CHAPTER 26

FRAMING LEARNING PERSPECTIVES IN COMPUTER MUSIC EDUCATION

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Music can be said to be a construction of the human imagination and the creative processes of the composer, the performer, and the listener. Crafting, interpreting, and appreciating a work all require recognition, reflection, and a personal resonance in response to the sounding material or the ideas embedded in it. From this perspective, teaching music becomes a complex issue. This is particularly the case for teaching computer music, which, in addition to training students and developing their knowledge of musical form and how it is crafted, often entails engaging students at the conceptual level in reflecting on what *counts* as music.

Yet, as with any music field or genre, education in computer music is essentially focused on advancing knowledge and an acceptance of some core disciplinary concepts and values. As with other genres, computer music education needs to be designed for different developmental levels and curricular plans, taking into account the institutional and social aspects of formal and informal learning contexts. However, the strong technical tool focus in computer music also has the potential to build on and extend students' everyday experimentation with new technologies and musical encounters in ways that are meaningful and relevant to them. We propose in this chapter that such an understanding is key to the teaching and learning of computer music and will advance its potential as a disciplinary field in the future. This is because computer music is related to all kinds of digital literacies and media consumption prevalent today. We seek a broader integration of computer music in educational contexts, and we investigate means of making computer music relevant as a discipline by drawing more directly on young people's increasingly complex digital literacies related to music.

The overall focus of this chapter is a discussion of approaches to learning and teaching computer music, with a particular focus on pedagogical design and the use of learning technologies among nonspecialists and young people in secondary and upper secondary school levels. The discussion is organized in three parts. It begins with a framing of computer music as a discipline taught at secondary and upper secondary levels and provides an overview of its core areas or knowledge domains. These are described as (1) listening, (2) physics, (3) signal processing, and (4) musical form. These core areas are understood as relevant to learning contexts within but also outside formalized educational settings. The second part of this chapter discusses learning perspectives and presents a frame for conceptualizing learning with digital technologies. In the third part, we discuss recent approaches to designing and implementing computer music technologies, with a particular focus on DSP, an online learning platform designed by NOTAM (Norwegian Network for Technology, Acoustics, and Music) that adopts an exploratory instructional approach to computer music. The technology design and pedagogical approach have been further developed through several years of work with DSP in workshops for upper secondary school students in Norway.

1. Framing Computer Music as a Discipline

Computers are by far the most common tools in any music production today; as a result, there is a huge variation in what is called *computer music*. As the term has become more imprecise, different approaches have recently been suggested to define computer music as a genre. Natasha Barrett, for example, described computer music as "including all that is not purely acoustic music, based on instrumental models, nor overtly commercially oriented" (2007, p. 232). Other researchers proposed analyzing technology-based sonic expressions and arriving at a taxonomy of computer music that is based on descriptions of the aesthetic characteristics. This has been discussed as a possible approach by Landy (2007), for example, as a means of addressing the wide distribution of technological tools and signal-processing methods that have emerged over the past ten to fifteen years through commercialization, among other trends.

Highly advanced tools are available at low cost, and electronic sounds and more comprehensive abstract sonic expressions crafted with electroacoustic methods are commonplace, found in all rich media environments. Broad access to advanced tools bypasses the traditional limitations of access that are based on economy and education, and in this sense the playing field has become more even—one can talk about a real democratization. Briefly summarized, the long trend that we see emerging from the use of commercial and social technologies on the Internet is the sustainability of niche cultures that are less dependent on the retail industry, publishing houses, and record companies. This is because of the inexpensive distribution means and the ease of network-building that is possible over the Internet. Niches have their roots in small interest groups and subcultures, and the low cost of making music available through the Internet has had the effect of making these niche expressions commercially interesting. In fact, the economic yield for large Internet retailers of music and books shows that the sum generated by very small titles amounts to nearly the same as what is generated by the "blockbuster industry" (Anderson 2006). This is due in part to the increased availability and visibility of niche products during recent years, encouraged by the tremendous growth in social networking technologies on the Internet, such as blogs and wikis. Such social software makes self-publishing of user-generated content and file distribution quite easy, with niche products marketed through social networks that largely bypass such traditional gatekeepers of content and economy as record companies and publishing houses.

Together, the possibility for self-publication and a market presence has facilitated flourishing of electroacoustic art outside traditional education institutions and mediation channels. However, the democratization process briefly outlined is nonetheless largely driven by commercialization and the commercial drive for globalization, supported by the Internet. This emphasis on commercialization means that recent advances in research and engineering are not fully exploited in the music market as a whole, with the result that quite similar types of tools now dominate entry level music production nearly everywhere. Although this near uniformity may foster a general digital literacy in music production, there are also creative consequences, bringing about aesthetic changes and a refocusing of the field that is much more oriented toward popular music.

