Making Digital Music Tools for Children

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The computer has become a musical instrument that is used in nearly every modern music production. The instrument works via software of varying complexity for professional and amateur use, and for composition with notes and recorded sounds. It changes pitch and timbre, it provides sound and control, and it supports structure and interaction. The computer has invigorated electroacoustic music, and has also been the basis of new technology-based genres such as electronic dance music (EDM) and the broad category of electronica. Despite this position in modern media production, educational music software for elementary and secondary schools hardly exists; any that is being used is often harvested arbitrarily from the World Wide Web, and not designed or constructed for pupils and young students. Students rarely develop any sort of musical or instrumental skills, nor any deeper understanding of what happens from a musical or technical perspective when they are using this software.

Digital technology for music education must be anchored to an understanding of technology, of music, and of educational science. These are prerequisites for broadening participation in the technology-based creation of music within a learning perspective. In particular, this is crucial for technology-based music, since the genres can't be taught without technology, while instrumental music can. Technology-based music and, more narrowly, electronic or electroacoustic music, has for the most part historically been ignored by schools, despite its high relevance from both a technical and social point of view. After all, most music that we hear is from loudspeakers or headphones, and has been composed, developed and processed using digital means. Nonetheless, most schools have remained in the acoustic world, and attempts to bridge the gap by teaching music technology are often half-hearted, largely due to the lack of relevant educational tools and an understanding of what the processes in the technology consist of.

This text describes the development of software and learning tools for children that the Norwegian Center for Technology in Music and the Arts (NOTAM) has undertaken since 1995, and the experiences and reflections which have emerged from this practice – from the digitally-pioneering days of the early 1990s until today. Furthermore, the increase in apps and browser-based software for children's musical play has brought several research questions to the fore, and these questions are of importance for assessing the creative and learning outcomes, in formal as well as informal learning situations.

Digital beginnings

NOTAM was established in 1992, and began its activities in January 1994. It was the composers' old dream of a national studio for electronic music brought to life, paired with emerging academic interest in digital tools for music. The need for building competence in the new domain of digital technology brought these divergent groups together, and their competence in digital music technology was for the most part limited to MIDI, which was a 1980s technology. Of course a few composers had briefly used computers for working directly with sound (not merely notes), but they were scarce.

It was in the early 1990s that affordable personal computers became fast enough for signal processing – for working with sounds themselves, rather than using MIDI to address external hardware such as synthesizers. The ability to go beyond the limited solutions of the different manufacturers constituted a huge freedom for composers, as close listening to early computer music easily verifies. Up until the early 1990s, computer music had been limited to the few composers who had access to academic computer facilities and labs, and no studio of this type existed in Norway. The educational institutions had almost no competence in computers and sound; this was the digital dawn.

With the establishment of NOTAM as a national centre in such an environment, it quickly became clear that the mere coordination of resources was insufficient to fulfil the mission of the network (as it was first called), and that a more proactive profile was necessary in order for the centre to further the development of the field. NOTAM had the advantage of a new machine base, Silicon Graphics computers, and during the course of two years produced several open-source software packages, all with a focus on the new possibilities in signal processing. Largely due to the new World Wide Web (launched in the autumn of 1993), this software achieved popularity around the world, and it became clear to us that this new sound technology could also be useful in schools. We believed that at some point, children's education must also be brought into contact with the digital domain, and draw on the competences in technology-based music. In general terms, this entailed making use of the typical affordances of the digital paradigm – easy control of complex parameters, a high degree of precision using numerical control, and cross-disciplinary fertilisation via data mapping between domains.

Educational entryways and goals

With digital technology increasingly permeating society in general, and media production in particular, children in the early 1990s were no longer surprised by processed sounds and images. After all, they had been primed by digital content in computer games, which had been an established genre since the introduction of arcade games and small home consoles as early as the 1970s. 1990 was still 15–20 years prior to the widespread, small-scale computing found in today's smartphones, but the personal computer had started to make its way into schools. However, no systematic educational effort was being made with computers, and the typical computer in (just a few) classrooms was Windows-based, slow, and with very small disk space. Yet many children had first-hand computer experience from digital games on a home computer. The Web was still in its infancy, and there was not much content for children online; neither were there common Web technologies that could allow for browser-based software in today's sense. CD-ROM was the preferred medium for delivering software and other types of content.

