

Music-Making and Musical Comprehension with Robotic Building Blocks

Niels Kristian Bærendsen, Carsten Jessen, and Jacob Nielsen

Center for Playware
Technical University of Denmark
The Danish School of Education, Aarhus University
Building 325, 2
2800 Lyngby
nkb@playware.dtu.dk, cje@playware.dtu.dk,
jacob_nielsen@teknologisk.dk

Abstract. Being able to express oneself musically and experiment with music composition is traditionally determined by one's ability to play an actual instrument with a certain degree of craftsmanship. Lack of skills may cause difficulties for children and young people to experience the joy of musical creativity. This paper presents a project where modular robotics is used to create a platform for creative musical expression that allows users to experiment with musical genres without any prior musical knowledge or skills. The project is an example of how to create "intelligent learning material" for educational use.

Keywords: Playware, music technology, music education, music-making, play, learning, constructivism.

1 Introduction

This paper presents a research project on creative music-making and musical comprehension and expression through the use of digital technology integrated in robotic building blocks. It is initiated as part of the continuous research at the cross-disciplinary Center for Playware, where researchers from the humanities, engineering and robotics cooperate closely to create new products for play and playful learning. The project presented here, tentatively named the RoboMusicKids project [1], aims at developing new ways for children to engage in music-making and experimentation by the use of elements from the field of modular robotics. The technology used is intelligent blocks, I-BLOCKS, which are small self-contained computer units that can communicate with each other when physically connected. In the RoboMusicKids project the user is able to create and experiment with musical composition when connecting the blocks in different ways using a multitude of pre-recorded instrumental and vocal figures. The combination of modular robotics and music in RoboMusicKids is in our view a new approach to music making that allows children to learn by doing through manipulation of physical objects and gain knowledge about music in the same natural manner as young children commonly

learn to know their environment through physical interaction. In relation to learning and technology in general, RoboMusicKids is an example of how learning can be transformed by altering the behavior of the objects that we allow children to get their hands on. In the project the objects become what we term “intelligent learning material”, which in use functions just as any other physical, tangible material in the hands of the user, who can manipulate and experiment freely. The pivotal difference in a learning perspective compared to other material is that advanced digital technology and robotics allow us to create physical products with behavior that can be learned through inductive thinking using observation, trial-and-error, and testing of hypothesis, which is a very natural way of learning, according to constructivist learning theory. This means that abstract concepts, models, and theory, which are difficult to explain and understand, can be made tangible and concrete to the learner. When creating intelligent learning material it is important to combine the technology and the specific subject field in such a way that the desired learning outcome will appear.

The RoboMusicKids project is based on the notion that technology, when used in a specific manner, can serve as a gateway into musical expression, experimentation and play, with the possibility of bypassing obstacles which may stand in the way of this in the more traditional musical contexts, such as the need of a certain type of craftsmanship, specific aptitudes or abilities.

In this paper we present our empirical findings from two user experiments as well as some key elements of the projects theoretical foundation. While the technology used in the project plays an important role in making this type of musical experimentation possible, our main goal is investigating new ways for children to engage in music making and the ways in which this was carried out and observed in our research. We will turn our attention mainly towards perspectives concerning musical learning and particularly musical comprehension and musical creativity.

2 Existing Music-Making Technologies and Concepts

Various research projects as well as commercial products exist that combine music making, musical play or other forms of musical engagement with new technologies. While the computer’s potential in regard to music making and musical expression is a fairly well-investigated field, the projects and products we will mention in the following paragraph combine music with technologies and aggregates that we can touch, move around and interact with in a physical space. This specific field has received great attention in recent years resulting in a wide range of products and concepts that present new ways of approaching music-making and musical expression using new technologies, new approaches to design and various sensing techniques.

The amount of interesting projects and products is large and ever growing. We have chosen to point out a few important projects that we believe have had or may have a great impact on future research and our understanding of the ways in which technology and music making can be joined together with great result.

The BeatBug

The Beatbug [2] is a hand-held percussive instrument that allow the creation, manipulation and sharing of rhythmic motifs through a simple interface. Several Beatbugs can be connected in a network, thereby letting the players form large-scale collaborative compositions. The Beatbugs are the end result of a series of projects investigating new forms of musical interaction by the use of technology. Much like the RoboMusicKids project, the Beatbug project is informed by a constructivist approach to learning and a main goal in the development of the Beatbug has been to create an instrument or controller which provides both novices as well as musically adapt users the possibility of expressing themselves through musical composition.

The ReacTable

The ReacTable [3] is a table based tangible user interface with which the user is able to generate and control sound by touching or placing various objects on the tabletop interface. The project is initiated by its creators' wish to create an interface using the advantages of computer technology in regard to sound production and control of the musical output but without the necessity of using usual 'computer tools' such as the keyboard and mouse. While the interface allows for everyone to produce sound, it is a very complex system which requires skill and practice in order to get a feeling of being able to create the exact musical output that one wishes to produce. It is our impression that it is mainly created as an instrument aimed at professional musicians.

Zizzle Zoundz

Zizzle Zoundz is a musical toy with which the user can experiment with music-making by placing various objects one three hotspots on a butterfly-shaped board. Touch-sensitive buttons on the board allow for experimentation with various sound effects, and by placing the differently shaped objects on the hotspots a range of variations are available. Another feature is the possibility of recording your own samples – for instance your voice – and use for experimentation. While Zizzle Zoundz is a toy designed to create playful experiences with musical experimentation it has potential in regard to music teaching as well, offering a simple approach to electronic music-making.

