CHAPTER 19

COMPUTERS AND TECHNOLOGY

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There has been a steady interest in children's musical growth and development from within music education and music psychology circles for many years. Paralleling this has been the substantial development of software and hardware, which have helped in the study of musical development. What has rarely been considered is how advances in music technology might help us practically support the actual developmental understanding of music in children. Our purpose is to review important aspects of musical development in terms of music perception, performance, preference, and creation, and link these to music technology. After a summary of music technology history in the last 30 years, we will draw connections between the literature on musical development and music technology—particularly music software. We also offer a brief review of studies that have used technology to more clearly understand aspects of music learning. Our chapter concludes with thoughts about future directions in considering music technology and the understanding of musical development.

Research findings from the literature on musical development

In addition to the authors in this book, many scholars have contributed to the literature on musical development (e.g., Sloboda, 1985; Hargreaves, 1986; Bamberger, 1991; Deliege & Sloboda, 1996; Hargreaves & North 2001). The intent of the section that follows is to highlight some of the findings from this literature that might relate to the music technology development and its use in teaching and learning. We organize the literature around the topics of music perception, performance, preference of music and the role of social learning, and generative behaviours such as composition and improvization. We also include a section on infant and pre-school development as that period is critical to further development and has some implications for early use of music technology. Music development in adulthood is also included as new interest in music learning for adults is emerging and relates well to technology and its application.

We should state at the outset that the line between musical development that occurs naturally and that development that is encouraged or facilitated by the environment is always a difficult one to draw. The use of music technology as a way to encourage music understanding is an environmental experience that ideally ought to coincide with both the natural growth patterns of children and the culture's traditions and expectations. For these reasons, solid matches between current technology and musical development is the focus of this chapter.

Pre-school development

Music awareness begins a few months before birth as the auditory system becomes formed (see Chapters 1 and 2). Infants become accustomed to structures in music and prefer patterns that conform to known structures by at least the end of the first year of life (Trehub *et al.*, 1997).

The time between 1 month and 5 years of age is marked by incredibly rapid growth in all areas of musical development. The ages from 1 to 3 years point to a time of major experimentation and play with sounds in the environment. This development can be enhanced by exposure to rich musical environments for experimentation and growth. Babbling in the early months progresses to formed songs during this period (Moog, 1976; Moorhead & Pond, 1978; McDonald & Simons, 1989; Deliege & Sloboda, 1996; Hargreaves, 1996). Studies indicate that children around age 5 understand diatonic scale structure and even begin to be sensitive to harmonic properties (Dowling, 1988; Lamont & Cross, 1994). The ability to distinguish between fast and slow tempi seems to also emerge between the third and fourth year, although comparative judgements (slow and slower) are more difficult and the language used to express this distinction may be not developed.

A more contemporary perspective of pre-school development relates to cross-modal perception. Meltzoff *et al.* (1991) have speculated that important to the development of musical perception are the connections between auditory stimuli, visual stimuli, and touch.

> The infant perceives the acoustical characteristics of the maternal voice (melody, contour, tempo, rhythmical structure, timbre) as synchronous with and analogous to his or her own sensory perception, to visual experiences, and to the movements of the mother. The development of such cross-modal perceptual schemata is likely to play an important role for the perception of musical expression.
>
> Gembris (2002, p. 491)

There is credible evidence that children by the age of 3 or 4 can identify fundamental expressivity in music and can match certain pictures correctly to music (Kastner & Crowder, 1990).

Perception

The advances in our understanding of music perception have leaped in recent years because of techniques in neurobiology, and specifically, brain research (see Chapter 3). The use of technology that allows brain imaging techniques such as PET, EEG, ERP, and MRI provide new and exciting tools for researchers to examine brain activity during musical activities such as listening. Though this research is relatively young, it is clear that different learning contexts for listening (e.g., formal versus informal musical exposure; long-term versus short-term activity; tonal versus atonal music) affect different brain areas and activities and in different ways (Gruhn & Rauscher, 2002). What is not yet clear is a developmental pattern in changes.

Outside of the technological advances, there are generalizations that can be made about the development of listening and discrimination skills. Response to and discrimination of dynamics and timbre develop first in infants, while pitch, rhythm, texture, and harmony develop later in the growth process. By the age of 6, nearly all students have developed the ability to perceive and discriminate differences in all of these areas (McDonald & Simons, 1989; Trainor & Trehub, 1992).

Dowling (1999) has shown that melodic perception in its early stages is linked to contour only and then to more specific intervallic details as age increases. This is particularly true if children are involved in formal and active music instruction, such as playing a musical instrument. Hair (1977) and Webster & Schlentich (1983) have shown that pitch perception in younger students cannot be judged by words or gestures alone and that their real perception of subtle pitch change may be more accurate at a young age than might be otherwise imagined.

Piagetian notions of 'conservation' (co-ordinating several different aspects of perception with children aged 7 or older) has inspired work in musical development. For example, Pflederer & Sechrest (1968), in an older but classic work, showed that 8-year-old children can identify different melodies as variations of the same melody when rhythmic, melodic, or tonal changes were made.

An interesting line of investigation in music perception is graphic representation of music. As a way to uncover the mental representation of sound, researchers have asked children to notate the music they hear with invented notation (Bamberger, 1991; Smith *et al.*, 1994; Gromko, 1994). In terms of rhythm, before the age of 6, children tend to notate a sequentially ordered series of symbols in a more figural (or what Bamberger called 'intuitive') way. Older children, especially those with more musical experience, tend to order notation in a more formal or 'metric' way. Hargreaves (1986) has commented that this movement from more figural (6–7 year olds) to more metric listening (11–12 year olds) may be related to other kinds of musical development by saying that it: '. . . is very clearly paralleled in the progression from 'outline' to 'first draft' songs . . . as well as in that from pitch contours to tonal scale intervals in melodic processing . . . ' (p. 99).

Children above the age of 6 seem to prefer harmonization that is more consonant (Zenatti, 1993). Enculturation into Western tonal system seems important here and it raises an interesting question if familiarity on a regular basis with more dissonant and perhaps atonal materials in younger years might create different results.

Schellberg (1998) has determined that, by age 6, most children can perceive different instruments by their sound. Again, it is reasonable to assume that continued exposure to formal study of timbre in the early grades in general music settings and experience with music performance ensembles would further the discrimination of timbre.

Performance

As shown in Chapter 16, singing skills develop rapidly between birth and 6 years. In their second year, children can sing short phrases and spontaneous improvizations—moving toward more accurate intervals consistent with the diatonic system (Moog, 1976). By the age of 6 years, most children's sense of key is stabilized and can sing most songs (in the appropriate range) fairly accurately (McDonald & Simons, 1989). Learning to sing as a soloist or in a choir presents a complex array of factors for success or failure. Because the body *is* the instrument, singers cannot necessarily see the physical issues to readily fix problems that arise, and the self-identity and emotion and feeling states of the person is essentially wrapped together with the singing voice. Auditory feedback is therefore essential in shaping better singing habits (Welch *et al.*, 2005).