Children had begun to develop what theorists today call 'digital competences' or 'digital literacies', and were typically more advanced than their teachers in developing those skills. Nowadays, digital competences are often described as necessary for full participation in society, in order to understand digital tools and avoid alienation. This was also one of our primary goals: to help children become comfortable with computers and digital representations, and, even better, to make them their own by creating something themselves – to formulate something rather than just consume content. Computer skills were not yet democratically distributed in society, and although many children had access to a computer at home, the number in the early 1990s was still less than half. In order to transform the experience of a technology from magic to logic, the user needs familiarity and practice, and creative activity is particularly valuable, as recent research confirms.[1]

No technology exists in a vacuum. Its basis, development and implementation are shaped in social contexts, and in turn it influences those contexts. Competence follows from the use of technology, and competence is so closely linked to the technology that it makes sense to see it as part of the technology, not separate from it. This way of understanding technology has been researched in several projects, and described in publications such as *The Social Construction of Technological Systems*[2]

Neither are technologies neutral: they shape how we think about things, as well as how we actually do things, and this loop between thinking and doing depends on design. Where does the software encourage the user, and where does it stop him or her? How is the workflow designed? For NOTAM, these questions translated into the desire for simplification of the planned software, to avoid unnecessary ideas and functions that could confuse students and lead them away from the purpose of composition with digital tools.

Children's rapid appropriation of the new digital domain made it necessary to link the educational software and tutorial programme to wider society. We imagined this type of linking would be crucial for the software to be perceived as relevant for the target group, and decided that the software should draw on the aesthetics that the children were already exposed to – computer games. It would also need to be designed so that it would be attractive both in and outside of the classroom. We believed that learning from software and textual material should not necessarily be limited to the classroom, and today researchers look at this type of learning outside of formalised contexts as informal learning. Theory in this field is growing rapidly (as of 2015), as the focus broadens to incorporate exactly such game-based activities.

A key ambition for NOTAM was to increase visibility for the (at the time) new aesthetic domain of technology-based music – to allow the children to explore and create, and to present their results in ways that made it clear that they were taken seriously – not just as something that only had interest in schools. In order to bring recognition to the music that the students made, we arranged nationwide competitions and concerts at the Ultima Festival for Contemporary Music in Oslo,

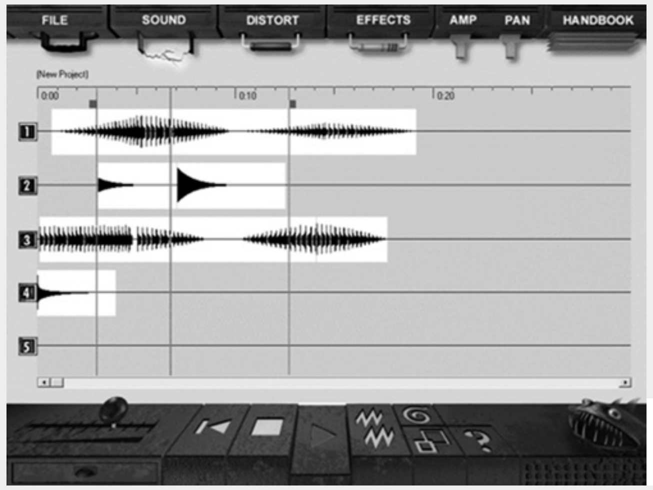

Figure 1: The DSP mixer with sounds loaded, playing a loop.

and some concerts were broadcast by the Norwegian Broadcasting Corporation (NRK). In order to launch this ambition on a large scale in 1995, NOTAM also took the initiative to have the loudspeaker orchestra from Groupe Recherches Musicales (GRM)[3] in Paris visit Oslo, in order to have the children's works performed on one of the best available instruments for electroacoustic music. This and other concerts were produced in collaboration with the Concert Institute of Norway, a national organisation tasked with bringing contemporary music to school concerts.

In order to gain access to schools, our software and workshop programme needed to address the learning goals that were set out in the national curriculum. These goals were laid out in fairly general terms in the Ministry of Education's revised learning plan L97[4], however the goals stated clearly that children should learn to compose, and investigate how, for example, sounds from nature could become music. The use of music technology was also encouraged.

