of the groove. *Journal of Experimental Psychology: General, 141*(1), 54-75. doi:10.1037/a0024208
Jensenius, A. R., Godøy, R. I., & Leman, M. (2010). *Musical gestures: Sound, movement and meaning*. New York: Routledge.
Johansson, R. S., & Westling, G. (1984). Roles of glabrous skin receptors and sensorimotor memory in automatic control of precision grip when lifting rougher or more slippery objects. *Experimental Brain Research, 56*(3), 550-564. doi:10.1007/bf00237997
Johnson, K. (2001). The roles and functions of cutaneous mechanoreceptors. *Current Opinion in Neurobiology, 11*(4), 455-461. doi:https://doi.org/10.1016/S0959-4388(00)00234-8
Johnson-Glenberg, M. C., Birchfield, D. A., Tolentino, L., & Koziupa, T. (2014). Collaborative embodied learning in mixed reality motion-capture environments: Two science studies. *Journal of Educational Psychology, 106*(1), 86-104. doi:10.1037/a0034008

10.1037/a0034008.supp (Supplemental)
Johnson-Glenberg, M. C., & Megowan-Romanowicz, C. (2017). Embodied science and mixed reality: How gesture and motion capture affect physics education. *Cognitive Research, 2*(1), 24. doi:10.1186/s41235-017-0060-9
Johnson-Glenberg, M. C., Megowan-Romanowicz, C., Birchfield, D. A., & Savio-Ramos, C. (2016). Effects of embodied learning and digital platform on the retention of physics content: Centripetal force. *Frontiers in Psychology, 7*, 1819. doi:10.3389/fpsyg.2016.01819
Jokela, T., Hiltunen, M., & Härkönen, E. (2015). Art-based action research – participatory art for the north. *International Journal of Education through Art, 11*(3), 433-448. doi:10.1386/eta.11.3.433_1
Juntunen, M.-L., & Hyvönen, L. (2004). Embodiment in musical knowing: How body movement facilitates learning within dalcroze eurhythmics. *British Journal of Music Education, 21*(2), 199-214.
Kalender, B., Trehub, S. E., & Schellenberg, E. G. (2013). Cross-cultural differences in meter perception. *Psychological Research, 77*(2), 196-203. doi:10.1007/s00426-012-0427-y
Keller, P. E., Novembre, G., & Hove, M. J. (2014). Rhythm in joint action: Psychological and neurophysiological mechanisms for real-time interpersonal coordination. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*(1658), 20130394. doi:10.1098/rstb.2013.0394
Kelso, J. A. S. (2012). Multistability and metastability: Understanding dynamic coordination in the brain. *Philosophical Transactions of the Royal Society B: Biological Sciences, 367*(1591), 906-918. doi:10.1098/rstb.2011.0351
Kersten, L., & Wilson, R. A. (2016). The sound of music, externalist style. *American Philosophical Quarterly, 53*(2), 139-154.
Kiefer, M., & Trumpp, N. M. (2012). Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education, 1*(1), 15-20. doi:10.1016/j.tine.2012.07.002
King, E., Gritten, A., & Welch, P. G. (2011). *New perspectives on music and gesture*. Abingdon, UNITED KINGDOM: Routledge.
Kirchhoff, M. D. (2012). Extended cognition and fixed properties: Steps to a third-wave version of extended cogntion. *Phenomenology and the Cognitive Sciences, 11*(2), 287-308. doi:10.1007/s11097-011-9237-8
Kirk, E., & Lewis, C. (2016). Gesture facilitates children’s creative thinking. *Psychological Science, 28*(2), 225-232. doi:10.1177/0956797616679183
Kirkman, P. R. (2011). Exploring contexts for development: Secondary music students' computermediated composing. *Journal of Music, Technology & Education, 3*(2/3), 107-124. doi:10.1386/jmte.3.2-3.107_1

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science, 18*(4), 513-549. doi:10.1207/s15516709cog1804_1

Kitchen, W. H. (2017). *Philosophical reflections on neuroscience and education*. London, UK: Bloomsbury Academic, an imprint of Bloomsbury Publishing.

Knill, D. C., & Pouget, A. (2004). The bayesian brain: The role of uncertainty in neural coding and computation. *Trends in Neurosciences, 27*(12), 712-719. doi:https://doi.org/10.1016/j.tins.2004.10.007

Koch, I., Poljac, E., Müller, H., & Kiesel, A. (2018). Cognitive structure, flexibility, and plasticity in human multitasking—an integrative review of dual-task and task-switching research. *Psychological Bulletin, 144*(6), 557-583. doi:10.1037/bul0000144

Koelsch, S. (2013). From social contact to social cohesion--the 7 cs. *Music and Medicine, 5*(4), 204-209.

Kohler, E., Keysers, C., Umilta, M. A., Fogassi, L., & et al. (2002). Hearing sounds, understanding actions: Action representation in mirror neurons. *Science, 297*(5582), 846-848.

Koner, K., & Eros, J. (2019). Professional development for the experienced music educator: A review of recent literature. *Update: Applications of Research in Music Education, 37*(3), 12-19. doi:10.1177/8755123318812426

Kraft, T. L., & Pressman, S. D. (2012). Grin and bear it: The influence of manipulated facial expression on the stress response. *Psychological Science, 23*(11), 1372-1378. doi:10.1177/0956797612445312

Kraus, N., Skoe, E., Parbery-Clark, A., & Ashley, R. (2009). Experience-induced malleability in neural encoding of pitch, timbre, and timing. *Annals of the New York Academy of Sciences, 1169*, 543-557. doi:10.1111/j.1749-6632.2009.04549.x

Krueger, J. (2014). Affordances and the musically extended mind. *Frontiers in Psychology, 4*(1003). doi:10.3389/fpsyg.2013.01003

Krueger, J. (2019). Music as affective scaffolding. In D. Clarke, R. Herbert, & E. Clarke (Eds.), *Music and consciousness ii*. UK: Oxford University Press.

Laban, R. (1947). *Effort*. London, UK: MacDonald & Evans.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. US: Basic Books.

Lanese, N. (2019, December 2019). Lonely antarctic expeditions shrink people's brains. *Live Science*. Retrieved from https://www.livescience.com/antarctic-expedition-changes-the-brain.html

Lederman, S., & Klatzky, R. (2009). Haptic perception: A tutorial. *Attention, Perception, a& Psychophysics, 71*(7), 1439-1459. doi:10.3758/APP.71.7.1439