Children who learn to play musical instruments often either start very young (such as in the Suzuki talent education programme) and learn to play by ear, or begin about the age 12–13 when they have opportunities to join a school band or chorus. While Suzuki learning emphasizes playing by ear, children who learn instruments in the more traditional way are confronted with the confounding factor of having to read notation. Studies indicate that the most efficient way to teach notation when learning an instrument is to teach 'sound before symbol'; that is when children begin to learn an instrument they should learn to play by ear first and later be introduced to the notation system (McPherson, 1993; McPherson & Gabrielsson, 2002; Haston, 2004). McPherson *et al.* (1997) found that providing students with 'enriching' activities such as composition and improvization had a positive impact on student's ability to play by ear and improvise, while their ability to play by ear had a strong effect on their ability to sight-read.

More is known today about music practice. Barry & Hallam (2002) summarized research on practice and noted the important need for models of good practice at various stages of development and the wisdom of creating practice strategies.

Music preference and social psychology

Children's musical preferences are already formed by the ages of 4–6 years and are clearly influenced by their home and listening environment (McDonald & Simons, 1989). What happens beyond that age is obviously very complex. Hargreaves & North (1999) indicate that there may be different periods of 'openness' to musical styles, particularly in early childhood to about age 8 and in adulthood. At the beginning of adolescence, there is clear evidence that this openness decreases and the importance of peer influence in music preference emerges (LeBlanc, 1991).

The key to the study of musical preference and listening skill is understanding the role of culture and context (see Chapter 7). Musical learning through listening can happen informally as well as formally (Palmer & Krumhansl, 1987; Upitis, 1987; Serafine, 1988; Smith & Cuddy, 1989). More whole, contextualized listening experiences (as opposed to isolated or de-contextualized fragments) will provide children with richer, and more authentic learning experiences.

What is more interesting for teachers, perhaps is the growing body of research related to clear adolescent preference and identity with popular music and its associated culture. Adolescent self-esteem and self-confidence are clearly linked to their musical tastes—their 'badges' of identity (North & Hargreaves, 1999; Tarrant *et al.*, 2002). Music serves as an important social function for teenage youth and benefits to self-identity and self-esteem often occur only through peer interaction in the type of unsupervised musical activities that typically take place outside of school (Green, 2001; Tarrant *et al.*, 2002). Adolescent youths' perception of others is also linked to musical tastes.

Of critical importance to contemporary youth and young adults is the role of music and mass media (Gembris, 2002). The availability of music by way of television, personal music players, the internet, and laser disc technology has provided delivery systems that have influenced dramatically listening preferences. This also raises interesting issues for the functionality of music. In younger children, the functionality of music is often defined by the parent and other authority figures, but in adolescents and beyond, the pervasiveness of music as distributed by media seems to be the more powerful force.

Creating music through improvization and composition

Studies of very young children by Moorhead & Pond (1978), and Flohr (1984) show that children beginning about age 3 enthusiastically explore sounds on musical instruments, mostly using motor energy, and also show a fascination for timbre. Flohr found that children as young as 3 were able to repeat musical patterns in their improvizations showing early understanding and ability to develop basic forms.

Kratus (1996) proposed a seven-level approach to improvization development, beginning with exploration-based behaviour with novices and ending with the highest level of personal improvization that is transformational for the genre. Intermediate stages include: (1) improvization that is product-based in which the individual becomes aware of the audience and traditions within a genre; (2) fluid improvization where a student has mastered certain technical aspects of the genre; and (3) structural improvization in which more expressive and more technically advanced improvizations are noted.

Pressing (1988) defined improvization and surveyed teaching techniques, offering a model that utilizes intuition, memory, and decision-making skills combined with motor processes. Berliner's definitive ethnographic work (1994) on jazz improvization offers still further insight into the development of improvization from the jazz perspective, including the critical role of music listening and developing a vocabulary of patterns.

In addition to the growing interest in improvization and its role in musical development, compositional thinking as a strategy for teaching music has become a major force in countries such as Australia, the United Kingdom, and the United States (McPherson & Dunbar-Hall, 2001; Wiggins, 2002). Hickey (2002) has suggested a developmental sequence for teaching composition that involves exploration of sound followed by the study of form. The cycle might move to concentration on musical elements and then the larger issues of tension, unity, and balance.

A four-stage model of composition development has been suggested by Swanwick & Tillman (1986) based on a sequence that involves the mastery of basic music materials followed by stages based on imitation, more formal property development, and metacognitve decision-making common with more adult behaviours. Each stage begins with activities that are egocentric in nature and concludes with a sense of social sharing. Similar models have been proposed by Hargreaves & Galton (1992) and Lamont (1998) and have related general musical understanding as well as creation. Interestingly, movement through these stages is highly dependent on enculturation and formal training, especially latter stages that involve movement from more figural and imitative to more formal understanding (Swanwick *et al.*, 2004).

Webster (2002) has proposed a model of creative thinking in music that speculates on the role of enabling skills and conditions and a process of thinking that moves through cycles of divergent and convergent thinking. Based on the growing empirical, philosophical, and practical literature on creative thinking and children, the model offers a perspective on developmental issues and is intended as a springboard for such research.

Music technology

> The rise of new media technology (e.g., computers and the internet) and the emergence of new musical styles contribute to an increasing variety of musical development in the fields of composition, performance, listening, and preferences. Therefore, parents and teachers should be aware that the children's and student's musical development may differ considerably from their own.
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> Gembris (2002, pp. 489–490)

We turn our attention now to music technology, its history and its relationship to the literature on musical development. Our intent is to suggest matches between current technology and those aspects of musical development noted earlier. The quotation from Gembris, however, reminds us of the fact that not only is it wise to consider how current technology might support what we know about development, but also how technology itself has a role in framing and perhaps even effecting this development.

History

It is fair to say that, until most recently, the history of music technology has not been driven by any interest in musical development and learning with its attendant literature. Instead, music technology's growth has been guided by: (1) practical needs in music production (music notation, sound recording and reproduction); (2) certain technical achievements in hardware (faster, smaller, and cheaper processors, laser disc technology); and (3) the internet as a medium of communication. That said, computer-assisted instruction has always been a part of the history of music technology and certain achievements in the development of software particularly hold promise for linkages to the development literature. This is especially true now that more musicians and educators are knowledgeable about research and are engaged in formal and informal software development.