The description of these learning goals failed to address methods or tools, and that left the implementation up to teachers who normally had low competence in the digital domain. NOTAM took the opportunity to define how electroacoustic and experimental music could be applied in schools, from software to practical implementation through classroom projects and workshops. Electroacoustic, or more broadly, technology-based music, had not yet been represented in schools across the country, but with digital technology becoming increasingly popular, it seemed timely to bring this music into elementary schools. The use of recorded sound and digital tools would open up possibilities for education, connecting across disciplines such as music, mathematics, physics, languages and social sciences. We wrote a series of suggestions for classroom projects for several disciplines where the software could be useful. Naturally, not all music education should revolve around music technology, but to have education without contact with recent developments would be unacceptable.

Learning, formal and informal

We believed that using the software would also be helpful in learning computer skills, and for many students our workshops were their first encounter with a computer. In today's terms, all of this would build digital competences, helping the young students master the tools needed in order to become full members of society. Our goals also went beyond the more instrumental ones, where technology was being used to pursue the specific aims that one currently finds measured in the results of, for example, the current PISA tests[5], as we began with cultural competence, something the PISA tests do not measure. We now know from Bamford's analysis of current PISA data[6], as well as from Loveless'[7] study, that schools which focus on creative disciplines such as music and the visual arts also show better results in disciplines such as mathematics. Furthermore, it has been pointed out by Cooper[8] that students on the whole are more inclined to work harder in music technology classes than in other classes, and this underpins the notion that the use of information and communications technology (ICT) in general adds value. All these findings correlate well with our experience when establishing the workshop programme that has been running since 1996/7.

As part of the cross-disciplinary perspective, questions of learning were brought into the equation – how could children best develop their digital competence and become comfortable with the digital paradigm? Which skills should they have, and why?

Composition is often thought of as a solitary activity, for which the traditional cognitivist and constructivist models of understanding would be good frameworks for describing the meaning-making processes. We, however, thought of learning as something the students should do together – that their meaning-making should be developed during interaction between them, and in open workshop form. Theorists such as Siemens later pointed out that technology has changed how we live, interact and learn, and that "learning needs and theories that describe learning principles and processes, should be reflective of underlying social environments". Siemens uses the term "social connectivism"[9] to describe this intersection.

The focus on process also entailed a focus on informal learning, where students would make something their own by experimenting and developing their skills via their own activities, in or out of school. This type of learning is not prescriptive in the sense that goals for what the students should know by the end of the week are precisely described. Instead, goals are kept very general or are quite loosely articulated. However, in order to retain a stronger curricular focus, the learning process must be planned, and much can be done in deciding how

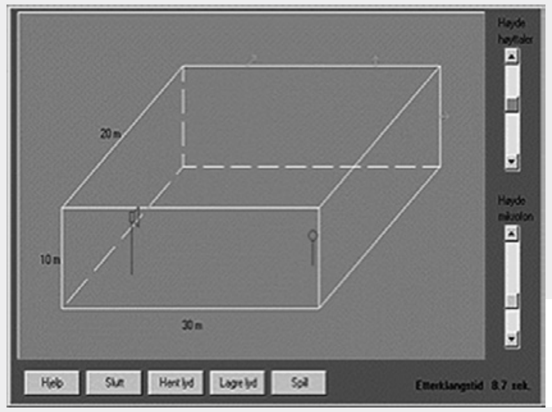

Figure 2: The subprogram for simulating reverb. The walls, speaker and microphone could be moved.

the software should direct the workflow of the students. There were significant differences between the educational initiatives that were launched at approximately the same time as DSP. Morton Subotnick's Creating Music software was oriented towards tonal composition but aimed for playful effortlessness without the use of notes. IRCAM's 10 Jeux d'ecoute from 2002 used forced moves in ten fixed audio games to take students through predetermined core topics; their perspective was linear, and correct answers were needed in order to progress to the next level. NOTAM's software was more exploratory and game-like, but with constraints that made it much easier to work with synthesized sounds and signal processing than with notes, bars and metre. NOTAM's software aimed to hold students within the new affordances of the digital domain without forcing procedural progres.