While such shifts do not reduce the value of the cultural heritage found in the electroacoustic tradition of computer music, they are nonetheless significant in terms of a convergence of tools and methods between art genres. Furthermore, this convergence has pedagogical implications as the expansion of computer music techniques and signal-processing methods into popular music genres and aesthetics has increasingly become part of students' digital literacy (Tyner 1998, Brown 2007), or rather "multiple literacies" (Gee 1990, Group 1996, Roth 2006). In other words, computer music as a discipline taps into the multiple literacies that students develop in convergences among signal-processing techniques, online and off-line social networks, niche music markets and interests, multimedia mixing tools, and popular music aesthetics. The concept of multiple literacies thus extends beyond reading, writing, and digital skills taught in formal school settings. Instead, multiple literacies is a term describing actions and emergent forms of knowledge as people are apprenticed into (digital) practices as part of a social group (Gee 1990). In the following, we describe some of core areas in computer music that transverse and intersect with such everyday multiple literacies, and we reflect on how these knowledge domains may be incorporated in pedagogical designs.

2. Core Areas in Computer Music

The goal of any musical training is to strengthen musical skills among the students. Students should develop language to describe and discuss music, they should recognize and identify formal qualities, and at best they should also be able to create musical value through personal expression and crafting of musical form. To reach these goals successfully in computer music, students need skills in understanding musical structure, practical knowledge about software and hardware tools, and familiarity with production aspects of computer music composition. Since composing computer music most often involves direct aural feedback to the composer in the process, the students also need listening skills beyond normal identification of pitch, tone, and interval and a consciousness of the importance of spatial distribution and development of musical material. Basic knowledge in acoustics and about the physical properties of sound is also beneficial. As a means of further articulating the disciplinary content of computer music as a secondary and upper secondary school subject, we identify the following four knowledge domains or core areas: listening, physics and psychophysics, signal processing, and musical form.

A. Listening

Computer music is real time in the sense that the composer gets near-immediate-sounding results when working with software and hardware. This sets it apart from working with notated music of the more traditional kind, which generally requires the composer to wait to hear the work until rehearsals start for the premiere. This technological aspect of composing computer music, combined with the normal use of material without pitch—recorded or synthesized—brings listening into the composition process at an early stage. Listening is a precondition for the entire process, and the use of abstract material immediately actuates questions about what the sounds are, what we are listening to, and what the meaning is.

The traditional way of listening to computer and electronic music has its roots in Pierre Schaeffer's (1966) late ideas of reduced listening to sounds only as they appear, isolated from their source, and considered only by their emergent qualities. Following Schaeffer, Denis Smalley (1986) developed a large taxonomy for categorizing sounds based on their spectral development and movement. Another listening approach was developed by Simon Emmerson (1986), who distinguished between abstract and abstracted syntax, aural and mimetic discourse. Emmerson opened for contextual listening, allowing the sounds' origins to be considered significant for reflection on the music. This focus on contextual listening was emphasized further by Murray Schafer (1977) and others in the genre *soundscape composition*, for which the founding idea is that any environment exposes itself through sound and can be presented through careful selection and recomposition of recorded material. These mentioned perspectives are complemented by the term *imaginary listening* (d'Escrivan 2007), which describes how sound in film, for example, is used to reveal events that are happening off screen or recorded sounds are treated to add drama to other objects and events than their source.

Common to all these perspectives is the focus on listening as a process and on the construction of meaning as a process that all participants in a musical experience share, including the composer, the performer, and the listener. Hearing thus becomes an acoustical phenomenon, while listening is an action (Barthes 1991). Careful listening reveals that silence does not exist, and that attention to sound, in an ecological perspective, makes us aware of crucial characteristics of our situation, in art or outside, personal and social. John Cage described the sounds in the world as musical, and in an interview, sound artist Bill Fontana stated: "From a musical point of view, the world is musical at any given moment" (Rudi 2005, p. 97). In Fontana's works, microphone placement translates to listening perspective, and he uses the recording equipment to focus and select some perspectives over others. We can say that use of technology changes the way we listen, and as such, we listen to mediated versions of someone else's intentionality.

The listening experience gets better with training, and the more experienced a listener is, the richer the experience. There is a body of research suggesting that as a listener's experience grows, the focus shifts from sound and source identification to pattern recognition and logic. Given that the types of listening described involve so much more than the focus on pitch, interval, and harmony that dominates most music education, listening literacies receive particular attention in computer music as a knowledge domain.