Hardware

The period staring in the mid 1970s to present day, can be considered the age of the integrated circuit.[1] The growth of small and powerful, personal computer systems mark this important time. Because of the effectiveness of the integrated circuit and the computer chip, number machines and electronic instruments have become smaller while increasing their ability to process digital information. The popular Apple IIe personal computer was developed in the late 1970s and add-on, digital-to-analog circuit cards gave the computer four-voice polyphony. The IBM Corporation soon followed with its own personal computer, which was emulated by many computer manufacturers in the coming years. In the mid-1980s, the Macintosh platform emerged with built-in sound to replace the Apple IIe and new IBM-type machines (commonly referred to as 'PCs') followed. New versions of both Macintosh and PC machines exist today as the dominant computers for music performance and education. Advances in hard disk and removable storage made it possible for more and more educators to experiment with their own computer programs. The development in the late 1980s of

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[1] For a more complete review of the stages in hardware and software development, see Williams & Webster (2006, pp. 4–11).

laser-driven, CD-ROM drives that could play music audio CDs was a major event in the ability of these personal computers to actually be used for music learning.

As this computer technology developed in this modern era, so has electronic music instruments. The MIDI (Music Instrument Digital Interface) protocol was developed in the mid-1980s and allowed music devices to transmit codes that described sound. The sound resources inside these devices have improved dramatically in recent years as sampling technology captured in chips has allowed the internal sounds of MIDI hardware to rival some of the best acoustic instruments. Since the beginning of the 1990s, music educators have used these MIDI-based devices to assist in music composition, performance, and listening. Today, MIDI hardware devices have become less prevalent as the sounds they produce are now easily contained in software. MIDI technology is used more often now as triggering music events either internally within the computer or from MIDI controller keyboard.

Software

The hardware advances in personal computing, MIDI, and laser technology have completely changed the nature of music instruction; however, the last 20-year period is equally impressive for its major advances in music software and it is here that some of the most important connections can be made with the musical development literature. It is during this time that music production software for music printing, sequencing, and digital audio emerged. In terms of software for computer-assisted instruction, more behaviouristic, drill-and-practice titles have been joined by more personalized, simulation and creative exploration software. Internet-based delivery of instruction marks some of the most recent trends.

From 1984 to 1994, the software aspect of music technology exploded in ways unparalleled in history. *Band-in-a-Box*[2] became the first commercial software to provide automated accompaniments for improvization. *Practica Musica* was published as one of the first music theory/aural skills programme to incorporate options for students and teachers—creating a kind of 'flexible-practice' software that could be adapted to individual learning needs. Each of these programs use the MIDI protocol to help the computer use external hardware as interactive partners in the learning process.

In addition to these computer-assisted instruction titles, the first programs for music notation were published, including the popular *Finale* software. Software for music sequencing such as *Cubase* and *Performer* were developing at the same time, allowing arrangers and composers to develop scores more effectively for commercial music, television, and film. Such software was used by music educators as well as commercial musicians to help students experiment with music production.

It was also during this 10-year period that the audio CD greatly influenced the development of multimedia software production. In 1989, the term 'hypermedia' was coined by Ted Nelson, building on a much earlier idea of inter-related text sources. Nelson's idea was to create a learning environment that allowed software to connect graphics, sound, and text into

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[2] Titles of music technology software presented in this chapter that are currently in print are documented more completely at http://www.emtbook.net/ under the link: 'Working Software List for Music Education.' Company and cost information is included there, including links to vendor sites that often offer demonstration copies.

an integrated whole. In this same year, Robert Winter designed the first commercial product in music to use this idea—an interactive program on Beethoven's *Symphony No. 9*, using a CD recording controlled by a software program. The software program was Apple's *HyperCard*, a toolkit for the development of hypermedia programs. HyperCard was a conceptual breakthrough for music software production because it allowed music educators without significant computer programming experience to create high-quality interactive software that used audio recordings on CD. This, together with Apple Computer's development of QuickTime technology, which allowed the capture and playback of digital video as part of computer software, inspired a number of professionally created interactive CD-ROMs devoted to music subjects.

The period from 1995 to the present has seen continued development of hypermedia titles, referred more often today as 'multimedia' experiences. In addition, software for music pedagogy has included new titles that encourage simulation and guided instruction.[3] *Making Music* and *Making More Music*, both authored by famed electronic music composer, Morton Subotnik, are significant music titles for music composition. These programs assume no knowledge of music notation and allow the student to discover musical structures using a drawing metaphor. The role of a composer is simulated in ways that help teach the processes of composition. *Music Ace I* and *II* use guided instruction to help students understand music theory and aural skills in an interactive environment using animation. Children are guided in their discovery of important music facts and opportunities are provided to test mastery with games and a composing space.

Music technology support for music performance has significantly increased in the last 5 years. Software such as *SmartMusic* have been successful in providing accompaniment support for instrumentalists and vocalists and has helped in the teaching of music intonation. Digital audio recording capabilities on modern personal computers have increased in quality in the last 5 years to a point where educators can take advantage of software that records performances directly to disc. Software such as *Audacity* and *Sound Forge* can be used to record and process sound with an impressive array of special effects. Music can now be easily recorded, processed, and 'burned' to audio CD in the basement of one's home using software such as *ProTools* and *Audition.*

Perhaps the most important trend for software recently has been the rise of internet-based materials for music teaching and learning. As more music teachers gain skills in the development of websites and as more schools gain access to the network, music teaching materials provided on-line at any time of day or night have begun to transform both content and delivery strategies. Individuals and companies now routinely distribute recorded music on the Internet in the form of compressed audio files. The *iTunes* software and its support for the popular player, iPod, is an excellent example.

Connection to musical development

This rather condensed review of music technology in the last 30 years reveals a movement to a more constructionist posture for developers and educators. For example, software

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[3] A complete review of many of the most influential software titles available today is contained in Williams & Webster (2006).

based on structured ways of rote learning, memorization, and patterns of convergent thinking that were commonly found in the early days of personal computers are now more likely to be augmented or even replaced with methods of discovery learning, problem-solving, and divergent thinking with more powerful hardware resources. Higher levels of synthetic thinking are seen as a more effective way to teach our children how to cope with complexity. Cooperative learning, peer teaching, and project-centred learning with the teacher in an overseeing role is much more valued than teacher-dominated interaction.

In the last 10 years, music educators have begun to use technology in a more constructionist context. Video, animation, text, and sound can unite to support a symbolically constructed world that represents reality in interesting and meaningful ways for children. With today's affordable personal computers, even the youngest of children can 'play along' with the computer, make increasingly more complex decisions about the composition of the music, or be asked to listen in new and exciting ways.

We believe that this use of music technology can be a powerful aid for music teachers to reinforce, extend, and refine the expected development of music perception, performance, preference, and creating that were noted in the first half of this chapter. Table 19.1 provides a suggested organization of current popular software by appropriate age level and by music content area. We also make a distinction between those software titles that are designed as computer-assisted instruction and those that are music production programs designed for personal productivity. Each of the titles can be used to match the emerging developmental aspects that were noted earlier in this chapter. In the sections that follow, we describe a few of these titles within each content area in music learning and why we feel the technology can be used as a match.