Unfortunately, there have been few studies of collaborative creative processes in music,[10] despite the clear relevance they would have for the broader issues of technology-facilitated empowerment.

The software

In order to address the need for digital tools and basic computer skills, as well as prescriptive and non-prescriptive learning, NOTAM designed and produced the software DSP, which stands for digital sound processing.[11] This term was not common at the time, but it pointed to the core of the project. DSP was designed to have the look and feel of a computer game, which made it stand out when compared to the primitive graphics and predefined learning goals that were normal in other educational software of the period. NOTAM's software was the opposite, with a simple interface that took over the screen in the shape of a mixing window. The mixing window would always be open, and resembled an electronic instrument enclosed in a corroded metal panel. These graphics, cutting-edge for the time, supplied extra references to things that did not normally appear in schools, and gave the software an out-of-class context. Drop-down menus were included in the window, shaped like electronic components, and the user interface did not reveal its Windows-basis. All the necessary choices for user interaction were placed inside the window, and this made the software easy to understand, much like the computer game functionality that children were familiar with; they of course had more experience with games than with standard computer software. When selecting either a synthesis or signal-processing subprogram (today they are called 'plugins' in DAW-implementations),[12] an instance of the subprogram would appear on top of the mixer window, and could not be moved to the background – it needed to be addressed and/or dismissed. No mistakes in the workflow were possible, and this was a method of controlling the workflow. When completing the operation in the processing window, the resulting sound would be dropped into the mixer, where it could be freely moved around between tracks.

There were small animated elements on the drop-down menus which extended the feeling of a computer game, and animated buttons at the bottom of the window, as well as an animated fish that would delete the sound files thrown into its mouth. There was also a drawer for storing sound files that were not in use. Additional small graphics would bring the screen to life: progress bars, an image of a glass fuse that would glow during processing, and so on. Operations in the mixing window were controlled by animated buttons with the look of (somewhat unusual) cassette-player controls, which we found to be a familiar cultural reference for nearly all students. Changing parameter values in the subprogram windows was done via breakpoint curves, for dynamic variation over the duration of the selected sounds. Initial parameter settings in all subprograms were important – they all sounded good when they were called up, and the allowed parameter range always kept the sounds within boundaries. This was a conscious design choice, since one could not expect much competence among teachers if a subprogram was to be set outside of audible range in one way or another. Nonetheless, the parameter space available to the young composers was larger than they could manage to fully explore, even with such limitations.

There were a few exceptions to this workflow design: the sound editor; a program for the simulation of reverb (where the user manipulated the room size); and finally the help window.

The help window was unique in that it called another instance of the subprogram that it was called from, so that users could experiment live with what the help text suggested. This made the software easy to learn – not only could students read about what to do, but actually do it as well. One could also access all the text files via a menu, and the help files appeared through a deep adaptation of the Microsoft Explorer browser, where everything that could reveal the browser technology had been hidden.

This software was published on a CD-ROM for Windows, and since no schools had Macintosh machines at the time, this posed no problems. In order to support teachers and particularly-interested students, we included tutorial texts,13 tasks for classroom use, and a computer music animation that was largely based on the author's pioneering computer music animation work from 1995, *When Timbre Comes Apart*.[14] The tutorial piece *And the Birds…?* was made using just the DSP software, and the process was explained in great detail and in interactive fashion, with all subprograms being called with the relevant sounds and parameter settings loaded in, ready for experimentation.

In brief, the functionality of DSP resembled what could be found at the time in professional software such as Ceres[15] and Pro Tools, with advanced tools for exploring sound. The graphic user interface (GUI) was simple and appealing. The educational model was investigative, and while it took a short time to understand the workings of the software, it took much longer to master the methods, and to fully understand the terminology and purpose. The more the student understood, the more he/she was able to do, and the more their effort made sense. There were no prescribed aesthetics or stylistic blueprints, but the package had clear multi-disciplinary perspectives. Here is a link to the DSP webpages from 1995: www.notam02.no/DSP/.