B. Physics and Psychophysics

Sound has physical properties, and the science of acoustics describes sound and sound propagation in space and through different materials. Issues such as absorption, reflection, and resonance are important in understanding the characteristics of signals as they fill, and move in, our surroundings. Further, knowledge of how sound can be analyzed and represented belongs to the discipline of computer music and is the basis for digital-recording techniques and signal processing. Different types of signal representation allow for different types of processing and in turn influence the construction of user interfaces, especially graphical interfaces for screen, but also physical interfaces for control and performance.

We often experience meaning as immediately embedded in sounds, as we recognize them, their presumed source, and their place and movement around us. These immediate interpretations go beyond our objective, acoustic reality, and form important parts of the specifically human species response and adaptation to acoustic nature and culture, or what is called *psychoacoustics*. This discipline includes issues of sound separation and interpretation of simple and complex, similar-sounding, and simultaneous audio streams and investigates our ability to recognize sounds and their placement. Our auditory system gives preference to certain types of signals and can thus be said to amplify some at the cost of others. In more specific musical contexts, there are issues of sound, melody, and music recognition when tone quality, pitch, masking, and time differences vary. Timbral matching allows us to "name that tune in no notes." Bregman (1990) collapsed these topics into what he called "auditory scene analysis." In education, this core area in computer music can provide critical awareness, reflection, and sensitivity to relationships among physics, acoustics, and the meaning of sounds in our natural and cultural environment.

C. Signal Processing

Recording, synthesizing, changing, and combining sounds in the digital domain are types of signal processing; the computer develops the sound in one way or another. Teaching computer music must therefore include information about how a computer works with sound and give some insight into the many synthesis and signal-processing types that are commonly employed. Directly linking knowledge of sound and how it can be taken apart, processed, and reconstructed using different signal-processing methods is essential to this core area. Explicitly linking the physical properties of sound with its numerical representation is also a means of conveying how creative ideas can be presented in different ways, for example, as expressions in mathematics and physics. This cross-disciplinary knowledge is at the core of old school computer music and expresses the principles of signal processing as a core area.

D. Musical Form

A central feature in most music education is to support students' appreciation of different types of music and their recognition and familiarity with the formal characteristics of different kinds of expressions. The underlying pedagogical aim is to expand the student's ability to find music in all acoustic art, to develop their skills in listening and analysis, and perhaps also to enable them to better enjoy musical styles with which they are less familiar.

In comparison to music that is built on instrumental models, computer music poses a challenge to students in that there is little focus on pitch structures, melodic material, or rhythm. The basic building blocks most listeners are used to are essentially missing, including recognizable genres. Pitch-based music dominates our hemisphere, to the point at which the representation of the music as notes is often described as the music itself. Edgard Varèse coined the description of music as "organized sound," and in computer music, this focus on timbral development as essential in composition is sustained. However, musical forms and their organization may be more difficult to comprehend and recognize on a concrete level because the forms are often inspired by the sounds themselves. The spatial distribution and performance of the elements is often a crucial component of computer music works and represent another departure from the more familiar pitch-space.

Once students begin to hear electronic sounds as musical, there is the hurdle of shaping credible forms, which demands a new level of abstraction. Musical forms take on different sizes and appear on many levels, in dominating or supporting roles, and structural terms such as foreground/background and micro-/meso-/macrolevels may be used to articulate compositional features (Roads 2001). In computer music, musical forms are often constructed in unconventional ways, from features and principles extracted from the sounds themselves or developed by algorithmic means. Both of these approaches differ from most methods based in tonal or rhythmic ideas.

Media today are filled with computer-processed material, and people are familiar with electronic sound quality and the abstract and abstracted discourse the material contains. In other words, this is part of an everyday digital literacy, not framed as a specific musical competence. Relating understandings of computer sounds to compositional forms in computer music involves resonance and recognition and depends on "something to hold on to" (Landy 1994). To meet this challenge of relating everyday knowledge of electronic sounds to musical form in computer music, a fundamentally broadened aesthetic understanding and discourse is needed.

3. Computer Music across Disciplines

Music education at secondary and upper secondary levels is typically not a significant part of a school's curriculum, and work with music technology may constitute a brief part of a semester, if it is made available at all. This negligence reflects the precarious and peripheral role of the arts in education in general, a situation worsened by the relatively limited empirical research on the arts compared, for example, to science education in schools.