Pre-school development

Each title in the Pre-School column in Table 19.1 is designed to engage children in music experiences without the use of extensive written words. The accent is on experimentation with sound using colourful graphics and recorded voice. Volume 2 of the *Thinkin' Things* series contains two sets of music activities, 'Oranga' and 'Tooney' that encourages the child to sequence sounds to create new music. Pattern formations are encouraged and pattern perception is reinforced. The *MiDisaurus* series encourages exploration of many musical elements including rhythm structures and melodies. Both programs use cross-modal exploration with graphics, sound, and movement—something that computers and software can do very well.

Perception

The *Music Ace* series and *Hearing Music* software titles are excellent for student's early development of melodic and harmonic perception. *Music Ace* provides a series of interactive, guided lessons that are consistent with what we know about music perception in the 6–10 age grouping. *Hearing Music* offers a series of game-like exercises that reinforce hearing melodic and rhythmic patterns. The *Sibelius Instruments* program offers excellent support for the development of music timbre. It supports not only timbres for individual instruments but also for ensembles.

Table 19.1 Current music software classified by music content, software type, and age

Software type	Music content	Age level for musical development			
		Pre-school	6–9	10–15	16–Adult
Computer-assisted instruction	Perception		*Musicus* (m/pc) *Hearing Music* (pc) *Music Ace 1, 2* (m/pc) *Sibelius Instruments* (m/pc)	*MusicTheory.net* (I) *MiBAC* *Music Lessons I, II* (m/pc) *Auralia* (m/pc) *Alfred Music Theory* (m/pc)	*Practica Musica* (m/pc)
	Performance	*Thinkin' Things 2* (m/pc) *MiDisaurus, Vols 1–8* (m/pc) *Cloud 9* (m/pc) *New York Philharmonic*(I)	*Early Keyboard Skills* (m/pc) *Singing Coach* (pc)	*eMedia Guitar* (m/pc) *SmartMusic* (m/pc)	
	Preference		*Beethoven Lives Upstairs* (pc)	*Pianist Series* (m/pc) *Oscar Peterson* (pc)	*Carnegie Hall Listening Adventures* (I) *Time Sketch Editor* (m/pc)
	Creating		*Making Music* (m/pc) *Doddle Pad* (m/pc) *Rock Rap'N Roll* (m/pc)	*Berklee Shares* (I) *Making More Music* (m/pc) *Band-in-a-Box* (m/pc)	*Sheddin' the Basics* (m/pc)
Music production	Perception			*Audacity* (m/pc) *Sound Forge* (pc) *Audition* (pc) *Toast (m)*	*Reason* (m/pc) *Reaktor* (m/pc)
	Performance				*Live!* (m/pc) *Max MSP* (m/pc)
	Preference			*iTunes* (m/pc) *RealAudio* (m/pc) *QuickTime Media Player* (m/pc)	
	Creating		*Super Duper Music Looper* (pc)	*Vermont MIDI Project* (I) *GarageBand (m)* *ACID Studio* (pc)	*Finale* (m/pc) *Sibelius* (m/pc) *Logic (m)* *Sonar* (pc)

Notes: a. (m/pc) = Mac and PC, (m) = Mac only, (pc) = PC only, (I) = Internet-based. b. Documentation for each product can be found in Webster Williams (2006), or online at http://www.emtbook.net

Aural skills continue to be reinforced with software such as *MiBAC Music Lessons*, *Auralia*, and *Practica Musica*. Each of these programs stresses more complicated melodic and rhythmic patterns, harmonic content, and music concepts such as cadences. Programs of this sort are appropriate for ages 10 through adult.

Development of music perception, of course, is also supported in music production software that focuses on digital audio. Sound editing programs such as *Audacity* and *Sound Forge* encourage deeper skills of sound manipulation. *Reason* and *Reaktor* are sound sculpting programs that help develop very fine levels of music perception and are appropriate for older students. It is interesting that many of these same titles, including *Audition*, which is an excellent multi-track, digital audio program, might also be considered under the 'Creating' music content area. This suggests a strong link in practice to how advanced perception work is the foundation for creative experiences in musical development.

Performance

Singing Coach is a software program useful for music singing skills. A computer and microphone are used to audit singing in real time, while offering visual feedback about accuracy. The software comes with song literature and additional music can be downloaded from the company's website. A more advanced edition of the software can support newly composed music and standard MIDI files. Such a resource can be a strong support for children learning to sing at both young ages and more advanced stages.

In a similar way, *SmartMusic* provides intelligent accompaniment for instrumental performance. The software can 'follow' the tempo of the performer and can even offer graphic representation of errors. Standard literature is provided with the software or can be created in a custom way. *SmartMusic* can be useful in reinforcing developing music performance skills and can play a dramatic role in the motivation for practice.

Technology can support live performance as well. Programs such as *Live!* And *MaxMSP* offer ways to use the computer and its sound sources as support for live performance. Such technology can assist in developing more sophisticated performance skills in older students and adults.

Music preference and social psychology

In developing preferences for music of various kinds, programs such as *Beethoven Lives Upstairs, Oscar Peterson*, and other multimedia programs can be most helpful. Repeated hearing of the music and learning about the social context of the music are aggressively supported in such software. Tools such as the *Time Sketch Editor* can be used by teachers and students alike to create graphic representations of the form of selected music. Various websites from music ensembles and from places such as Carnegie Hall can add greatly to the developmental growth of children of all ages. It is here that internet-based resources can play a major part in the music preferences of children.

Of course, recent developments in music distribution have created great potential for students to learn about music of all kinds. Internet-based music stores like the Apple Music Store that supports the *iTunes* software and the iPod personal music player are a good example of this. Internet-based playback of music through *RealAudio* and *QuickTime* should also be noted. Such resources can be used wisely by teachers and parents to help broaden and focus music listening and patterns of music preference.

Creating music through improvization and composition

This is perhaps the most powerfully supported of all music content areas. *Making Music* allows young students to draw music shapes that are then turned into music. The shapes can be manipulated much like an adult composer might do by using repetition, augmentation, inversion, and many other ways to alter a gesture. Timbre and dynamics can be changed as well. Shapes can be drawn on top of one another to create simple or very complex textures. In a more advanced version of the software, *Making More Music*, the gestures can be turned into traditional notation. Such software can be used not only to support the imaginative development of children but also for enhancing music perception development.

Traditional music notation and sequencing programs play a part in musical development for the older student. Programs such as *Sibelius* and *Sonar* are excellent for these purposes as students strive for the creation of more sophisticated music.

Other music composition programs built on the current interest in loop-based music offer exciting possibilities for musical development. Such programs as *Super Duper Music Looper, ACID,* and *GarageBand* provide excellent support for students to explore the combination of loops of various timbres and from various genres to create their own compositions. This 'instant' music making needs to be tempered with expert teaching to help challenge students to develop more sensitive and complex ways to think musically. Little is known about how this can be done well or in a way consistent with current theories such as those of Swanwick & Tillman (1986), Hargreaves & Galton (1992), Lamont (1998), or Hickey (2002).