The introduction into schools of Linux, as well as the increased number of Macintosh computers there, prompted NOTAM to port the software to the Web in 2003. The aim was platform independence, and to have the software be able to run in a browser. This decision was also influenced by our observation that the 1995 interface was outdated, and that we wanted to give the software a new one. The 1995/6 interface was more playful and game-like than the new one; nevertheless it seemed old, not least because game technology had developed significantly since 1995, so that the visual link to the gaming world had been lost. The affordances of the migrated software remained the same, and the port to the Web made it easier to incorporate translations into different languages. Today, the software has been translated into six languages, and adapts automatically to the language of the operating system. The website is more-or-less completely translated into four languages, in addition to Norwegian. The software was renamed DSP02,[16] and was made freely available as a downloadable application here: www.archive.notam02.no/DSP02/. We chose not to make the program code open source, since we wanted to protect the educational model that we had embedded into the software from arbitrary modification.

The workshops

We found that workshops were good for introducing new technologies into schools, especially in order to develop both teacher and student skills in collaboration with the workshop leaders. A brief introduction to the software would be given at the start of the workshop, and students would then explore on their own for a variable period. If they had questions, help would be provided. Creative exploration is a proven method for good learning, as Chemi points out.[17] Students would be seated in pairs, according to the teacher's suggestions, and further encouragement towards collaboration was unnecessary. They would familiarise themselves with the software, as would their teachers, then discuss the results and establish common goals for experimentation – all key elements in developing shared meaning and understanding. However, observations from the use of DSP clearly suggest that mere play loses its value over time, and that teacher intervention is a necessary component of the workshops. This suggests that understanding and mastering a computer program for music composition is not the same as having learned to compose, regardless of how appealing the results may be. This point is still important today, as the software for portable computing becomes ever-easier to use. Play is not enough.

After students had mastered the software and roughly understood its affordances, it became clear that a higher-order common goal was needed – a reason for playing with the software. Workshop leaders would introduce musical tasks – forms and elements that depended on the overarching goal of the workshop – some preconceived, some made up on the spot from what the instructors had heard during the free exploration phase. These tasks would be combined in a variety of ways into collective compositions, or presented as standalone works, depending on the students' skills and how the material sounded. The key idea was to have each student pair develop their work as freely as possible, and to help organise the results into forms that could be presented for the whole class, school, or even for larger events such as festivals. In this manner, the workshops combined informal and formal learning.

This workshop-based, facilitating approach, as opposed to a more curriculum-bound, instructional approach, provides challenges for assessing the educational results. It is tempting to suggest that the students' independent goals for learning might, to a large degree, be self-affirming rather than challenging, so for inclusion in normal school curricula, it may be necessary to introduce some metrics in terms of quizzes, tests, obligatory tasks, etc., but until now (2015) the educational authorities have not been interested in implementing metrics of this type in the current curricular demand – the goal of having children compose with technology has been left somewhat unspecified.

NOTAM's workshops have for the most part been prepared in collaboration with the professional project organisation Drivhuset (The Greenhouse) which has schools as its focus. This collaboration has encouraged the development of workshops for several different purposes, addressing local and environmental situations and concerns. Student recordings of their own preferred sounds have become very successful material for engaging them, especially when they are recording and playing with their own voices and the voices of other students – their friends. Personal is good! More programmatic approaches have also been explored, where working with sound has entered into a conscious exploration of the environment from an ecological perspective. Recordings would describe the environment via acoustic means, and reveal it to the students in a new way, thus opening discussions from this new basis. Observation data from workshops with this orientation confirms the value of the listening and analysis that is at the core of Murray Schafer's work in the soundscape and acoustic ecology genres.[18]

The need for research

The key goal for research in this area is to develop a better understanding of how the creative process of learning music composition can be facilitated by technology. Such an understanding is a necessary basis for technology-supported music education, and for the development of educational materials, tools and didactical methods for the classroom.

Music technology is a relatively new field, and researched only in a zmentary manner. However, on a general level, being able to use ICT is considered crucial for social participation, and ICT has been found to increase engagement with and motivation for learning.[19] With this as a point of departure, it is unrealistic for music education to remain focused on traditional methods: it must find ways to engage with technology, and to decide on relevant learning objectives and the methods for determining which approaches might be helpful in reaching those objectives. Government ambitions for education are generally high, and ICT is considered pivotal to the development of future education. For example: "Integration of the arts and interactive technologies are essential to the future of quality arts education learning for students in the 21th century"[20].