Such limitations pose a real challenge for computer music since the field, as we have seen, is quite comprehensive, focusing on composition and technology with underpinnings in acoustics, psychoacoustics, recording, synthesis, and signal processing. A natural ambition for computer music educators is to increase musical work with technology by integrating and relating this work across knowledge domains and other school subjects. Computer music is relevant to the study of music history, for example, as its aesthetics are best understood as springing from the Western art music tradition and from the desire to break away from some of its conventions. Digital representation of music's physical properties also allows for interesting tasks in mathematics and physics classes, especially if clear links to the perception and understanding of musical properties can be maintained. Music has wittingly been described as a special instance of applied physics, reducing music to the physical properties of sound only and thus actuating the question of musical representation. These are two instances in which computer music and electro-acoustic techniques can serve as point of departure for a cross-disciplinary revitalization and competence building in art education, particularly in light of the large convergence in media technology.

The significance of music and arts education for human development raised by John Dewey in the early part of the 20th century is a large and ongoing discussion that exceeds the scope of this chapter. In cognitive psychology, for example, arguments are made for the transfer of conceptual development across subjects based on studies of music lessons for IQ enhancement (Schellenberg 2004) or of aesthetic understanding for critical thinking (Housen 2001–2002). Often, assessment issues raised by such studies are framed by interests at the policy level and by the need for empirical studies that demonstrate a causal relationship to students' achievement (Gadsden 2008). In this chapter, we point to the need for research that is framed more broadly, addressing social as well as cognitive dimensions and questions of how learning and teaching in the arts, like other subjects, are linked to issues of identity, multiple literacies, life experiences, and contexts outside formalized educational settings.[1]

4. Learning Perspectives and Computer Music

Perspectives on learning in computer music are largely undeveloped, and there is a strong need for empirical research of pedagogical approaches to the discipline. A recent contribution to the field was provided by Brown (2007), who addressed the use of computers in music education in general, pointing to their potential in four main areas: music production, presentation, reflection, and implementation. Brown adopted a constructivist perspective on learning, a broad term that draws mainly on the thinking of Jean Piaget, Dewey, and Jerome Bruner and emphasizes the active role of the individual learner in constructing knowledge through experience, inquiry, and discovery. Another constructivist position that has been significant for education in the arts is Howard Gardner's (1984) theory of multiple intelligences, with musical intelligence identified as one of seven types. Gardner's view has been popular for contributing to awareness of the richness and complexity of human cognition and represents in this sense a continuation of Dewey's (1934) views on aesthetic knowing, which emphasizes the development of individual perceptual processes and cognitive faculties through immediate, somatic experience (Shusterman 2000, Pierroux, 2003).

This emphasis on identifying learning with individual cognition and the development of mental schemata is what most clearly distinguishes constructivism from sociocultural perspectives, which focus on the development of cognition through human activity in a system of social relations and cultural tools. Based on the work of Russian psychologist Lev Vygotsky (1978, 1986), and developed over recent generations, sociocultural perspectives adopt the position that "mind is no longer to be located entirely inside the head; higher psychological function are transactions that include the biologically individual, the cultural mediational artifacts, and the culturally structured social and natural environments of which persons are a part" (Cole and Wertsch 1996, p. 253).

Such an understanding of the significance of human activity, cultural tools, and social context for learning has implications for understandings of what computer music is, for pedagogical approaches to computer music in schools, and for the design of learning technologies for computer music. This broader understanding of human development is needed for framing approaches to teaching computer music since, as mentioned, the core areas comprising the knowledge domain are closely linked to ongoing changes in social practices and multiple literacies outside formal school settings. In education research, for example, ethnographic methods are useful in analytical accounts of the mediating role of social interaction, the situated context, and the institutional setting in learning processes (Rasmussen et al. 2003, Roth 2006, Pierroux forthcoming). In other words, as mentioned, an articulated learning perspective and empirical studies are needed that will make apparent connections between literacies in musical form, acoustics, signal processing, and listening to integrate computer music better in different educational settings.

5. Design Approaches to Learning Technologies

Computers have been used in different ways to create environments for learning for the past twenty years. Current developments in learning systems may be grouped in terms of supporting students' activities through investigative elements (inquiry or discovery learning), play (gaming), production (modeling, composition, wikis), and collaboration (synchronous and asynchronous systems). In environments designed for inquiry in science learning, for example, investigative elements include simulating and modeling aspects of natural phenomena, tools for analyzing or visualizing data, and ways of modeling learners' theories and hypotheses to study the consequences (van Joolingen et al. 2007).

Brown (2007) likewise distinguished between different learning technologies and e-learning according to types of interaction or educational support that they provide. Technologies designed specifically for educational purposes are characterized as interactive software, asynchronous communication, asynchronous collaboration, synchronous collaboration, and Web content creation. However, rather than defining the learning by the technology, we suggest that a more useful approach may be to conceptualize these as features or components that may be integrated into environments according to an overall pedagogical design intent.