On the improvization side of music making, the *Band-in-a-Box* software can be used effectively to develop skills in improvization consistent with models such as that of Kratus (1996). The software provides an intelligent backup ensemble for improvizations over chord changes that the user provides. Different styles of music are represented and the user has control over tempo. Improvizations can be recorded and changed into notation for study.

Effectiveness of music technology

Just how effective is all of this software on musical development? The evidence to date can best be described as positive but meagre in quantity and quality, especially for young children and adolescents. Higgins (1992) summarized well the classic problems with research on music technology, including poor design, Hawthorne effects, inadequate treatment, and the confounds that the changing nature of technology bring. Berz & Bowman (1994), in their review of experimental work, point to either a neutral or slightly positive overall effect of music technology in increasing learning in music. They do stress the generally positive attitudes of students toward the use of technology in learning. Webster's comprehensive review of the literature (2001) from 1990 to 2000 revealed similar results and stressed the importance of context in understanding research results. He pointed to strong gains in the use of technology for enhancing music performance and noted the need to increase our level of sophistication in evaluating the effectiveness of more exploratory and creative-based software.

Music listening and perception

In terms of music listening and perception, McCord (1993) reported on the effects of computer-assisted instruction on development of music fundamentals understanding in middle school instrumental students. Using an interactive, multimedia program with MIDI support, she found gains in low, middle and high-level music performance groups in the understanding of music fundamentals such as note name identification, key and time signature understanding, and knowledge of symbols and scales.

Goodson (1992) documented the development and trial of an interactive hypermedia program for basic music listening. Her study involved 128 sixth-grade students. Using a four-group comparison model that included groups with no contact, traditional instruction, computer instruction in small groups, and computer instruction with one large group, she found interactive hypermedia instruction required less instructional time in order to achieve equal or higher scores on a 22-item music listening test.

Bush (2000) investigated 84 sixth- and seventh-grade students after individually completing either a 40-minute session with two specially designed multimedia programs or a group expository lesson on the same subject. He was interested in the effect of multimedia software use on cognitive style (field dependence/independence) and on gender in terms of performance on retention of factual information. The subject matter was a lesson on the steel bands of Trinidad. Hypermedia content included text, audio, digital photographs, and movies. The dependent variable was a 20-question, multiple-choice test that was evaluated for validity and reliability. This post-test was given once at the end of the experiment and again after a 6-week time period. Results indicated statistically significant differences with both post-tests for treatment in favour of the control group (expository lecture) and for field independent students. There were no differences for gender. The results for cognitive style, which showed field independent students doing well in both conditions but field dependent doing less well in computer-based group, reinforced past research. The gender result demonstrated that, despite evidence that male/female attitudes may differ for technology, real achievement as measured by the test does not. The result for the main effect of treatment was a surprise in light of other studies on multimedia in music instruction. Bush speculated that the nature of the multiple-choice test might not be a good predictor of what was learned in multimedia work. He also wondered if the expository lecture was better at preparing the students for multiple-choice assessment. Another possibility might be the short time for software use in an unstructured environment has no real effect on factual recall.

In a more qualitative study, Greher (2003) provided evidence that multimedia music used in an inner city, at-risk middle-school population encouraged thoughtful discussion about music outside of the student's experience and highly motivated student discussion and attention. Multiple tracks of audio, video images, and digital movies were combined and students were encouraged to watch and listen, then answer questions before moving on to other music. Opinions were solicited and recorded in a database. There were also possibilities for students to compose their own music to match film clips. Field notes, teacher interview data, and student surveys showed very positive reactions to the music and to the use of the technology.

Taken as a group these studies are representative of what we seem to know from current research about technology and music listening and perception. Certain factual knowledge about music can be effectively taught by computer-based resources, freeing teachers to focus on more complex and meaningful aspects of the art form. Multimedia use can be very effective, especially if designed to encourage personal involvement and higher-level thinking skills. Our ability as researchers to measure the effects of technology's use in music listening and perception remains a problem.

Music performance

The evidence of the role of technology in helping music performance skills develop is growing in both quantity and quality. Orman (1998) reported results of a project to evaluate the effect of a multimedia program on beginning saxophonists' achievement and attitude. Experimental and control groups were formed from sixth-grade students ($n = 44$) in four middle schools. Content was based on a number of topics in beginning saxophone books and verified by experts. She designed her work to support short periods of instruction by having students in the experimental group complete sections of 8–15 minutes with the computer in a nearby room, then return to regular band class. Results on post-tests of both written knowledge and video recorded ability to apply understanding favoured the experimental group significantly. Data also demonstrated strong, positive attitudes for the computer-assisted instruction.

Simpson (1996) investigated pitch accuracy among high school choral students and its possible improvement with technology-assisted visual and aural feedback. The subjects were 69 students in an urban, multi-ethnic high school, divided evenly into three groups. The first group received teacher-guided instruction in a small group in addition to the regular choral rehearsal. The second group received visual/aural feedback on pitch as part of the choral rehearsal. The third group received both the small group instruction and the technology help. Comparison between post-tests demonstrated no significant difference, but the second group, which received just the technology treatment, did improve from post-test scores.

Work with intelligent accompaniment programs continues to be done. Tseng (1996) described its use with flute students using a cross-participant, case study approach. Her results supported the notion that the software helps music learning, intonation, and performance preparation. Ouren (1998) also used this software, but with middle school wind performers. Using pre- and post-interviews and independent assessments of performance achievement, he studied eight students' progress over a 6-week period. No control group was employed. Performance evaluations showed improvement for seven of the eight students, especially in rhythm and interpretation/musicianship. Interview data indicated positive reactions to the technology.

Creating music through improvization and composition

Some of the most extensive and rich work done on computer-based, compositional thinking was reported by Folkstead and his associates (Folkestad *et al.*, 1998). The purpose was to document the process of creation for 129 pieces by 14, 15, and 16 year olds over a 3-year period in Sweden. MIDI files were collected during the process of composition and interviews and observations of participants were recorded. Students with no previous compositional experience worked after school, once a week. Interviews with the students were conducted after the completion of a composition in order to understand how each student worked and what the thought processes were. The interviews were undertaken at the computer workstation (computer with standard sequencing software and keyboard synthesizer) and access to previous versions of the compositions was possible. From the data, a typology for compositional strategies emerged. Two principal types were labelled 'horizontal' and 'vertical.' Horizontal composers worked at the start with a conception of the piece from beginning to end. Further divisions of this approach included how the composer used the keyboard or the computer. Horizontal composers tended to complete one line at a time. Some composers worked exclusively on the computer and others would opt to use an acoustic instrument, such as a guitar, to work out ideas first before entering them into the computer. Vertical composers worked on bits of the whole at a time with one part completed before moving on to the next vertical space. Some vertical composers had an idea of the whole 'orchestra' ahead of time and defined each line of the vertical space from the start. Others worked this out as they composed bits of the work. This research is useful because it resulted in a model that other researchers can use to investigate different aged children, differences caused by past experience, or with different media.