Leman, M., Desmet, F., Styns, F., Van Noorden, L., & Moelants, D. (2009). Sharing musical expression through embodied listening: A case study based on chinese guqin music. *Music Perception, 26*(3), 263-280.
Leman, M., Lesaffre, M., Nijs, L., & Deweppe, A. (2010). User-oriented studies in embodied music cognition research. *Musicae Scientiae, 14*(2_suppl), 203-223. doi:10.1177/10298649100140S212
Leman, M., & Maes, P.-J. (2015). The role of embodiment in the perception of music. *Empirical Musicology Review, 9*(3-4), 236-246. doi:10.18061/emr.v9i3-4.4498
Lima, C. F., Krishnan, S., & Scott, S. K. (2016). Roles of supplementary motor areas in auditory processing and auditory imagery. *Trends in Neurosciences, 39*(8), 527-542. doi:https://doi.org/10.1016/j.tins.2016.06.003
Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher, 42*(8), 445-452. doi:10.3102/0013189X13511661
Litwin-Kumar, A., & Doiron, B. (2014). Formation and maintenance of neuronal assemblies through synaptic plasticity. *Nature Communications, 5*, 5319. doi:10.1038/ncomms6319
Livingstone, R. S., & Thompson, W. F. (2009). The emergence of music from the theory of mind. *Musicae Scientiae, 13*(2 suppl), 83-115. doi:10.1177/1029864909013002061
Llinas, R. (2001). *The i of the vortex: From neurons to self*. Cambridge, MA: MIT Press.
Loehr, J. D., & Vesper, C. (2016). The sound of you and me: Novices represent shared goals in joint action. *Quarterly Journal of Experimental Psychology, 69*(3), 535-547. doi:10.1080/17470218.2015.1061029
Logan, T., & Chaffin, R. (2020). Movement is part of the meaning of music notation: A musical stroop effect for trombonists. *Psychology of Music*, 0305735619900921. doi:10.1177/0305735619900921
Machado, S., Cunha, M., Velasques, B., Minc, D., Teixeira, S., Domingues, C. A., . . . Ribeiro, P. (2010). Sensorimotor integration: Basic concepts, abnormalities related to movement disorders and sensorimotor training-induced cortical reorganization. *Rev Neurologia, 51*(7), 427-436.
MacRitchie, J., Herff, S. A., Procopio, A., & Keller, P. E. (2018). Negotiating between individual and joint goals in ensemble musical performance. *Quarterly Journal of Experimental Psychology, 71*(7), 1535-1551. doi:10.1080/17470218.2017.1339098
Maes, P.-J., & Leman, M. (2013a). The influence of body movements on children's perception of music with an ambiguous expressive character. *PLoS ONE, 8*(1), e54682.

Maes, P.-J., & Leman, M. (2013b). The influence of body movements on children's perception of music with an ambiguous expressive character. *PLoS ONE, 8*(1).
Maes, P.-J., Leman, M., Palmer, C., & Wanderley, M. (2014). Action-based effects on music perception. *Frontiers in Psychology, 4*(1008). doi:10.3389/fpsyg.2013.01008
Maes, P.-J., Leman, M., Palmer, C., Wanderley, M. M., Croom, A. M., Lotze, M., & Hove, M. (2014). Action-based effects on music perception. *Frontiers in Psychology, 4*, 1-14. doi:10.3389/fpsyg.2013.01008
Maes, P.-J., Van Dyck, E., Lesaffre, M., Leman, M., & Kroonenberg, P. (2014). The coupling of action and perception in musical meaning formation. *Music Perception, 32*(1), 67-84. doi:10.1525/MP.2014.32.1.67
Makin, T. R., Holmes, N. P., & Zohary, E. (2007). Is that near my hand? Multisensory representation of peripersonal space in human intraparietal sulcus. *The Journal of Neuroscience, 27*(4), 731.
Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends in Cognitive Sciences, 8*(2), 79-86. doi:https://doi.org/10.1016/j.tics.2003.12.008
Markus, K., & Pulvermuller, F. (2012). Conceptual representations in mind and brain: Theoretical developments, current evidence and future directions. In (Vol. 48, pp. 805-825).
Marsh, H. W., Craven, R. G., & Debus, R. (1991). Self-concepts of young children 5 to 8 years of age: Measurement and multidimensional structure. *Journal of Educational Psychology, 83*(3), 377-392. doi:10.1037/0022-0663.83.3.377
Martin, E. (Ed.) (2015) Concise Medical Dictionary (9th ed.). Oxford: Oxford University Press.
Martín-Loeches, M. (2015). Neuroscience and education: We already reached the tipping point. *Psicología Educativa, 21*(2), 67-70. doi:https://doi.org/10.1016/j.pse.2015.09.001
Martin-Martin, R., & Brock, O. (2017). Cross-modal interpretation of multi-modal sensor streams in interaction perception based on coupled recursion. In: Robotics and Biology Laboratory, Technische Universita ̈t Berlin, Germany.
Masataka, N. (2010). Attunement in the perception of affordances as the origin of musical emotions. *Physics of Life Reviews, 7*(1), 28-29. doi:https://doi.org/10.1016/j.plrev.2009.12.003
Mathias, B., Palmer, C., Perrin, F., & Tillman, B. (2015). Sensorimotor learning enhances expectations during auditory perception. *Cerebral Cortex, 25*(8), 2238-2254.
Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and cognition: The realization of the living* (Vol. 42). Dordrecht, Holland: D. Reidel Pub. Co.

Matyja, J. R., & Schiavio, A. (2013). Enactive music cognition: Background and research themes. *Constructivist Foundations, 8*(3), 351-357.
McIntosh, M. J., & Morse, J. M. (2015). Situating and constructing diversity in semi-structured interviews. *Global Qualitative Nursing Research, 2*, 2333393615597674. doi:10.1177/2333393615597674
McKenney, S. E., & Reeves, T. C. (2012). *Conducting educational design research*. New York, NY: Routledge.
McKenney, S. E., & Reeves, T. C. (2019). *Conducting educational design research*. New York: Routledge.
Menary, R. (2006). Attacking the bounds of cognition. *Philosophical Psychology, 19*(3), 329-344. doi:10.1080/09515080600690557
Menary, R. (2010). Introduction to the special issue on 4e cognition. *Phenomenology and the Cognitive Sciences, 9*(4), 459-463. doi:10.1007/s11097-010-9187-6
Menin, D., & Schiavio, A. (2012). Rethinking musical affordances. *Avant: Journal of Philosophical-Interdisciplinary Vanguard, 3*(2/2012), 202-215.
Merchant, H., Grahn, J., Trainor, L., Rohrmeier, M., & Fitch, W. T. (2015). Finding the beat: A neural perspective across humans and non-human primates. *Philosophical Transactions of the Royal Society B: Biological Sciences, 370*(1664). doi:10.1098/rstb.2014.0093
Merleau-Ponty, M. (1962). *Phenomenology of perception*. London: Routledge.
Merzenich, M. M. (2013). *Soft-wired: How the new science of brain plasticity can change your life*. San Francisco, US: Parnassus.
Merzenich, M. M., Van Vleet, T. M., & Nahum, M. (2014). Brain plasticity-based therapeutics. *Frontiers in Human Neuroscience, 8*, 385. doi:10.3389/fnhum.2014.00385
Michael, J., Sebanz, N., & Knoblich, G. (2016). Observing joint action: Coordination creates commitment. *Cognition, 157*, 106-113. doi:https://doi.org/10.1016/j.cognition.2016.08.024
Michaelian, K., & Sutton, J. (2013). Distributed cognition and memory research: History and current directions. *Review of Philosophy and Psychology, 4*(1), 1-24. doi:10.1007/s13164-013-0131-x
Mišić, B., & Sporns, O. (2016). From regions to connections and networks: New bridges between brain and behavior. *Current Opinion in Neurobiology, 40*, 1-7. doi:https://doi.org/10.1016/j.conb.2016.05.003
Mooney, J. (2010). Frameworks and affordances: Understanding the tools of music-making. *Journal of Music, Technology & Education, 3*(2), 141-154. doi:10.1386/jmte.3.2-3.141_1
Moreau, Q., Galvan, L., Nazir, T. A., & Paulignan, Y. (2016). Dynamics of social interaction: Kinematic analysis of a joint action. *Frontiers in Psychology, 7*, 2016. doi:10.3389/fpsyg.2016.02016
Morgan, J. E., & Ricker, J. H. (Eds.). (2018). *Textbook of clinical neuropsychology* (2nd ed.). New York. NY.: Routledge.