While design approaches may vary, there is generally a pedagogical aim to change and improve students' conceptual understanding of disciplinary issues related to specific knowledge domains (Krange and Ludvigsen 2008). In computer music, these domains have been described here as listening, physics, signal processing, and musical form. However, in addition to disciplinary knowledge, there is a creative and productive aspect to learning in the arts that brings gaming, experimenting, and discovery to the foreground in learning technologies designed for music education, particularly computer music. Instructional approaches that prioritize modeling and procedural knowledge may be unable to support learners in their creative and experimental work with sound and musical forms and in then relating these to core disciplinary concepts. This is because guided instructional design often solely entails a set of "forced" or "obligatory" sequence of steps or problems that must be solved before learners are allowed to move on to the next task (Pickering 1995). IRCAM's (Institut de Recherche et Coordination Acoustique/Musique's) software 10 Jeux d'ecoute (2000) is an example of an instructional perspective that emphasizes the use of forced moves, structured around computer music' core areas and taking students through ten fixed audio games.

In contrast, as discussed in greater detail in the following section, environments designed with a more experimental approach combine forced moves that support discovery and inquiry learning through investigative elements but also emphasize direct engagement by integrating game features or composition tools with more "open" or "optional" moves. As Smith and Dean (2002) pointed out, a nonlinear interaction with information is often desirable when encouraging learners to generate new ideas and interpretations in educational contexts. Thus, a balance between forced and open moves in design also represents an epistemological stance and is at the crux of designing "technological" learning scaffolds.

Although there is a relatively long history of digital learning environments and research on effectiveness and efficiency, findings from evaluation and analysis of their use suggest some recurring issues. First, there is a problem in designing for the complexity of social interaction and actual use in different settings, which tend to have a significant impact on how the learning technologies are taken up by students. Chief among the concerns here is the role of the teacher, or more capable peer, whose guidance is key to learning. The second finding that runs through much of the research relates to the tension mentioned between guided instruction, which provides information and fully explains the concepts that students are expected to learn in a procedural, task-solving approach, and "minimal guidance" designs that engage and support learners in abstract, conceptual thinking by drawing on their unique prior experience as they collaboratively and experimentally construct knowledge and solve tasks (Kirschner et al. 2006). Issues here revolve around the level and types of guidance, the complexity of the task, the types of representations used, and the use of modeling versus experimental activities. The general concern is that if the task and the information to which inexperienced or less-able learners need to relate to solve the problem are too complex and there is only a minimum of guidance, then the "problem-solving" activity will hinder abstract and conceptual thinking related to the knowledge domain. Approaches to these challenges are discussed next in relation to learning in computer music.

6. Some Examples of Music Software as Learning Tools

In addition to a small number of learning technologies specifically designed for computer music education, there are an increasing number of tools on the "open market" developed for musical purposes as software and computers become more powerful. Most of these are professional or semiprofessional tools, but an increasing number are also designed for nonspecialists. Some software tools focus on music appreciation and train recognition of sound and form, some train recognition of specific musical repertoire, some are technically oriented toward signal-processing methods, while others are oriented toward experimentation and creative work within varying sets of constraints. The last are very diversified, with programs ranging from a simple combination of ready-made samples, to more open-ended programs by which users can create and process sounds and do their own sampling. Sequencers and sequencer-like software have become the most common production tools, integrating both signal processing and definition of timeline in larger-scale forms. However, the sequencer model conceptualizes the musical narrative as a linear and pitch-based movement, with little emphasis on principle-driven musical development or spatial composition.

In terms of learning resources, some Web sites include texts that describe theoretical aspects of sound and sound processing, often including simple demos of some principles by which one can change a parameter and hear and see the result. An example of this approach can be found on BBC's Web site Music Sense,[2] although it is oriented toward traditional concepts such as pitch, interval, chords, and scales. The ambitious education project by the Massachusetts Institute of Technology aimed at the developing world, One Laptop Per Child (OLPC),[3] is particularly interesting in that it is developed according to principles of collaborative learning and sharing. Adaptation of the free and open source Linux operating system allows students to select, share, and view activities and networking opportunities at group, local (neighborhood), and global levels. A suite of simple learning activities in math, art, reading, and music is preinstalled and available for continual development as open source software in the OLPC wiki.

Among the preinstalled OLPC activities is a music program called TamTam,[4] which is a suite of four programs with Csound as the audio engine. Students at different developmental levels may collaboratively play, perform, edit, record, and share music using one of these programs. The musical focus of TamTam is largely on pitch and rhythm, complemented for more advanced students by a "synthlab", in which the workflow design is modeled on Max/MSP (Max Signal Processing). For composition, the paradigm is piano roll representation in a sequencer interface. A certain level of assessment by teachers is also possible through a visualization tool that renders individual student activities in a journal feature.