Stauffer (2001) reported work with one child on a limited number of projects and used the *Making Music* software. After describing her role as a consultant in the development of the software, Stauffer described the composition processes of one, 8-year-old child, Meg, as she manipulated the software to compose. The description tells a rich story of how Meg developed a musical style by exploring and developing fluency with sound over time. Different types of exploring and developing are described. In telling the story, Stauffer integrates previous research in composition and creative thinking as examples of Meg's behaviour. A more recent study by Stauffer (2002) also includes case-study data on sixth-grade composers and connections between life experiences and their music. In this study, several computer-based composition programs were used and rich information about cultural context and music was revealed.

Younker (1997) used technology in an imaginative way to offer a platform for composition that allowed for the analysis of thought processes and strategies of different aged children. Nine students, ranging in age from 8 to 14, were asked to compose using a standard software sequencer with a computer and MIDI keyboard much like the one used by Folkestad. Students were asked to think aloud while composing at the computer and respond to questions in an unstructured fashion. Data revealed differences in thought processes and strategies that could serve as the basis for a developmental model.

Lendáyi (1995) used a qualitative case study approach to examine the compositional thought processes of four high school students from a suburban high school. A computer and MIDI keyboard was used, together with a music notation program. Evaluation of both open and close-ended tasks revealed very different compositional styles. One of her major findings was that there may well be four classifications of novice composers at this level: (1) archetypal (possessing the 'gift' of imaginative ideas, but without much experience and knowledge); (2) style emulator (strongly influenced by popular genres with few original ideas of their own); (3) technician (students who seem to concentrate on surface details without connecting to deeper musical meaning); and (4) super composer (students with the 'gift' and with past training and experience to achieve a high level of attainment).

Hickey has completed studies evaluating creative thinking ability. Process and product data were compared from a creative thinking perspective with 21 fourth and fifth grade subjects (Hickey, 1995). MIDI data were unobtrusively captured from a custom program stack that controlled a keyboard synthesizer and was designed to encourage compositional thinking. The program guided the subjects through a variety of possibilities organized around five musical elements: melody, rhythm, texture, timbre, and dynamics. The MIDI data created by the custom program was cleverly collected for both the process and product data analysis. Final compositions were evaluated by a panel of judges using consensual assessment techniques. Compositions rated in the high third and low third were then evaluated descriptively and quantitatively. Hickey used this same custom program to explore two subjects in detail (Hickey, 1997). In this work, she was interested in the subjects' moments of most creative output in relation to a theory of interaction between reward and task conditions. Because the technology records experimentation with musical materials unobtrusively, she was able to capture and compare compositional thinking products when the subjects were exploring and developing ideas (presumably not under pressure for a final, evaluated product) and under more demanding conditions for a final product. She provided background information on both students, placing the resulting data in context. The comparison of musical content under both conditions revealed qualitatively different descriptions, with the less pressured situation resulting in far more creative content based on the established notions of divergence and convergence. The relationships between these conditions of task structure and creative music making await much more systematic work, but the use of technology to reveal these subtleties is worth note.

Daignault (1996) examined children's computer-mediated strategies in relation to craftsmanship and creative thinking. Twenty-five subjects, ranging in age from 10 to 11 were asked to: (1) record three to eight improvizations into a typical sequencer program; (2) select the one they preferred; and (3) develop the selection further using graphic, 'piano-roll' notation. The main data came by observing carefully the development process using a video camera trained on the computer screen. Interestingly this use of a video camera for data collection was greatly improved by Seddon & O'Neill (2000) who reported use of a special video card in a computer that recorded student behaviour directly to video-tape. Using techniques similar to Hickey, Daignault asked judges to assess consensually the final developed compositions for craftsmanship and creativity and the top and bottom rated compositions served as an indicator of which process data to evaluate carefully. Analyses of process data for high and low craftsmanship and creativity lead to conclusions about compositional thinking.

The future

Advances in the science of how people learn have influenced teaching and are worth mentioning here because of the potential intersection with the advancements in music technology. A 2-year study by 16 individuals on the 'Committee on Developments in the Science of Learning' resulted in a text[4] that compiles the latest research about how people learn and the best way to teach and create learning environments based on these findings (Brandsford *et al.*, 1999). They conclude that most effective learning takes place in constructive, learning-centred environments where children learn by doing and by replicating, as best as possible, 'real-world' learning problems: 'Because many new technologies are interactive, it is now easier to create environments in which students can learn by doing, receive feedback, and continually refine their understanding and build new knowledge. . . . The new technologies can also help people visualize difficult-to-understand concepts.' (pp. 206–207).

While the thrust of these findings relate to learning in science and math, many of the conclusions are as appropriate and important for learning in music. Technology provides for constructive learning instances: students find problems to solve and can work these out in creative ways through new technologies such as music notation, sequencing, and CAI programs. Technology brings 'real-world' experience into the classroom. Students hear sounds that are real, can manipulate sound and obtain immediate feedback. Technology is also creating a new literacy that children may grasp quicker than (and in spite of) their music teachers (Hickey, 2004).

Perhaps the most exciting potential for technology relates to the topic of this chapter: the intersection of music technology tools, games, and software with musical development. The newest software presents new windows into the musical actions of children because it offers constructive, learning-centred environments where children *are* learning by doing. What if researchers *observed* or experimented with children using the software, for instance, listed in Table 19.1, to learn more about the developmental aspects of preference, performance, perception, and creating. How a 6-year-old child interacts and learns with Subotnik's colourful CAI program *Hearing Music,* may inform us more about musical development than we've ever known. The choices adolescents make to create music in *GarageBand* may provide researchers with answers concerning the musical preferences, learning style, and developmental peaks that have not yet been revealed in research to date. It is also conceivable that not only will new technology and software enhance our understanding of children's musical development, but it may also *advance* the development process of musical learning and understanding in those that use it.

Folkestad *et al.* (1998), Savage (2005), and many others whose work is summarized in the previous section are examples of researchers who have used technology to gather powerful information about the musical understandings (and hence, potential developmental information) of adolescent musicians. However, the connection between music technology and our understanding of musical development in children has yet to be fully bridged. More research must be done in this area: observing and experimenting with children as they work in the music technology environments such as those provided in the most popular and recent software (see Table 19.1). The potential for major advances in our knowledge of musical development is very great indeed.

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[4] The full text is also available as a website at: http://books.nap.edu/html/howpeople1

References

Bamberger, J. (1991). *The mind behind the musical ear: How children develop musical intelligence.* Cambridge, MA: Harvard University Press.

Barry, N. & Hallam, S. (2002). Practice. In R. Parncutt & G. E. McPherson (eds), *The science and psychology of music performance: Creative strategies for teaching and learning* (pp. 151–166). New York: Oxford University Press.