Nalepka, P., Kallen, R. W., Chemero, A., Saltzman, E., & Richardson, M. J. (2017). Herd those sheep: Emergent multiagent coordination and behavioral-mode switching. *Psychological Science, 28*(5), 630-650. doi:10.1177/0956797617692107

NESA. (2018). *Australian professional standards for teachers*. Sydney Australia: NSW Education Standards Authority Retrieved from https://educationstandards.nsw.edu.au.

Niedenthal, P. M. (2007). Embodying emotion. *Science, 316*(5827), 1002-1005. doi:10.1126/science.1136930

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and social psychology review : an official journal of the Society for Personality and Social Psychology, Inc, 9*(3), 184-211. doi:10.1207/s15327957pspr0903_1

Nijs, L., & Bremmer, M. (2019). Embodiment in early childhood music education. In R. Bader (Ed.), *Music in early childhood: Multi-disciplinary perspectives and inter-disciplinary exchanges* (pp. 87-102). Switzerland: Springer.

Niland, A. (2009). The power of musical play: The value of play-based, child-centered curriculum in early childhood music education. *General Music Today (Online), 23*(1), 17-21.

Noë, A. (2012). *Varieties of presence*. Cambridge, MA, USA: Harvard University Press.

Noel, J.-P., Grivaz, P., Marmaroli, P., Lissek, H., Blanke, O., & Serino, A. (2015). Full body action remapping of peripersonal space: The case of walking. *Neuropsychologia, 70*, 375-384. doi:https://doi.org/10.1016/j.neuropsychologia.2014.08.030

Novembre, G., & Keller, P. E. (2014). A conceptual review on action-perception coupling in the musicians' brain: What is it good for? *Frontiers in Human Neuroscience, 8*, 603. doi:10.3389/fnhum.2014.00603

O'Regan, J. K., & Noe, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences, 24*(5), 1011-1031.

Obhi, S. S., & Hall, P. (2011). Sense of agency and intentional binding in joint action. *Experimental Brain Research, 211*(3), 655. doi:10.1007/s00221-011-2675-2

Odendaal, A., Levänen, S., & Westerlund, H. (2019). Lost in translation? Neuroscientific research, advocacy, and the claimed transfer benefits of musical practice. *Music Education Research, 21*(1), 4-19. doi:10.1080/14613808.2018.1484438

Odgers, S. (2005). *Bunyips don't*. Gosford, Australia: Scholastic Australia.

Osgood-Campbell, E. (2015). Investigating the educational implications of embodied cognition: A model interdisciplinary inquiry in mind, brain, and education curricula. *Mind, Brain, and Education, 9*(1), 3-9. doi:10.1111/mbe.12063

Overy, K., & Molnar-Szakacs, I. (2009). Being together in time: Musical experience and the mirror neuron system. *Music Perception, 26*(5), 489-504. doi:10.1525/mp.2009.26.5.489

Oxford dictionary of english. (2011). (A. Stevenson Ed. 4th ed.). Oxford UK: Oxford University Press.

Oztop, E., Kawato, M., & Arbib, M. A. (2006). Mirror neurons and imitation: A computationally guided review. *Neural Networks, 19*(3), 254-271. doi:10.1016/j.neunet.2006.02.002

Pacherie, E. (2014). How does it feel to act together? *Phenomenology and the Cognitive Sciences, 13*(1), 25-46. doi:10.1007/s11097-013-9329-8

Pacherie, E., & Dokic, J. (2006). From mirror neurons to joint actions. *Cognitive Systems Research, 7*(2–3), 101-112. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.cogsys.2005.11.012

Palghat, K., Horvath, J. C., & Lodge, J. M. (2017). The hard problem of 'educational neuroscience'. *Trends in Neuroscience and Education, 6*, 204-210. doi:https://doi.org/10.1016/j.tine.2017.02.001

Palmer, C., & Zamm, A. (2017). Interactons in ensemble music performance: Empirical and mathematical accounts. In M. Lesaffre, P.-J. Maes, & M. Leman (Eds.), *The routledge companion to embodied music interaction* (pp. 370-379). New York, NY: Routledge.

Park, H.-J., & Friston, K. (2013). Structural and functional brain networks: From connections to cognition. *Science, 342*(6158). doi:10.1126/science.1238411

Pascoe, R., Leong, S., McCallum, J., Mackinlay, E., Marsh, K., Smith, B., . . . Winterton, A. (2005). *National review of school music education* (0642-775710). Retrieved from ACT:

Pascual-Leone, A. (2003). The brain that makes music and is changed by it. In I. Peretz & R. A. Zatorre (Eds.), *The cognitive neuroscience of music* (pp. 396-409). Oxford: Oxford University Press.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105-119. doi:10.1111/j.1539-6053.2009.01038.x

Pasquinelli, E. (2012). Neuromyths: Why do they exist and persist? *Mind, Brain, and Education, 6*(2), 89-96. doi:10.1111/j.1751-228X.2012.01141.x

Patané, I., Farnè, A., & Frassinetti, F. (2017). Cooperative tool-use reveals peripersonal and interpersonal spaces are dissociable. *Cognition, 166*, 13-22. doi:https://doi.org/10.1016/j.cognition.2017.04.013

Penhune, V. B. (2011). Sensitive periods in human development: Evidence from musical training. *Cortex, 47*(9), 1126-1137. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.cortex.2011.05.010

Petzold, H. (1995). *The inherent - the foreign - in common*. Paper presented at the International Symposium "The Inherent - The Foreign - In Common, Salzburg Austria.

Pezzulo, G. (2011). Shared representations as coordination tools for interaction. *Review of Philosophy and Psychology, 2*(2), 303-333. doi:10.1007/s13164-011-0060-5
Pezzulo, G., Barca, L., Bocconi, A. L., & Borghi, A. M. (2010). When affordances climb into your mind: Advantages of motor simulation in a memory task performed by novice and expert rock climbers. *Brain and cognition, 73*(1), 68-73. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/j.bandc.2010.03.002
Phillips-Silver, J. (2009). On the meaning of movement in music, development and the brain. *Contemporary Music Review, 28*(3), 293-314. doi:10.1080/07494460903404394
Phillips-Silver, J., & Keller, P. E. (2012). Searching for roots of entrainment and joint action in early musical interactions. *Frontiers in Human Neuroscience, 6*(00026), 1-11. doi:10.3389/fnhum.2012.00026
Phillips-Silver, J., & Trainor, L. (2005). Feeling the beat: Movement influences infant rhythm perception. *Science, 308*(5727), 1430.
Phillips-Silver, J., & Trainor, L. (2007). Hearing what the body feels: Auditory encoding of rhythmic movement. *Cognition, 105*(3), 533-546. doi:10.1016/j.cognition.2006.11.006
Pols, A. J. K. (2012). Characterising affordances: The descriptions-of-affordances-model. *Design Studies, 33*(2), 113-125. doi:10.1016/j.destud.2011.07.007
Prinz, J. J., & Barsalou, L. W. (2014). Steering a course for embodied representation. In D. Eric & B. M. Arthur (Eds.), *Cognitive dynamics: Conceptual and representational change in humans and machines.* (pp. 51-77). New York, USA.: Psychology Press.
Purdy, N., & Morrison, H. (2009). Cognitive neuroscience and education: Unravelling the confusion. *Oxford Review of Education, 35*(1), 99-109. doi:10.1080/03054980802404741
Purves, D., Cabeza, R., Huettel, S. A., LaBar, K. S., Platt, R. L., & Woldorff, M. G. (2013). *Principles of cognitive neuroscience* (2nd ed.). Sunderland, Mass. USA: Sinauer Associates.
Quian Quiroga, R. (2013). Meaning from sensory information. *Physics of Life Reviews, 10*(1), 101-102. doi:https://doi.org/10.1016/j.plrev.2013.01.006
Quian Quiroga, R. (2016). Neuronal codes for visual perception and memory. *Neuropsychologia, 83*, 227-241. doi:https://doi.org/10.1016/j.neuropsychologia.2015.12.016
Rademaker, R. L., Wu, D.-A., Bloem, I. M., & Sack, A. T. (2014). Intensive tool-practice and skillfulness facilitate the extension of body representations in humans. *Neuropsychologia, 56*, 196-203. doi:https://doi.org/10.1016/j.neuropsychologia.2014.01.011
Radford, L., & Roth, W.-M. (2011). Intercorporeality and ethical commitment: An activity perspective on classroom interaction. *Educational Studies in Mathematics, 77*(2), 227-245. doi:10.1007/s10649-010-9282-1