However, these are rather generalised statements, and although observation confirms their relevance, it is not clear exactly what type of value ICT brings to arts education. Furthermore, most research on ICT and music in learning perspectives is oriented towards note-based music and the tools that facilitate such an approach, while very little has been done on technology-based music.[21]

1) Theoretical framing

The theoretical framing of how learning happens is necessary, and while the focus on individual meaning-making processes is important, it is equally important to recognise that technology has changed how we live and interact, and how we learn. Siemens[22] points out that the theories which are most often used to describe it – behaviourism, cognitivism and constructivism – were all developed before technology made the inroads into education that we see today. Learning is a culturally-conditioned activity, and the theoretical framing should reach beyond the individual to look at social interaction as well. Rudi and Pierroux present a thorough description of this theoretical framing,[23] while Dillon points out that there is a lack of research into the interaction processes in semi-formal and non-formal learning situations that involve computer and music technologies.[24]

2) Electroacoustic music – an unusual instance or a unique combination of qualities?

Since current music technology is, with few exceptions, electroacoustic, it is important to determine what technology-based music can offer in addition to (or instead of) other types of music. We believe that technology-based music is essential for music education, but we can't really answer the question until specific research has been undertaken to compare electroacoustic aesthetics with conventional acoustic aesthetics.

Is technology-based music just an unusual instance of music, or does it represent a unique combination of qualities? To put this another way: did music technology change music, or just give it a new face? As Mills and Murray ask: which musical competences does technology-based music draw on?[25] Which core values are operative, and how are they influencing meaning-making processes and benefiting a learning perspective? Are there interesting genre-distinctions, and are they important?

3) Creativity

Critical thinking and the ability to discern are at the base of creativity, and both rest on reflection. This iterative and recursive process encompasses creativity as an individual and a social activity, including both the executors and appreciators. The most important aspect is that it does not depend on predefined criteria for success – what is creative for one person might not be so for another. However, an approach as wide as this poses methodological problems when assessing the effects of different digital tools. One can for example, as per Cooper[26], use reported frustrations with limitations in available software packages as an entry-point for understanding which compositional intentions could not be realised. Discourse analysis of the interaction between students will reveal negotiation themes and other interesting topics, and

Figure 3: A typical CwS processing window, where different processing is represented via icons in the top left corner.

numerical methods may even weigh in, should the studies be structured around clearly defined and detailed questions.

4) Design of tools, workflow and interaction

Finally, design issues should be investigated. Software always suggests how it is to be used, and what it is good at and good for. The user's perception of these affordances is largely framed by the design, and in educational software the design of interface and workflow must find their focus in the learning objectives. Design also influences the amount and type of supplementary didactic material, thus situating it at the core of the interaction loops between students, and between students and instructors. This type of interaction design can easily be informed by results from, for example, similar studies in industrial design and other technology-intensive disciplines. Investigations of interactive design processes may reveal interesting data on the relevance of the themes that education seeks to encompass, and also on the importance of the process itself – were there many changes, and how fundamental were they?

The learning goals are key, and any educational software and its supplementary material must be measured in terms of how well the students achieve the goals. User observations and studies will form an empirically-sound basis for what works, and how one might assess different types of teacher/instructor intervention – how curriculum-bound, instructional approaches compare to more facilitating approaches in ensuring that students reach curricular goals. Which types of intervention yield the best results? How large an aesthetic variation does specific software encourage, how many choices do the students have, and how do the choices and results compare with the learning goals?

Criteria such as these will help teachers orient themselves and assess the tools they find in the huge flow of apps and Web-based software that currently exists. Many of these apps are technology – or commercially-driven, and it may be difficult for the non-specialist to determine which tools may be the most appropriate for the task.

Severe limitations in software for combinatory exercises such as, for example, sampling programs where pre-recorded and edited sounds slip into tempo grids and pre-conceived structures, make for an effortless exercise void of musical learning or creativity.[27] What is the significance of student influence on timbre, music type, pitch or melodic structures? What learning do they miss if only combining presets? Playful apps might offer fun ways to play sound back, for example by rolling balls on moving planes or moving birds between telephone wires, but with no control over timbral or pitch content; such software encourages no learning other than interface control. Nonetheless, such types are frequently found in schools, and are used in attempts to answer the curricular demand for composition with technology. A study into how different levels of complexity combined with such simple user interfaces affect learning would be interesting, comparing similar data from more game-like software where simple choices between pre-made sounds replace the compositional processes. Clearly, there is a need for research-based criteria, so that the 'creative' aspects of music technology can be brought into music education at the expense of random dilettantism.