In addition to such integrated approaches to digital learning tools and music software, there are educational texts on the Internet that describe how to construct specific musical forms, often using a particular software, such as Audacity.[5] An example of this, written by Bruno Bossis,[6] can be found on the UNESCO (United Nations Educational, Scientific, and Cultural Organization) Digi-Arts Web site.[7] The Web site describes its aim as the "development of interdisciplinary activities in research, creativity and communication in the field of media art"[8] and contains theoretical and historical texts, tutorial texts for free software, step-by-step exercises, and links to other Web sites with software. The design of this Web site is a good example of a guided instructional approach, explaining musical history, physics, and signal processing at an advanced level and with little emphasis on exploration or the creativity of the viewers/users. In the pedagogical approaches listed in this chapter, instruction tends to follow a procedural track by which one specific task needs to be completed before the next step can be taken.

An example of a gaming approach to learning pitch and rhythm with minimal guidance is Morton Sobotnick's Creating Music software for children,[9] which includes the use of open sketchpads in working with pitch-based music. Here, users can set their own pitches and change timbre for playback of these pitches. Musical staffs and conventional notation for accurate pitch and rhythm are not used on this Web site. Instead, the sketchpad window is quantized, so the results stay within the conventional bounds without requiring effort to do so. An example of a Web site that encourages experiments with other tuning systems is NOTAM's Portable Pure Tuning.[10] This Web site contains a pure tuning automat software for downloading and informative texts about principles and research behind the pure tuning system.

There are also examples of Web sites designed to support both creative processes and the mediation of musical productions, such as school performances. An example of the latter is Sonic Postcards,[11] at which Internet technology is used to disseminate musical results. The Web site has been developed with a teacher's kit, intended to build competence and deepen the teacher's understanding of the project. Such tutorials, however, have their limitations as educational tools. The availability of theoretical texts on different levels is an important step in reaching out beyond specialist circles, but it is not really sufficient as a scaffold for learning in nonexpert classrooms settings.

In sum, as Brown (2007) pointed out, many of the features in generally available technologies can scaffold learning experiences in music education, including software that provides accompaniments for performance; allows playback during the compositional process; generates analysis, feedback, and error adjustments for compositions; enables real-time networking between composers for developing ensemble skills; and provides online discussion forums and peer group support environments.[12] However, these are often technology-led solutions and lack pedagogically informed frameworks for activities and tasks for use in real learning settings. In recent years, this problem has been recognized in many disciplines, and the development of learning technologies for specific educational settings has begun to gain momentum.

A. DSP as Learning Tool

To illustrate the educational approach outlined in the beginning of this text as a combination of crafting, interpreting and appreciating music, and critical reflection on what counts as music, we consider in greater detail NOTAM's software DSP.[13] The software attempts to address the need for specific learning technology for computer music and was first introduced at the International Computer Music Conference (ICMC) in 1997 (Rudi 1997). The software was developed in response to national curriculum changes in secondary schools in Norway; composition became an obligatory part of music education, and the use of technology while composing was encouraged. At the time, there was a lack of suitable educational music technology available for Windows and Mac OS other than simple sequencers, and the limitations of a pitch-based approach made it attractive to come up with another solution for teaching composition.

The application DSP is for composition and signal processing, with a simple user interface and a help system that can be accessed from any point inside the application. It makes use of the most common synthesis and signal-processing methods and is in keeping with most established graphical user interface (GUI) conventions to ensure a user-friendly interface (Rudi 2007). A normal student at secondary and upper secondary levels intuitively understands how to use the software as he or she is led directly into the creative workflow of the software, with the signal generation and processing automatically moving results into a mixer. This means that the student is immediately working on a first composition. Particular attention has been paid to the graphic design of an appealing GUI, motivating younger users through the professional look and feel of the software. The pedagogical design supports a discovery, inquiry learning approach, employing what Erstad (1999) described as a "student-centered" perspective. During the design process, emphasis was placed on tasks and activities that would require little formal training of the students, an approach that has also been discussed by Regelski (2004).

B. DSP in Learning Settings

For the nonspecialist groups with which NOTAM has been involved, a workshop model has invariably given good results. Workshop teachers lead the activities, and in school projects the class teacher is involved as well. The presence of workshop leaders and teachers with specialized disciplinary knowledge is a key aspect of the success of the educational design employed by NOTAM in DSP workshops. Recent studies in education science affirmed that teacher interventions in student group work is often key to assisting students in understanding the disciplinary nature of a task, particularly when learning technologies are involved (Rasmussen et al. 2003). At the same time, classroom teachers scaffold their own knowledge in workshop settings through working alongside specialists in electroacoustic thinking and techniques.