Radin, J. L. (2009). Brain-compatible teaching and learning: Implications for teacher education. *Educational Horizons, 88*, 40-50.
Rao, R. P. N. (2009). Bayesian cortical models. In L. R. Squire (Ed.), *Encyclopedia of neuroscience* (pp. 119-126). Oxford: Academic Press.
Reese, J. A. (2016). Field experiences using ipads. *Journal of Music Teacher Education, 26*(1), 96-111.
Reeves, T. C. (2006). Design research from a technology perspective. In K. G. J. van den Akker, S. McKenney & N. Nieveen (Ed.), *Design research from a technology perspective* (pp. 52-66). London: Routledge.
Reybrouck, M. (2005). Body, mind and music: Musical semantics between experiential cognition and cognitive economy. *Trans: Transcultural Music Review, 9*.
Reybrouck, M. (2006). Music cognition and the bodily approach: Musical instruments as tools for musical semantics. *Contemporary Music Review, 25*(1-2), 59-68. doi:10.1080/07494460600647451
Reybrouck, M. (2013). From sound to music: An evolutionary approach to musical semantics. *Biosemiotics, 6*(3), 585-606. doi:10.1007/s12304-013-9192-6
Rizzolatti, G. (2005). The mirror neuron system and its function in humans. *Anatomy And Embryology, 210*(5-6), 419-421.
Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual review of neuroscience, 27*(1), 169-192. doi:10.1146/annurev.neuro.27.070203.144230
Rizzolatti, G., & Destro, M. F. (2007). Understanding actions and the intentions of others: The basic neural mechanism. *European Review, 15*(2), 209-222. doi:10.1017/S1062798707000221
Rizzolatti, G., & Fabbri-Destro, M. (2008). The mirror system and its role in social cognition. *Current Opinion in Neurobiology, 18*(2), 179-184. doi:10.1016/j.conb.2008.08.001
Rizzolatti, G., & Fabbri-Destro, M. (2010). Mirror neuron mechanism. In G. F. Editors-in-Chief: Koob & R. F. Thompson (Eds.), *Encyclopedia of behavioral neuroscience* (pp. 240-249). Oxford: Academic Press.
Rizzolatti, G., & Fadiga, L. (2007). Grasping objects and grasping action meanings: The dual role of monkey rostroventral premotor cortex (area f5). In *Novartis foundation symposium 218 - sensory guidance of movement* (pp. 81-108): John Wiley & Sons, Ltd.
Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research, 3*(2), 131-141. doi:10.1016/0926-6410(95)00038-0
Rizzolatti, G., & Fogassi, L. (2014). The mirror mechanism: Recent findings and perspectives. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 369*(1544). doi:10.1098/rstb.2013.0420

Rizzolatti, G., & Sinigaglia, C. (2016). The mirror mechanism: A basic principle of brain function. *Nature Reviews: Neuroscience, 17*(12), 757-765.
Rocha, E., Costa, B., Ferreira, I., & Fregni, F. (2018). Neural basis of learning. *Revista de Medicina, 97*(1), 1+.
Rohlf, S., Habets, B., von Frieling, M., & Röder, B. (2017). Infants are superior in implicit crossmodal learning and use other learning mechanisms than adults. *eLife, 6*, e28166. doi:10.7554/eLife.28166
Roth, W.-M. (2001). Gestures: Their role in teaching and learning. *Review of Educational Research, 71*(3), 365-392.
Roth, W.-M., & Jornet, A. (2013). Situated cognition. *Wiley Interdisciplinary Reviews: Cognitive Science, 4*(5), 463-478. doi:10.1002/wcs.1242
Rowe, M. L., Özçalışkan, Ş., & Goldin-Meadow, S. (2008). Learning words by hand: Gesture's role in predicting vocabulary development. *First Language, 28*(2), 182-199. doi:10.1177/0142723707088310
Rozmajzl, M., & Boyer-Alexander, R. (2000). *Music fundamentals, methods, and materials for the elementary classroom teacher* (3rd ed.). New York, NY: Longman.
Ryan, K., & Schiavio, A. (2019). Extended musicking, extended mind, extended agency. Notes on the third wave. *New Ideas in Psychology, 55*, 8-17. doi:https://doi.org/10.1016/j.newideapsych.2019.03.001
Sayer, L., & Poncia, V. (1976). You make me feel like dancing. On *Endless Flight*. UK: Chrysalis Records.
Scarantino, A. (2003). Affordances explained. *Philosophy of Science, 70*(5), 949-961.
Schiavio, A., Biasutti, M., van der Schyff, D., & Parncutt, R. (2018). A matter of presence: A qualitative study on teaching individual and collective music classes. *Musicae Scientiae*, 1029864918808833. doi:10.1177/1029864918808833
Schiavio, A., & De Jaegher, H. (2017). Participatory sense-making in joint musical practice. In M. Lesaffre, M. Leman, & P.-J. Maes (Eds.), *The routledge companion to embodied music interaction* (pp. 456). New York, NY: Routledge.
Schiavio, A., & Høffding, S. (2015). Playing together without communicating? A pre-reflective and enactive account of joint musical performance. *Musicae Scientiae, 19*(4), 366-388. doi:10.1177/1029864915593333
Schiavio, A., & Timmers, R. (2014). Motor and audiovisual learning consolidate auditory memory of tonally ambiguous melodies. *Music Perception, 34*(1), 21-32. doi:10.1525/MP.2016.34.1.21
Schiavio, A., & van der Schyff, D. (2018). 4e music pedagogy and the principles of self-organization. *Behavioral Science, 8*(72), 15. doi:10.3390/bs8080072
Schiavio, A., van der Schyff, D., Biasutti, M., Moran, N., & Parncutt, R. (2019). Instrumental technique, expressivity, and communication. A qualitative study on learning music in individual and collective