In essence, the studies of design issues should be focused on uncovering and describing the meaning-making processes on all levels, and holding them up against the learning goals for evaluation.

Recent software and future work

As stated initially, digital music technology for music education must be anchored in an understanding of technology, of music, and of educational science. These are prerequisites for broadening participation in the technology-based creation of music within a learning perspective. The key goal for future work is to develop a better understanding of how the creative process of learning music composition can be facilitated by technology. This understanding is a necessary basis for quality technology-supported music education, and for the development of educational materials, tools and didactical methods for the classroom which fit the learning goals.

NOTAM's most recent engagement with the development of software for education is as a partner in the European project *Compose with Sounds* (CwS). Having already developed working software for children, we were interested in the approach set forward by the project leader, De Montfort University. The differences between this new software and DSP are partly technical, partly educational. DSP, due to the hardware limitations of the mid-90s, replaced the original sounds with the transformed sounds and made much use of synthesis, while CwS has an updated technical solution and stronger focus on a structured learning approach. CwS draws on increased processing power to achieve its sound processing in real-time – the original sounds are not overwritten – and the focus of CwS is on musique concrète and sound processing rather than synthesis. The DSP sound parameter manipulation window, where breakpoint curves are laid on top of a time-domain display of a sound, has been replaced by a rotating card that on one side shows a picture with a reference to the sound, and on the other a display of static sliders and visual animations that help the student to understand what occurs during sound processing.

While the DSP interface had all the menus included in a game-like window, the interface of CwS combines a screen-based mixer window with conventional top-bar menus, so that users can choose how to operate the program. There are other differences as well, the most important being that CwS adds focus on a more structured learning approach, allowing the teacher to select subsets of functions in the software, and to conduct classes with stricter curricular control.[28] This can be beneficial in classroom settings where the learning goals are more clearly defined, and perhaps more useful in some countries than in others. There are advantages to both approaches, and it will be interesting to see the results as they arrive.

Despite the differences broadly outlined above, DSP and CwS are quite similar programs. It is clear that both point the students towards 'classic' electroacoustic music rather than EDM and similar genres, and both have fixed sound files as the end musical result. They are not oriented towards real-time composition, improvisation and performance, and in this sense they both ignore the real-time possibilities that current computing power easily delivers. Technology-based music has changed, and real-time electronics in semi-composed forms is more currently the norm than the exception. This shift also needs to inform music education; smartphones and tablets are interesting platforms. Finally, considering the time the average student spends with social media daily, it seems impossible to ignore the potential benefits that this type of close communication can bring to compositional practice, with regard to interaction and participation across distance.

CwS has now become integrated into the EARS 2 website, as described elsewhere in this journal, and this inclusion makes it part of the most powerful tool in existence for teaching what initiator Leigh Landy describes as "sound-based music".[29]

NOTAM's immediate plans in the area of educational software aim for a combination of tablet-based computing and live improvisation with a number of signal-processing algorithms, brought into schools using the previously-developed workshop model. Earlier ideas about networked composition for portable computation may expand the project if the first step proves successful. The measures of success would be a sizeable variety of technology-based music from participating schools, systematic observations that confirm high user engagement in the schools, and significant use in other types of settings than formal learning situations. In order to arrive at these results, an iterative design loop will be needed, where user input re-shapes the original ideas, complementing the specialist perspectives.