Berliner, P. (1994). *Thinking in jazz.* Chicago, IL: University of Chicago Press.

Berz, W. L. & Bowman, J. (1994). *Applications of research in music technology.* Reston, VA: Music Educators National Conference.

Brandsford, J., Brown, A. L., & Cocking, R. R. (eds) (1999). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academies Press.

Bush, J. E. (2000). The effects of a hypermedia program, cognitive style, and gender on middle school students' music achievement. *Contributions to Music Education*, **27**, 9–26.

Daignault, L. (1996). *Children's creative musical thinking within the context of a computer-supported improvisational approach to composition.* (Doctor of Philosophy, Northwestern University). *Dissertation Abstracts International.* 57/11-A, 4681. (University Microfilms No. 9714572).

Deliege, I. & Sloboda, J. (eds) (1996). *Musical beginnings: Origins and development of musical competence.* New York: Oxford University Press.

Dowling, J. (1988). Tonal structure and children's early learning of music. In J. Sloboda (ed.), *Generative processes in music: The psychology of performance, improvisation, and composition* (pp. 113–128). New York: Oxford University Press.

Dowling, J. (1999). The development of music perception and cognition. In D. Deutsch (ed.), *The psychology of music* (pp. 603–625). San Diego, CA: Academic Press.

Folkestad, G., Hargreaves, D. J., & Lindström, B. (1998). Compositional strategies in computer-based music-making. *British Journal of Music Education*, **15**, 83–97.

Flohr, J. (1984). *Young children's improvisations: A longitudinal study.* Paper presented at the Music Educators National In-Service Conference (49th, Chicago, IL, March 23, 1984)

Gembris, H. (2002). The development of musical abilities. In R. Colwell & C. Richardson (eds), *The new handbook of research on music teaching and learning* (pp. 487–508). New York: Oxford.

Goodson, C. A. (1992). *Intelligent music listening: An interactive hypermedia program for basic music listening skills.* Doctor of Philosophy, The University of Utah.) *Dissertations Abstracts International*, 53/11-A, 3837. (University Microfilms No. 9307303).

Greher, G. R. (2003). Multimedia in the classroom: Tapping into an adolescent's cultural literacy. *Journal of Technology in Music Learning*, **2**(2), 21–43.

Green, L. (2001). *How popular musicians learn: A way ahead for music education.* Burlington, VA: Ashgate Publishing.

Gromko, J. E. (1994). Children's invented notations as measures of musical understanding. *Psychology of Music*, **22**(2), 136–147.

Gruhn, W. & Rauscher, F. (2002). The neurobiology of music cognition and learning. In R. Colwell & C. Richardson (eds), *The new handbook of research on music teaching and learning* (pp. 445–460). New York: Oxford University Press.

Hair, H. I. (1977). Discrimination of tonal direction on verbal and nonverbal tasks by first-grade children. *Journal of Research in Music Education*, **25**(3), 197–210.

Hargreaves, D. J. (1986). *The developmental psychology of music.* New York: Cambridge University Press.

Hargreaves, D. J. (1996). The development of artistic and musical development. In I. Deliege & J. A. Sloboda (eds), *Musical beginnings: Origins and development of musical competence* (pp. 145–170). Oxford: Oxford University Press.

Hargreaves, D. J. & Galton, M. J. (1992). Aesthetic learning: psychological theory and educational practice. In B. Reimer & R. A. Smith (eds), *The arts, education, and aesthetic knowing* (pp. 124–150). Chicago: National Society for the Study of Education; distributed by University of Chicago Press.

Hargreaves, D. J. & North, A. C. (1999). Developing concepts of musical style. *Musicae scientiae: Journal of the European Society for the Cognitive Sciences of Music*, **3**(2), 193–216.

Hargreaves, D. J. & North, A. C. (2001). Complexity, prototypicality, familiarity, and the perception of musical quality. *Psychomusicology*, **17**(1–2), 77–80.

Haston, W. (2004). *Comparison of a visual and an aural approach to beginning wind instrument instruction.* (Doctor of Philosophy, Northwestern University). *Dissertation Abstracts International*, 65/05-A, 1711. (University Microfilms No. 3132535).

Hickey, M. (1995). *Qualitative and quantitative relationships between children's creative musical thinking processes and products.* (Doctor of Philosophy, Northwestern University). Dissertations Abstracts International. 57/01-A, 145. (University Microfilms No. 9614754).

Hickey, M. (1997). The computer as a tool in creative music making. *Research Studies in Music Education*, **8**(July), 56–70.

Hickey, M. (2002). Creative thinking in the context of music composition. In M. Hickey (ed.), *Why and how to teach music composition: A new horizon for music education* (pp. 31–54). Reston, VA: MENC.

Hickey, M. (2004). Music technology in schools—the 'Garage bands' of the future? *Triad*, **71**(4), 27–19.

Higgins, W. (1992). Technology. In R. Colwell (ed.), *Handbook of research on music teaching and learning* (pp. 480–497). New York: Schirmer Books.

Kastner, M. P. & Crowder, R. G. (1990). Perception of the major/minor distinction. IV: Emotional connotation in young children. *Music perception: An interdisciplinary journal*, **8**(2), 189–201

Kratus, J. (1996). A developmental approach to teaching music improvisation. *International Journal of Music Education*, **26**, 27–37.

Lamont, A. (1998). Music, education, and the development of pitch perception: The role of context, age and musical experience. *Psychology of Music*, **26**, 7–25.

Lamont, A. & Cross, I. (1994). Children's cognitive representations of musical pitch. *Music Perception*, **12**, 27–55.

LeBlanc, A. (1991). Some unanswered questions in music preference research. *Contributions to Music Education*, **18**, 66–73.

Lendáyi, K. (1995). *Processes of musical composition facilitated by digital music equipment.* (Doctor of Philosophy, University of Illiois at Urbana-Champaign.) *Dissertation Abstracts International.* 56/09-A, 3494. (University Microfilms No. 9543638).

McCord, K. (1993). Teaching music fundamentals through technology in middle school music classes. In K. Walls (ed.), *Third international conference on technological directions in music education* (pp. 68–71). San Antonio, TX: IMR Press.

McDonald, D. T. & Simons, G. M. (1989). *Musical growth and development: Birth through six.* New York: Schirmer Books.

McPherson, G. E. (1993). Factors and abilities influencing the development of visual, aural and creative performance skills in music and their educational implications (Doctor of Philosophy, University of Sydney (Australia)). *Dissertation Abstracts International*, 54/04-A, 1277. (University Microfilms No. 9317278).

McPherson, G. E. & Dunbar-Hall (2001). Australia. In D. J. Hargreaves & A. C. North (eds), *Musical development and learning: The international perspective* (pp. 14–26). New York: Continuum.