settings. *Frontiers in Psychology, 10*(737). doi:10.3389/fpsyg.2019.00737
Schiavio, A., van der Schyff, D., Kruse-Weber, S., & Timmers, R. (2017). When the sound becomes the goal. 4e cognition and teleomusicality in early infancy. *Frontiers in Psychology, 8*, 1585. doi:10.3389/fpsyg.2017.01585
Schlaug, G. (2015). Chapter 3 - musicians and music making as a model for the study of brain plasticity. *Progress in brain research, 217*, 37-55. doi://dx.doi.org.ezproxy.lib.uts.edu.au/10.1016/bs.pbr.2014.11.020
Schoenfeld, M. A., Tempelmann, C., Martinez, A., Hopf, J. M., Sattler, C., Heinze, H. J., & Hillyard, S. A. (2003). Dynamics of feature binding during object-selective attention. *Proceedings of the National Academy of Sciences, 100*(20), 11806. doi:10.1073/pnas.1932820100
Scholtens, M. C. (2019). Using music to encourage joint attention for students with autism spectrum disorder: Attention as a reciprocal relationship. *Music Educators Journal, 105*(4), 45-51. doi:10.1177/0027432119846954
Schöner, G., Reimann, H., & Lins, J. (2015). Neural dynamics. In G. Schöner & J. Spencer (Eds.), *Dynamic thinking: A primer on dynamic field theory*: Oxford Scholarship Online.
Schroeder, F. (2015). Bringing practice closer to research - seeking integrity, sincerity and authenticity. *International Journal of Education through Art, 11*(3), 343-354. doi:10.1386/eta.11.3.343_1
Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: Bodies and minds moving together. *Trends in Cognitive Sciences, 10*(2), 70-76. doi:https://doi.org/10.1016/j.tics.2005.12.009
Sedlmeier, P., & Weigelt, O. (2011). Music is in the muscle: How embodied cognition may influence music preferences. *Music Perception, 28*(3), 297-305. doi:10.1525/mp.2011.28.3.297
Shamrock, M. (1997). Orff-schulwerk an integrated foundation. *Music Educators Journal, 83*(6), 41.
Shams, L., & Seitz, A. R. (2008). Benefits of multisensory learning. *Trends in Cognitive Sciences, 12*(11), 411-417. doi:https://doi.org/10.1016/j.tics.2008.07.006
Shapiro, L. (2013). Dynamics and cognition. *Minds and Machines, 23*(3), 353-375. doi:10.1007/s11023-012-9290-2
Sharlin, E., Watson, B., Kitamura, Y., Kishino, F., & Itoh, Y. (2004). On tangible user interfaces, humans and spatiality. *Personal and Ubiquitous Computing, 8*(5), 338-346. doi:10.1007/s00779-004-0296-5
Shatz, C. J. (1992). The developing brain. *Scientific American, 267*(3), 60-67.
Sidhu, D. M., Kwan, R., Pexman, P. M., & Siakaluk, P. D. (2014). Effects of relative embodiment in lexical and semantic processing of verbs. *Acta psychologica, 149*, 32-39. doi:10.1016/j.actpsy.2014.02.009

Simones, L. (2019). Understanding the meaningfulness of vocal and instrumental music teachers' hand gestures through the teacher behavior and gesture framework. *Frontiers in Education, 4*(141). doi:10.3389/feduc.2019.00141
Sinigaglia, C. (2013). What type of action understanding is subserved by mirror neurons? *Neuroscience letters; The Mirror Neuron System, 540*(0), 59-61. doi://dx.doi.org/10.1016/j.neulet.2012.10.016
Small, C. (1999). Musicking — the meanings of performing and listening. A lecture. *Music Education Research, 1*(1), 9-22. doi:10.1080/1461380990010102
Smith, L. B. (2005). Cognition as a dynamic system: Principles from embodiment. *Developmental Review, 25*(3), 278-298. doi:https://doi.org/10.1016/j.dr.2005.11.001
Smith, L. B. (2006). Movement matters: The contributions of esther thelen. *Biological Theory, 1*(1), 87-89. doi:10.1162/biot.2006.1.1.87
Spampinato, D., & Celnik, P. (2018). Deconstructing skill learning and its physiological mechanisms. *Cortex*. doi:https://doi.org/10.1016/j.cortex.2018.03.017
Spence, C., & Parise, C. V. (2012). The cognitive neuroscience of crossmodal correspondences. *i-Perception, 3*(7), 410-412. doi:10.1068/i0540ic
Spencer, J. P., Clearfield, M., Corbetta, D., Ulrich, B., Buchanan, P., & Schoner, G. (2006). Moving toward a grand theory of development: In memory of esther thelen. *Child Development, 77*(6), 1521-1538. doi:10.1111/j.1467-8624.2006.00955.x
Spruston, N. (2008). Pyramidal neurons: Dendritic structure and synaptic integration. *Nature Reviews. Neuroscience, 9*(3), 206-221. doi:10.1038/nrn2286
Stahn, A. C., Gunga, H.-C., Kohlberg, E., Gallinat, J., Dinges, D. F., & Kühn, S. (2019). Brain changes in response to long antarctic expeditions. *New England Journal of Medicine, 381*(23), 2273-2275. doi:10.1056/NEJMc1904905
Stephan, M. L. (2015). Conducting classroom design research with teachers. *ZDM, 47*(6), 905-917. doi:10.1007/s11858-014-0651-6
Stewart, J., Gapenne, O., & Di Paolo, E. A. (2011). *Enaction : Towards a new paradigm for cognitive science*. Cambridge, MA, USA: MIT Press.
Strasser, A. (2012). Mental representations. In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning* (pp. 2218-2221). Boston, MA: Springer US.
Suchak, M., Eppley, T. M., Campbell, M. W., Feldman, R. A., Quarles, L. F., & de Waal, F. B. M. (2016). How chimpanzees cooperate in a competitive world. *Proceedings of the National Academy of Sciences of the United States of America, 113*(36), 10215-10220. doi:10.1073/pnas.1611826113
Sutton, J., Harris, C. B., Keil, P. G., & Barnier, A. J. (2010). The psychology of memory, extended cognition, and socially distributed

remembering. *Phenomenology and the Cognitive Sciences, 9*(4), 521-560. doi:10.1007/s11097-010-9182-y
Tanaka, S. (2015). Intercorporeality as a theory of social cognition. *Theory & Psychology, 25*(4), 455-472. doi:10.1177/0959354315583035
Tardif, E., Doudin, P.-A., & Meylan, N. (2015). Neuromyths among teachers and student teachers. *Mind, Brain, and Education, 9*(1), 50-59. doi:10.1111/mbe.12070
Teneggi, C., Canzoneri, E., di Pellegrino, G., & Serino, A. (2013). Social modulation of peripersonal space boundaries. *Current Biology, 23*(5), 406-411. doi:https://doi.org/10.1016/j.cub.2013.01.043
The Design-based Research Collective, c. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5.
Thelen, E. (1995). Motor development: A new synthesis. *American Psychologist, 50*(2), 79-95. doi:10.1037/0003-066X.50.2.79
Thelen, E. (2000). Grounded in the world: Developmental origins of the embodied mind. *Infancy, 1*(1), 3-28. doi:10.1207/S15327078IN0101_02
Thelen, E., Schöner, G., Scheier, C., & Smith, L. B. (2001). The dynamics of embodiment: A field theory of infant preseverative reaching. *Behavioral and Brain Sciences, 24*(1), 86.
Thompson, E. (2005). Sensorimotor subjectivity and the enactive approach to experience. *Phenomenology and the Cognitive Sciences, 4*(4).
Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind*. Cambridge, Mass.; London: Belknap.
Thompson, M. R., & Mendoza, J. I. (2014). Book review: New perspectives in music and gesture. *Psychomusicology: Music, Mind and the Brain, 24*(4), 344-350. doi:10.1037/pmu0000084
Thorne, S. (2016). *Interpretive description: Qualitative research for applied practice* (2nd ed.). New York, NY: Taylor & Francis.
Tomasello, R., Garagnani, M., Wennekers, T., & Pulvermüller, F. (2017). Brain connections of words, perceptions and actions: A neurobiological model of spatio-temporal semantic activation in the human cortex. *Neuropsychologia, 98*, 111-129. doi:https://doi.org/10.1016/j.neuropsychologia.2016.07.004
Tovar-Moll, F., & Lent, R. (2016). The various forms of neuroplasticity: Biological bases of learning and teaching.(brain science, education and learning: Making connections)(abstract). *Prospects, 46*(2), 199. doi:10.1007/s11125-017-9388-7
Trainor, L. J., & Hannon, E. E. (2013). Musical developent. In D. Deutsch (Ed.), *The psychology of music* (3rd ed. ed., pp. 423-497). London: Academic Press.
Trehub, S. E. (2003). The developmental origins of musicality. *Nature Neuroscience, 6*(7), 669. doi:10.1038/nn1084
Trehub, S. E., Becker, J., & Morley, I. (2015). Cross-cultural perspectives on music and musicality. *Philosophical Transactions of the Royal*