Without updated music education with research-based focus on the genres of technology-based music, music in schools will clearly lose its relevance for students, and the consequence is that music will not appear to be taken seriously. That may be a loss that we can poorly afford to sustain. ■

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8 L. Cooper, *The Gender Factor: Teaching Composition in Music Technology Lessons to Boys and Girls in Year 9*, in: J. Finney, P. Burnard, *Music Education with Digital Technology*, Continuum, London 2007.
9 See: G. Siemens, *Connectivism: A Learning Theory for the Digital Age*, elearnspace, [www.elearnspace.org/Articles/connectivism.htm, accessed: May 20, 2015].
10 For example, Theresa Dillon notes that there is a distinct lack of research on the interaction processes in semi-formal and non-formal learning settings where computer and music technologies are involved.
11 For a brief overview, see: J. Rudi, *DSP – for children*, 1997, [www.notam02.no/~joranru/DSPforChildren.html, accessed: August 22, 2015].
12 The following algorithms are found in the software: Chorus; Flanger; Delay (including Doppler and resonant filters); Harmonizer; Filter (Highpass, Lowpass, Bandpass and Bandstop); Reverb (constructed through room simulation); Ring Modulation; Sieve; Spectrum Shift; Time Stretch; Granulation; Synthesis (Additive, FM, Plucked String, Buzz, Noise); Recorder; Sound Editor; Reverse; Scratch; Algorithmic Composition.
13 The following tutorial texts are found in the software: *The History of Electroacoustic Music*; *What is Sound?* (simple acoustics, frequency and amplitude); *Sound in the Environment*; *Harmonics and Spectra*; *Sampling* (how sound is represented in the computer); *Synthesis* (musical signal processing); W*orking with Sound vs. Working with Notes*; *Algorithmic Composition*; *Cross-Disciplinary Common Characteristics Between the Arts*; *Real-Time MIDI Performance*; *Technology in Pop/Rock Music*; *Computer Music Animation* (movement through spectra).
14 [www.notam02.no/~joranru/wtca/index.html, accessed: August 22, 2015].
15 *Ceres* was NOTAM's phase vocoder from 1994/5. A brief description can be found on NOTAM's site, [www.notam02.no/web/2006/01/ceres/, accessed: August 22, 2015].
16 J. Rudi, *Computer Music Composition for Children*, "IEEE Signal Processing Magazine", March 2007, 140. This article was written after the launch of *DSP02*. [www.ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4117938, accessed: August 22, 2015].
17 [vbn.aau.dk/en/publications/artfulness-i-laering-og-undervisning(946b684f-7ff7–49dd-87cc-6efe2c54d22b).html, accessed: May 20, 2015].
18 Murray Schafer is credited with coining the word "soundscape", and a good introductory book is *The Tuning of the World*, New York–Toronto 1977.
19 As stated in Janet Mills and Andy Murray, J. Mills, A. Murray, *Music technology inspected: good teaching in Key Stage 3*, "*British Journal of Music Education*", 2000, 17 (2).
20 M. Dunmill, A. Arslanagic, *ICT in Arts Education – A Literature Review*, Te Puna Puoru National Centre for Research in Music Education and Sound Arts, University of Canterbury, New Zealand 2006, p. 57.
21 See: J. Rudi, *Research on education in electroacoustic composition with children – future challenges*, paper presented at the conference *Electronic Sounds in the Classroom*, ZKM, Karlsruhe, April 27, 2013, [www.notam02.no/~joranru/Rudi_ZKM_2013.pdf, accessed: May 20, 2015].
22 G. Siemens, *Connectivsm: A Learning Theory for the Digital Age*, [www.elearnspace.org/articles/connectivism.htm, accessed: May 20, 2015].
23 J. Rudi, P. Pierroux, *Framing learning perspectives in computer music education*, in: R. Dean (ed.), *The Oxford Handbook of Computer Music and Digital Sound Culture*, Oxford University Press, Oxford 2009, pp. 536–555.
24 T. Dillon, *'It's in the mix baby': Exploring how meaning is created within music technology collaborations*, in: D. Miell, K. Littleton, *Collaborative Creativity*, Free Association Books, London 2004.
25 J. Mills, A. Murray, *op. cit.*, pp. 157–181.
26 L. Cooper, op. cit., p. 34.
27 One example is Incredibox, which as of May 2015 is in use at an elementary school in the author's neighbourhood, [www.incredibox.com/, accessed: August 22, 2015].
28 The differences are described in the conference presentation: *Two educational softwares – DSP and Composing With Sounds*, [www.users.notam02.no/~joranru/Vatican%20conf%20DSP_CwS.pdf, accessed: August 22, 2015]
29 See: L. Landy, *Opening the world of organising sounds to young people: EARS 2 and Compose with Sounds*, [www.glissando.pl/en/