In the DSP workshop model, a normal school computer lab setup is adequate, and students are typically teamed up two or three per machine to collaborate in solving the aesthetic and technical problems they encounter during the workshop. This is another important principle in sociocultural perspectives on learning as discourse and interaction are viewed as central to the construction of meaning and knowledge in classroom settings (Wells 1999, Wegerif 2001, Arnseth and Ludvigsen 2006). The teacher introduces the tasks to the students by saying that they will be working with invited instructors to complete a class project in composition and performance. The basic technologies are the DSP software, software for sample editing, microphones, and recording equipment. In some workshops for festivals or other performance-oriented events, the computer work may be combined with actual instruments, homemade electronics, found objects, and combinations of microphones and effect processors for greater diversity and more interesting stage performances. The NOTAM workshops involve collaborations with external partners with relevant teaching skills and experience for the specific age group involved, and the workshops are often partially financed through national initiatives.

The pedagogical approach aims to integrate knowledge from the core areas in response to students' questions, which invariably arise after a period of exploring, experimenting, and getting to know the tools. At the onset of every workshop, students are immediately engaged in experimentation and constructive investigation, mediated by the program's open construction, which includes all elements needed for music production. Students' general digital literacy makes this a low-threshold entry into the workshop, and we have found that computer skills have improved dramatically since we started these workshops some ten years ago. Significantly, after having learned how things work, and after having made and processed a number of sounds, students have established some basic skills and begin to question and look for some kind of direction, either theoretically or in the form of concrete tasks. This pattern corresponds with findings in educational research and is the basis for exploratory approaches in inquiry-based designs for learning technologies (van Joolingen et al. 2007). A period of creative exploration is also generally acknowledged as fundamental to learning approaches in the arts.

In the DSP workshop model, learning scaffolds thus include disciplinary knowledge and tasks introduced in situ by the teachers, the collaborative meaning making of the students as they creatively engage with the software, "help" texts that describe algorithms employed by the program, theoretical texts dealing with physics and aesthetics, and an animated demo piece that is available as a "worked example" to guide students step-by-step through analytical approaches to sound material. In addition, DSP contains extensive resources for teachers with suggestions for interdisciplinary classroom projects.

Creative work is supported by the listening activities in the DSP program as students find and record sounds that hold meaning for them and place them in new contexts to express something specific and thus give the sounds new significance. Recording their own material facilitates students' reflections on their sounding environment, a kind of attention that is also emphasized by workshop leaders when introducing the project. Through artistic exploration, the students create musical values, rendering forms to which they have assigned meaning. The contexts for the workshops are important for the kinds of meanings that emerge, whether school projects with a duration of several weeks or projects designed to produce a result in a matter of a couple of hours. Although time constraints determine the amount of free experimentation, the approach is the same, building on students' everyday digital literacies and creative impulses.

Observations and feedback from participants over an extended period suggest that through collaborative creative work students engage with the core areas in computer music as well as acquire software-specific computer skills, practical skills for stage performance, and general audio technical skills. We have observed that there is a concentration on creative work in the DSP workshops, and that problems that arise in connection with this work are solved collaboratively, through student discourse and interaction and through the support of the teachers. Student concentration is centered on the disciplinary domain of music rather than on mastering the technology. However, as with the other technologies described, empirical studies of use in schools and workshop settings will need to be designed and conducted to provide a richer account of how the DSP platform, participants' interactions and previous knowledge, and institutional factors mediate students' learning in the core areas of computer music.

C. Design Development

In 2003, DSP was migrated from Windows and rewritten in Java for cross-platform availability. The software was renamed DSP02[14] and first developed to run in a browser from a comprehensive Web site that contains texts, examples, and tutorials. When it was found that many users experienced problems with an online Internet solution, the program was changed to become a stand-alone application. Now, DSP02 may be downloaded free from the Web site and runs independently from a browser as a Java applet without being connected to the Internet. Some additional functionality has been developed, and the software has to date been translated into seven languages. The software itself adapts to any of these according to the language used in the operating system of the computer. The graphic interface was redesigned in 2003, and the engine now utilizes Phil Burk's Jsyn library.[15]

The DSP software is now more than ten years old and is in use around the world, with several hundred downloads every month. Although the educational approach incorporated into DSP is apparently easily implemented in a range of learning settings, the software design would certainly benefit from new methods that capitalize on current social networking features to support collaboration and dissemination. Future design developments are currently being explored through analyses of DSP projects in Norwegian school settings and informal learning workshops that use wiki platforms and learning management systems for communication and file exchange, such as The Music Workshop,[16] in which DSP is used in combination with the Blender[17] software from NOTAM.