Society B: Biological Sciences, 370(1664). doi:10.1098/rstb.2014.0096
Tuthill, J. C., & Azim, E. (2018). Proprioception. *Current Biology, 28*(5), R194-R203. doi:https://doi.org/10.1016/j.cub.2018.01.064
Valdesolo, P., Ouyang, J., & DeSteno, D. (2010). The rhythm of joint action: Synchrony promotes cooperative ability. *Journal of Experimental Social Psychology, 46*(4), 693-695. doi:https://doi.org/10.1016/j.jesp.2010.03.004
van der Schyff, D. (2017). *Concepts for an enactive music pedagogy: Essays on phenomenology, embodied cognition, and music education.* (PhD), Simon Fraser University, Canada. (etd10162)
van der Schyff, D., Schiavio, A., & Elliott, D. J. (2016). Critical ontology for an enactive music pedagogy. *Action, Criticism & Theory for Music Education, 15*(5), 81-121. doi:10.22176/act15.5.81
van der Schyff, D., Schiavio, A., Walton, A., Velardo, V., & Chemero, A. (2018). Musical creativity and the embodied mind: Exploring the possibilities of 4e cognition and dynamical systems theory. *Music & Science, 1*, 1-18. doi:10.1177/2059204318792319
van Ernst, B. (1994). Perspectives on music education research. *Research Studies in Music Education, 2*(1), 46-48. doi:10.1177/1321103X9400200108
van Praag, H., Kempermann, G., & Gage, F. H. (2000). Neural consequences of environmental enrichment. *Nature Reviews.Neuroscience, 1*(3), 191-198.
Varma, S., McCandliss, B. D., & Schwartz, D. L. (2008). Scientific and pragmatic challenges for bridging education and neuroscience. *Educational Researcher, 37*(3), 140-152.
Vernon, D., Lowe, R., Thill, S., & Ziemke, T. (2015). Embodied cognition and circular causality: On the role of constitutive autonomy in the reciprocal coupling of perception and action. *Frontiers in Psychology, 6*(1660). doi:10.3389/fpsyg.2015.01660
Vesper, C., Abramova, E., Bütepage, J., Ciardo, F., Crossey, B., Effenberg, A., . . . Wahn, B. (2017). Joint action: Mental representations, shared information and general mechanisms for coordinating with others. *Frontiers in psychology, 7*, 2039-2039. doi:10.3389/fpsyg.2016.02039
Vilares, I., & Kording, K. (2011). Bayesian models: The structure of the world, uncertainty, behavior, and the brain. *Annals of the New York Academy of Sciences, 1224*(1), 22-39. doi:doi:10.1111/j.1749-6632.2011.05965.x
Wakefield, E. M., & James, K. H. (2011). Effects of sensori-motor learning on melody processing across development: An interdisciplinary journal an interdisciplinary journal. *Cognition, Brain, Behavior, 15*(4), 505-534.
Walton, A. E., Washburn, A., Richardson, M. J., & Chemero, A. (2018). *Empathy and groove in musical movement*. Paper presented at

the UC Irvine: A Body of Knowledge Conference 2016, UC Irvine. https://escholarship.org/uc/item/30h4m2mp
Wan, C. Y., & Schlaug, G. (2010). Music making as a tool for promoting brain plasticity across the life span. *The Neuroscientist, 16*(5), 566-577. doi:10.1177/1073858410377805
Wang, Y. (2013). Formal models and cognitive mechanisms of the human sensory system. *International Journal of Software Science and Computational Intelligence (IJSSCI), 5*(3), 1942-9045. doi:10.4018/ijssci.2013070104
Whitehead, A. N. (1950). *The aims of education and other essays* (2nd ed. ed.). London: Benn.
Will, B., Galani, R., Kelche, C., & Rosenzweig, M. R. (2004). Recovery from brain injury in animals: Relative efficacy of environmental enrichment, physical exercise or formal training (1990–2002). *Progress in Neurobiology, 72*(3), 167-182. doi:https://doi.org/10.1016/j.pneurobio.2004.03.001
Willingham, D. T. (2009). Three problems in the marriage of neuroscience and education. *Cortex, 45*(4), 544-545. doi:https://doi.org/10.1016/j.cortex.2008.05.009
Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625-636. doi:10.3758/BF03196322
Wilson, M. (2010). The re-tooled mind: How culture re-engineers cognition. *Social cognitive and affective neuroscience, 5*(2-3), 180-187. doi:10.1093/scan/nsp054
Windsor, L. (2016). Gestures in music-making: Action, information and perception. In A. Gritten & E. King (Eds.), *New perspectives on music and gesture* (pp. 45-66). UK: Routledge.
Windsor, L., & de Bézenac, C. (2012). Music and affordances. *Musicae Scientiae, 16*(1), 102-120. doi:10.1177/1029864911435734
Zatorre, R. J., Chen, J. L., & Penhune, V. B. (2007). When the brain plays music: Auditory–motor interactions in music perception and production. *Neuroscience Nature Reviews*(7), 547-558. doi:10.1038/nrn2152
Zbikowski, L. M. (2016). Musical gesture and musical grammar: A cognitive approach. In A. Gritten & E. King (Eds.), *New perspectives on music and gesture* (pp. 83-98). UK: Routledge.
Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science, 21*(2), 179-217. doi:10.1207/s15516709cog2102_3
Zimmerman, E., & Lahav, A. (2012). The multisensory brain and its ability to learn music. *Annals of the New York Academy of Sciences, 1252*(1), 179-184. doi:10.1111/j.1749-6632.2012.06455.x
Zipoli Caiani, S. (2014). Extending the notion of affordance. *Phenomenology and the Cognitive Sciences, 13*(2), 275-293. doi:10.1007/s11097-013-9295-1

GLOSSARY

Term	Definition and reference
Affordance	Affordances are relations between the abilities of animals and features of the environment (Chemero, 2003, p. 181). Use of objects, material or metaphorical, for tool-use. Tool-use supports specialisation of perceptual-motor skills and develops cognitive ability and flexibility (Deak, 2014, p. 150)
Attunement	The act of being harmonious together (*Oxford dictionary of english*, 2011).
Axon	The extension of a neuron that carries the action potential from the nerve cell body to a target (Purves et al., 2013, p. 566)
Bayesian	"The probabilistic integration of top-down prior information with bottom-up image likelihood information" to make predictions" (Rao, 2009, p. 125). This is based on the hierarchical model of Bayesian inference because cortical models (of how the brain works) seem to be hierarchical.
cognitive neuroscience	an approach that aims to understand human cognition by combining information from brain activity and behaviour (Eysenck & Brysbaert, 2018, p. 728)
cognitive psychology	studies the processes involved in acquiring, storing and transforming information (Eysenck & Brysbaert, 2018, p. 728)
coupling	An interaction between two different parts of a system ("A dictionary of physics," 2019)
cross-modal attention	the coordination of attention across two or more sense modalities (visual and hearing) (Eysenck & Brysbaert, 2018, p. 729)