McPherson, G. E. & Gabrielsson, A. (2002). From sound to sign. In R. Parncutt & G. E. McPherson (eds), *The science and psychology of music performance: Creative strategies for teaching and learning* (pp. 99–116). New York: Oxford University Press.

McPherson, G. E., Bailey, M., & Sinclair, K. E. (1997). Path analysis of a theoretical model to describe the relationship among five types of musical performance. *Journal of Research in Music Education*, **45**, 103–112.

Meltzoff, A. N., Kuhl, P., & Moore, M. K. (1991). Perception, represenation, and the control of action in newborn and young infants towards a new synthesis. In M. J. S. Weiss & P. R. Zelazo (eds), *Newborn attention: Biological constraints and the influence of experience* (pp. 377–411). Norwood, NJ: Ablex.

Moog, H. (1976). The development of musical abilities in the first years of life. *Psychology of Music*, **1**, 14–20.

Moorhead, G. E. & Pond, D. (1978). *Music of young children.* Santa Barbara, CA: Pillsbury Foundation.

North, A. C. & Hargreaves, D. J. (1999). Music and adolescent identity. *Music Education Research*, **1**, 75–92.

Orman, E. K. (1998). Effect of interactive multimedia computing on young saxophonists' achievement. *Journal of Research in Music Education*, **46**, 62–74.

Ouren, R. W. (1998). *The influence of the* Vivace *accompaniment technology on selected middle school instrumental students.* (Doctor of Philosophy, University of Minnesota). *Dissertation Abstracts International*, 58/07-A, 2456. (University Microfilms No. 9738468).

Palmer, C. & Krumhansl, C. (1987). Independent temporal and pitch structures in determination of musical phrase. *Journal of Experimental Psychology: Human Perception and Performance*, **13**, 116–126.

Pflederer, M. & Sechrest, L. (1968). Conversation-type responses of children to musical stimuli. *Council for Research in Music Education*, **13**, 19–36.

Pressing, J. (1988). Improvisation: methods and models. In J. Sloboda (ed.), *Generative processes in music: The psychology of performance, improvisation and composition* (pp. 129–178). New York: Oxford University Press.

Savage, J. (2005). Sound2Picture: *Developing compositional pedagogies from the sound designer's world.* Proceedings of the Fourth International Research in Music Education Conference (RIME) (pp. 182–185). Exeter, UK: University of Exeter, April, 2005.

Schellberg, G. (1998). *Zur entwicklung der klangfarben-wahrnehmung von vorschulkindern.* Münster, Germany: Lit Verlag.

Seddon, F. & O'Neill, S. (2000). Influence of formal instrumental music tuition (FIMT) on adolescent self-confidence and engagement in computer-based composition. In C. Woods, G. Luck, R. Brochard, F. Seddon, & J. Sloboda (eds), *Sixth International Conference on Music Perception and Cognition* (CD-ROM). Keele, UK: Keele University.

Serafine, M. L. (1988). *Music as cognition: The development of thought in sound.* New York: Columbia University Press.

Simpson, E. H. (1996). *The effects of technology-assisted visual/aural feedbgack upon pitch accuracy of senior high school choral singing.* (Doctor of Musical Arts, University of Hartford.) *Dissertation Abstracts International*, 57/03-A, 1070. (University Microfilms No. 9622215).

Sloboda, J. (1985). *The musical mind: The cognitive psychology of music.* New York: Oxford University Press.

Smith, K. C. & Cuddy, L. L. (1989). Effects of metric and harmonic rhythm on the detection of pitch alterations in melodic sequences.*Journal of Experimental Psychology: Human Perception and Performance*, **15**(3), 457–471.

Smith, K. C., Cuddy, L. L., & Upitis, R. (1994). Figural and metric understanding of rhythm. *Psychology of Music*, **22**, 117–135.

Stauffer, S. L. (2001). Composing with computers: Meg makes music. *Council for Research in Music Education*, **150**, 1–20.

Stauffer, S. L. (2002). Connections between the musical and life experiences of young composers and their compositions. *Journal of Research in Music Education.* **50**(4), 301–322.

Swanwick, K. & Tillman, J. (1986). The sequence of musical development: A study of children's compositions. *British Journal of Music Education*, **3**(3), 305–339.

Swanwick, K., Hallam, S., Lamont, A., O'Neill, S., Green, L., Cox, G., Hennessy, S., Farrell, G., & Welch, G., (2004). Mapping music education research in the UK. *Psychology of Music*, **32**(3), 239–290.

Tarrant, M., North, A. C., & Hargreaves, D. J. (2002). Youth identity and music. In R. MacDonald, D. J. Hargreaves, & D. Meill (eds), *Musical identities* (pp. 134–150). New York: Oxford University Press.

Trainor, L. J. & Trehub, S. E. (1992). The development of referential meaning in music. *Music Perception*, **9**(4), 455–470.

Trehub, S. E., Hill, D. S., & Kamenetsky, S. B. (1997). Parents' sung performances for infants. *Canadian Journal of Educational Psychology*, **51**(4), 385–396.

Tseng, S. (1996). *Solo accompaniments in instrumental music education: The impact of the computer-controlled* Vivace *on flute student practice.* (Doctor of Philosophy, University of Illinois at Urbana-Champaign.) *Dissertation Abstracts International*, 57/04-A, 1536. (University Microfilms No. 9625203).

Upitis, R. (1987). Children's understanding of rhythm: the relationship between development and music training. *Psychomusicology*, **8**, 141–160.

Webster, P. (2001). Computer-based technology and music teaching and learning. In R. Colwell & C. Richardson (eds), *The new handbook of research on music teaching and learning* (pp. 416–439). New York: Oxford.

Webster, P. (2002). Creative thinking in music: advancing a model. In T. Sullivan & L. Willingham (eds), *Creativity and music education* (pp. 16–33). Edmonton: Canadian Music Educator's Association.

Webster, P. & Schlentrich, K. (1983). Discrimination of pitch direction by preschool children with verbal and nonverbal tasks. *Journal of Research in Music Education*, **30**, 151–161.

Wiggins, J. (2002). Creative process as meaningful musical thinking. In T. Sullivan & L. Willingham (eds), *Creativity and music education* (pp. 78–88). Edmonton AB: Canadian Music Educators' Association.

Williams, D. B. & Webster, P. R. (2006). *Experiencing music technology* (3rd edn). Belmont, CA: Thomson Higher Education.

Younker, B. (1997). *Thought processes and strategies of eight, eleven, and fourteen year old students while engaged in music composition.* (Doctor of Philosophy, Northwestern University.) *Dissertation Abstracts International*, 58/11-A, 4217. (University Microfilms No. 9814345).

Zenatti, A. (1993). Children's musical cognition and taste. In T. J. Tighe & W. J. Dowling (eds), *Psychology and music: The understanding of melody and rhythm* (pp. 177–196). Hillsdale, NJ: Erlbaum.