Advances in Internet technology accentuate the need for adapting the educational material and to incorporate the social aspects of electronic learning environments. We also see the need for collaboration with textbook publishers to make the learning resources available in other kinds of settings. An important aspect of such initiatives is the desire to integrate computer music into the social fabric on a broader scale and to disseminate student activities. Similar approaches to dissemination of student work with music include the Beacon project[18] at Museu de Arte Contemporânea de Niterói in Brazil and its Norwegian equivalent, Kunstfyret.[19] Repositories of diverse projects can serve as a learning resource, and results from DSP use are shared on the Web site, including Norwegian school workshops Lydoku[20] and Sound Treasure Hunt[21]; and music festivals such as St. Olav Festival 2008,[22] Ultima,[23] and the Hauge/Tveit Jubilee in 2008.[24] Importantly, the diverse settings also contribute to expanding the use of the software into other sonic arts, including soundscape composition, text/sound art, and remix performances.

7. Conclusion

In the DSP case described, envisioned design improvements incorporate features for teachers' assessment needs as well as for organizing student and teacher activities. In terms of the latter, this means linking DSP more closely with students' and teachers' literacies in social software, allowing participants to shape and share the learning environment, collaboratively adding to and modifying materials, and making connections across local and global levels of knowledge building. As for assessment, an important issue at stake for teachers when using collaborative, open learning environments is the need for visualizations of student contributions at both individual and group levels (Lund et al. 2007, Pierroux et al. 2008).

Importantly, increased use of social software in learning technology designs and a sociocultural perspective on computer music literacies will require new methods and a broader unit of analysis in music education research. It entails a shift from a primary research focus on assessing relations between music and individual cognition and affect to studies of how knowledge is constructed across such shared communities and made relevant in students' music literacies in specific settings. Such a shift has political as well as theoretical implications. Traditionally, learning research has investigated the significance of music and art education in terms of factors in affective and cognitive development and critical thinking. Findings from such research often argue for the transfer effect of cognitive development across other subject areas and thus become a political tool to promote better integration of the arts into national curricular plans.

While acknowledging the usefulness of psychological studies of music and human development, the argument made in this chapter for computer music education is another. The point to be made here is that there is an inextricable link between the cultural historical development of computer music as a genre and learning technologies like DSP, which as a tool has material as well as ideational aspects. Digital tools change in keeping with cultural, historical, and literacy practices in formal and informal learning settings, and there is at the same time a reflexive relationship between these tools and changes in computer music as a musical genre. It is here, we propose, that the future framing of learning perspectives in computer music education lay, in greater awareness of this reflexivity between tools and the development of human ideas and creativity.

Relating core areas in computer music to everyday multiple literacies entails developing a language of aesthetics for abstraction, distortion, and simulation in contemporary music and sounding materials. In addition, music education needs to be updated with digitally based methods and principles that draw on simpler commercial music software and technologies. This means that developments in the teaching and learning of computer music hinge on creating a better balance between the sharper research edge in computer music and more commercially driven standard solutions to music technology.

Computer music education will have a larger impact if included in the broader fabric of society and texture of everyday life. Moreover, changes in educational approaches to computer music are needed to meet the demands of public institutions and funding bodies to reach larger audiences. We propose that better integration of computer music in secondary and upper secondary education is possible by adapting teaching methods and core knowledge to diverse collaborative learning settings; by designing for students' creativity and digital literacies in exploratory, inquiry-based activities; and by incorporating social software features as pedagogical scaffolds in computer music learning technologies.

NOTES

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12. See, for example, Smartmusic. http://www.smartmusic.com/; Exploding Art Music Productions, Exploding Art. http://www.explodingart.com/jam2jam.html; Empire Interactive Limited, E-jay. http://www.ejay.com/News.aspx?newsid=21, all accessed October 15, 2008.

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17. See Drivhuset, Blender under *verktøy*. http://www.musikkverksted.no/musikk/, accessed September 1, 2008.

18. Museu de Arte Contemporânea de Niterói. http://www.macniteroi.com.br/index.php?op=noticias&notice_id=08, accessed September 1, 2008.

19. Tony Larsson, Art Lighthouse. http://www.oslofjorden.org/skole/kunstfyret.shtml, accessed September 1, 2008.

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21. Drivhuset, Sound Treasure Hunt. http://drivhuset.musikkverksted.no/lydskattejakten/, accessed September 1, 2008.

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