GLOSSARY

Term	Definition and reference
Dendrite	The extension of a neuron that receives synaptic input: usually branches near the cell body (Purves et al., 2013, p. 569)
Entrainment	The process of synchronizing two or more rhythmic behaviours with respect to phase. Entrainment can occur without any intention to coordinate or even despite individuals attempting not to coordinate their actions (della Gatta et al., 2017, p. 53)
Embodied Cognition	Embodied cognition asserts that cognition arises out of the body's interactions with its physical environment (Wilson, 2002). This involves the brain the body and the world in continual dynamic interaction between perception, action and cognition (Anderson et al., 2012)
Episodic memory	A type of declarative memory concerned with personal experiences of the details of the when, where etc of that memory (Eysenck & Brysbaert, 2018, p. 295)
Extended Cognition	**Extended cognition** is when mental processes are offloaded into the environment through tools, so that things that would be too big a cognitive load could still remain usable by us. e.g. a road map, a shopping list (Clark & Chalmers, 1998; Krueger, 2014). Krueger termed this a "**coupled system**" (2014, p. 5). Menary describes the integration of internal and external processes as "**cognitive integration**" (Menary, 2006, p. 333).
functional magnetic resonance	a brain-imaging technique based on imaging blood oxygenation using an MRI scanner; it has very good spatial resolution and reasonable temporal resolution (Eysenck & Brysbaert, 2018, p. 732).

GLOSSARY

Term	Definition and reference
imaging (fMRI)	
Generative (model of the brain)	Where predictions from past experiences give meaning to what is being perceived
Gesture	Movements that communicate meaning. "Unlike actions, gestures do not bring about change in the environment…They represent rather than replicate action" (Cartmill et al., 2012, p. 129)
Glial cell (or neuroglia)	Any of several types of non-neural cells found in the peripheral and central nervous systems that carry out a variety of functions that do not directly entail signalling (Purves et al., 2013, p. 575)
Grey matter	Regions of the central nervous system that are rich in neuronal cell bodies (Eagleman, 2015, p. 572)
Hebbian process	Neurons that fire at the same time develop connections amongst one another (Merzenich et al., 2014).
Joint Action	Coordination of action or behaviour between two or more individuals (Keller et al., 2014, p. 1)
Mirror Neuron	Mirror neurons are nerve cells in the brain that fire in response to perceiving and performing actions. They have a fundamental role in action understanding and learning through imitation (Rizzolatti & Craighero, 2004).
Modularity	the assumption that the cognitive system consists of several fairly independent or separate modules or processors, each of which is specialised for a given

GLOSSARY

Term	Definition and reference
	type of processing (e.g. face processing) (Eysenck & Brysbaert, 2018, p. 736)
Multimodal	Information that can be experienced through multiple-sense modalities (Hollich & Bahrick, 2008, p. 164). Another description: https://multimodalityglossary.wordpress.com/embodiment/
Myelin and Myelination	The membranous wrapping of axons by certain classes of glial cells that makes brain regions with axonal pathways look whitish. The process, myelination, is where glial cells wrap axons to form multiple layers of glial cell membrane that electrically insulate the axon, thereby speeding up the conduction of action potentials (Purves et al., 2013, p. 575).
Multisensory integration	The integration of sensory information to provide a complete and coherent representation of the world (Dionne-Dostie et al., 2015, p. 32), facilitating the linking of that information together into one perceptual object (Purves et al., 2013, p. 575)
Neural dynamics	Patterns of activity between neurons and systems of neurons (Schöner et al., 2015)
Neuron	A specialised cell found in both the central and nervous systems, including the brain, spinal cord, and sensory cells, that communicates to other cells using electrochemical signals (Eagleman, 2015, p. 216).
Neuroplasticity	The neuronal and synaptic changes that take place as a result of learning or experience (Martin, 2015)
Noise (neuronal)	Background neuronal activity, even in the absence of sensory stimulation (Hartmann et al., 2015, p. 1)

GLOSSARY

Term	Definition and reference
Perception	The ability to select, organise and interpret various sensory experiences into recognisable patterns. These recognised patterns create organisational principles on which to analyse immediate experiences (Corsini, 2001, p. 705)
Priming	facilitated processing of (and response to) a target stimulus because the same or a related stimulus was presented before (Eysenck & Brysbaert, 2018, p. 738)
Procedural memory	A form of non-declarative memory involving learned skills and knowing how to do things (Eysenck & Brysbaert, 2018, p. 294)
Schema	a set of related propositions, which forms a packet of typical knowledge about the world, events, or people (Eysenck & Brysbaert, 2018, p. 740)
Sensorimotor integration	Action and perception systems that synchronise, making networks that organise behaviour to achieve a goal and develop skills (Machado et al., 2010)
Synapse	A specialised point of contact between the axon of a neuron (the presynaptic cell) and a target (postsynaptic) cell. Information is transferred between the …cells by the release and receipt of biochemical neurotransmitters (Purves et al., 2013, p. 569)
Top-down processing	stimulus processing that is determined by expectations, memory, and knowledge rather than directly by the stimulus (Eysenck & Brysbaert, 2018, p. 742)

Appendices

Appendix A:	Participant Consent Form
Appendix B:	Parent / Care Giver Consent Form
Appendix C:	Participant Information Sheet
Appendix D:	School Information Sheet

Appendix A: Participant Consent Form

Robyn Staveley
Education - Faculty of Arts and Social Sciences
UTS
PO Box 123
Broadway NSW 2000

CONSENT FORM - Participants
The impact of cognitive neuroscience on music education pedagogy
(UTS HREC REF No. ETH16-0564)

I ____ *(participant's name)* agree to participate in the research project, **The impact of cognitive neuroscience on music education pedagogy** (UTS HREC REF No. ETH16-0564) being conducted by Robyn Staveley, robyn.staveley@uts.edu.au (02) 9514 5381 of the University of Technology, Sydney for her PhD degree.

I understand that the purpose of this study is to find out how cognitive neuroscience research can impact music pedagogy.

I understand that I have been asked to participate in this research because I am an experienced music educator with demonstrated past interest in professional development and therefore will have the background experience and expertise to contribute to this research. My participation in this research will involve a 3 day course (15 & ½ hours); I will teach 3x40-minute lessons, followed by a 60 minute written reflection on each lesson. I will meet with the other teacher participants for 2 & ½ hours to discuss my perceptions of the impact of cognitive neuroscience on my music pedagogy. If this is not possible, other arrangements to participate in this will be organised, such as Skype or a conference call at the same time as other participants meet, or at another time at my convenience. One of my lessons will be observed, either by the researcher or video-recorded and sent to the researcher to observe. Other video recordings will occur during the course and discussions when the teacher participants meet to discuss their perceptions of the impact of the research on their pedagogy, but these recordings will not be viewed by anyone but the researcher and are recorded for the collection of data only. I will receive a copy of the teacher participants' perceptions and discussion. All teacher participant data will be deidentified and confidential but it is possible that teacher participants will recognise the responses by other participants. No names or any identifying information will be revealed in any reports of the research. Data arising from this research will inform future courses of study in the field of music pedagogy. Publication of the data will include thesis, reports, conference papers and journal articles.

I am aware that I can contact Robyn Staveley on 02 9514 5381, or robyn.staveley@uts.edu.au; or her supervisor, Professor Rosemary Johnston on 02 9514 9079, or rosemary.ross.johnston@uts.edu.au if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Robyn Staveley has answered all my questions fully and clearly.

I agree that the research data gathered from this project may be published in a form that does not identify me in any way.

____ ____/____/____
Signature (participant)

____ ____/____/____
Signature (researcher or delegate)

NOTE:
This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 2478 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

Robyn Staveley
Education - Faculty of Arts and Social Sciences
UTS
PO Box 123
Broadway NSW 2000

Appendix B: Parent / Care Giver Consent Form

Robyn Staveley
Education - Faculty of Arts and Social Sciences
UTS
PO Box 123
Broadway NSW 2000

CONSENT FORM – Parent/Care Giver consenting for their child
Permission to Video
The impact of cognitive neuroscience on music education pedagogy
(UTS HREC REF No. ETH16-0564)

I ____ *(parent name)* agree to my child

____*(child's name)* being in a video recording of my teacher, who is participating in the research project, **The impact of cognitive neuroscience on music education pedagogy** (UTS HREC REF No. ETH16-0564) being conducted by Robyn Staveley, robyn.staveley@uts.edu.au (02) 9514 5381 of the University of Technology, Sydney for her PhD degree.

I understand that the purpose of this study is to find out how neuroscience research can impact music teaching.

I understand that my child has been asked to participate in the video recording of a music lesson because their teacher is involved in a project that will provide valuable insights into how neuroscience is implemented in music teaching. I am aware that no-one but the researcher will view this recording, my child will not be identified, my child may not appear on the video, but if they do, their actions, behaviour or words will not be noted.

I am aware that I do not have to say yes, and that participation is voluntary. If I say no, nothing will happen.

I am aware that I can contact Robyn Staveley on 02 9514 5381, or robyn.staveley@uts.edu.au; or her supervisor, Professor Rosemary Johnston on 02 9514 9079, or rosemary.ross.johnston@uts.edu.au if I have any concerns about the research. I also understand that I am free to withdraw my child's participation from this lesson at any time I wish, without consequences, and without giving a reason.

I agree that Robyn Staveley has answered all my questions fully and clearly.

I agree that the research data gathered from this project may be published in a form that does not identify my child in any way.

____ ____/____/____
Signature (parent / care giver)

____ ____/____/____
Signature (researcher or delegate)

NOTE:
This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 2478 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

Appendix C: Participant Information Sheet

Robyn Staveley
Education - Faculty of Arts and Social Sciences
UTS
PO Box 123
Broadway NSW 2000

INFORMATION SHEET - Participants

The impact of cognitive neuroscience on music education pedagogy
(UTS HREC REF No. ETH16-0564)

WHO IS DOING THE RESEARCH?

My name is Robyn Staveley and I am an HDR student at UTS. My supervisor is Professor Rosemary Johnston.

WHAT IS THIS RESEARCH ABOUT?

This research is to find out about how cognitive neuroscience research can impact music pedagogy.

IF I SAY YES, WHAT WILL IT INVOLVE?

I will invite you to take part in a 3 day course, "Neuropedagogy in Music", to be held during the school holidays, at UTS. During the course, you will learn about cognitive neuroscience and how it applies to music pedagogy. Within 8 weeks of the course, you will teach three 40-minute music lessons, with the cognitive neuroscience research embedded in your pedagogy. These lessons will be part of your regular music program, but redesigned during the course to embed cognitive neuroscience in the pedagogy. One of these lessons will be observed and videoed by me at your school or where you will be teaching. If this is not possible, you will send me a video of one lesson. You will also write a reflection of your perceptions of the impact of this research on your pedagogy. This will take approximately 60 minutes per lesson. During the following school holidays, you will meet with me and the other participant teachers from the course to discuss your perceptions. This will take place at UTS, in a morning session of 2 & ½ hours duration and will also be video-recorded. If you cannot attend at this time, other arrangements such as a Skype or conference call will be arranged. I will collate and send you a copy of the reflections and perceptions of all teacher participant findings following this meeting. All data collected is confidential and will be deidentified. All videoed material will not be used for any other purposes other than this research, and will not be viewed by anyone else but me. As this project is quite a substantial time commitment, it is also possible to say yes to just parts of the project after the 3 day course.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. You may feel uncertain, embarrassed, and participation may take up more time that you had anticipated. It is possible that as you will be meeting with other teacher participants to discuss your perceptions of your pedagogy, you will be able to identify others' information in the group responses. In total, the initial course will be 15 & ½ hours, you will teach 3x40-minute lessons, followed by a 60 minute written reflection. You will meet with the other teacher participants for 2 & ½ hours to discuss findings.

WHY HAVE I BEEN ASKED?

You are able to give me the information that I need to find out about the impact of cognitive neuroscience on music pedagogy, because you are an experienced music teacher who has demonstrated past commitment to developing your teaching practice through completion of professional development in music education. The development of your pedagogy through this research, and your perception of its impact, will provide valuable insights into how cognitive neuroscience is implemented in music pedagogy.

DO I HAVE TO SAY YES?

You do not have to say yes. Your participation is voluntary.

WHAT WILL HAPPEN IF I SAY NO?

Nothing. I will thank you for your time so far and will not contact you about this research again.

IF I SAY YES, CAN I CHANGE MY MIND LATER?

You can change your mind at any time and you do not have to say why. I will thank you for your time so far and will not contact you about this research again.

WHAT IF I HAVE CONCERNS OR A COMPLAINT?

If you have concerns about the research that you think I, or my supervisor can help you with, please feel free to contact me on 02 9514 5381, or robyn.staveley@uts.edu.au; or Professor Rosemary Johnston on 02 9514 9079, or rosemary.ross.johnston@uts.edu.au

If you would like to talk to someone who is not connected with the research, you may contact the Research Ethics Officer via Research.Ethics@uts.edu.au, and quote this number **UTS HREC REF No. ETH16-0564**

Appendix D: School Information Sheet

Robyn Staveley
Education - Faculty of Arts and Social Sciences
UTS
PO Box 123
Broadway NSW 2000

SCHOOL INFORMATION SHEET - about teacher participating in research, and videoing of a lesson.

The impact of cognitive neuroscience on music education pedagogy
(UTS HREC REF No. ETH16-0564)

My name is Robyn Staveley and I am an HDR student at UTS. My supervisor is Professor Rosemary Johnston. This letter is to inform you that your teaching staff member, ... is a participant researcher in a research project to find out about how cognitive neuroscience research can impact music pedagogy.

....(teacher's name) has participated in a 3 day course, "Neuropedagogy and Music", which was held during the school holidays, July 4 – 6, 2016, at UTS. The course presented research on cognitive neuroscience and how it applies to music pedagogy. Following this, teachers who did the course agreed to design lessons, embedding neuroscientific principles in their music pedagogy. These lessons are part of their regular music program, but redesigned during the course to embed cognitive neuroscience in the pedagogy. I am seeking permission to observe and video one of these lessons.

The video will be focusing on the teacher, <u>not the students</u>. If any student does appear in the video, they will not be identified, and their behaviour, voice, words or actions will not be noted. No-one else will view the video recording except myself, the researcher. The students' permission, through their parents, will also be sought, ensuring the conditions as above, that their participation in the lesson is voluntary, and if they do not wish to participate or be videoed, they can withdraw and do not have to say why, and nothing will happen to them. Data will not be recorded about the students.

....(teacher's name) has agreed to provide reflections of their perceptions of the impact of cognitive neuroscience in their music pedagogy and this will provide valuable insights into how cognitive neuroscience is implemented in music pedagogy.

If you have concerns about the research that you think I, or my supervisor can help you with, please feel free to contact me on 02 9514 5381, or robyn.staveley@uts.edu.au; or Professor Rosemary Johnston on 02 9514 9079, or rosemary.ross.johnston@uts.edu.au