Sony Block Jam

Sony Block Jam [4] is a musical interface controlled by the arrangement of 25 tangible blocks. By arranging the blocks musical phrases and sequences are created, allowing multiple users to play and collaborate. The system takes advantage of both graphical and tangible user interfaces. Much like the RoboMusicKids project, the creators of the Sony Block Jam aim at creating a musical controller which is fun and engaging for both musically trained users as well as beginners, albeit not with a pronounced purpose in regard to music education or learning as such.

While the aforementioned projects share similarities with the RoboMusicKids project, none of them aim specifically towards development of musical comprehension through music making or the integration of a multitude of genres on the same platform.

3 The RoboMusicKids Project

Part of our approach to the RoboMusicKids project was based on a desire to create an alternative way of approaching music-making and musical expression much like in the projects mentioned above. However, we took notice that the musical output the user could create in most of the recent projects in the field was characterized by sounds, melodic figures and rhythms typically found in electronic music genres. We wanted a musical scenario where the user was able to experiment with music from a wide range of genres, including e.g. 1940's jazz, 1970's reggae, 1980's thrash metal and early rock n' roll and rockabilly.

The basic idea behind the project is to separate the components of a musical piece and connect these components to the blocks giving the user the possibility of creating his or her own arrangement of a musical piece by connecting the blocks in various ways. We will get back to how the music is structured after the following, which is a short description of the technology used.

3.1 I-BLOCKS Technology

The I-BLOCKS are cubic modular robotic building blocks that can communicate with each other when physically connected. Each cube is fully self-contained with respect to power, connectors and processing. At the edges of a cube are 4 RGB LEDs, which can light up in different colors. The I-BLOCKS communicate locally via IR-transceivers. Each I-BLOCK makes use of a 3D accelerometer to detect its orientation with respect to gravity. This makes it able to detect, for instance, which side is facing down. The I-BLOCKS connect physically to each other using magnets, allowing for uni-sex connection at 90-degree angles.

The music created by the user is computed and played back on a PC, using the Ableton Live © music software as a playback unit responding to midi messages coming from the I-BLOCKS. In order to allow the blocks to “talk midi” to a PC we have made a wireless device, named “Midi Box” that converts serial wireless data coming from an XBEE-enabled ‘master I-BLOCK’ into midi signals. By using wireless technology we allow users to manipulate the blocks freely just like conventional building blocks.

Note the black master I-BLOCK in figure 1, which communicates wirelessly with the Midi Box, and therefore has to be present in every construction, in order for the PC to generate music.



Fig. 1. Music setup with I-BLOCKS, Midi-box and PC

3.2 The Project's Musical Content

As mentioned, the music that has been produced for the project has been composed using a set of well defined genre characteristics from a selection of music genres. Also the actual recording of the music has been done in the same way or similar to the ways in which music of that particular genre was originally recorded.

The pieces of music in this project have all been constructed using these rules: There are six predefined instruments (varying according to genre) and within each piece of music there are six variations per instrument – one for each side of the block. Every variation on every instrument must fit together rhythmically and harmonically so that every possible composition of instruments will result in a well-sounding outcome. When the user grabs an I-BLOCK, representing an instrument, the block's orientation - which side is facing up - determines the variation of that specific instrument. The I-BLOCK LEDs change color depending on their orientation, in order to make it possible for the user to remember and activate specific variations. Each of the instrument I-BLOCKS has been given a color to represent a specific instrument. For instance, the color coding for a 1950's rockabilly track has been implemented as follows:

Red: Drums

Blue: Double bass

Green: Piano

Yellow: Guitar

Cyan: Lead vocals

Pink: Choir / backup vocals

The music is loop-based, meaning that when active, each variation of each instrument is playing a certain time and then repeating itself over and over until it is finally deactivated when the user removes the current instrument I-BLOCK from the structure or shifts its orientation.

A short example: A user connects a yellow guitar I-BLOCK to the black master I-BLOCK. Immediately the PC-music software starts playing one of six guitar tracks depending on how the block is rotated when connected. Another user might then add a red drum I-BLOCK to the structure, which will additionally initiate a drum track, which is synchronized with the guitar track. More instruments can be added, and others removed, and all instruments will constantly be in sync. If the user chooses to rotate the entire structure, all the instruments present will start playing a different variation.

This manipulation with musical pieces is a kind of “sampling in real time” which is known from music software on computers (e.g. Ableton Live and Garage Band). The difference between such software and RoboMusicKids is, of course, the physical building-blocks that allow for a more intuitive hands-on approach.

4 User Experiments

During the development of the music integrated in the I-BLOCKS we ran a number of tests and experiments in order to figure out how users responded to the music as well

as the way in which the blocks enabled them to navigate this. The following section focuses on two experiments carried out in an after-school centre and presents some of the observations we made in the execution of these.

4.1 After-School Experiments

The experiments at an after-school centre were of an explorative nature, as our focus was towards discovering ways to improve both the music implemented in the I-BLOCKS and ways to experiment with this as well as discovering the projects' potential regarding musical comprehension and musical creativity. The participating children, aged between 10 and 12, were divided into groups of four. Some of these groups consisted of only boys or girls and some were mixed groups. Some of the children had prior experience with formal instrumental music tuition while others had little or no experience. All group sessions were recorded on video.

The following is a description of some of the main findings as observed in the participants' use of the I-BLOCKS. In this description an overall pattern regarding the structure of events observed in each session is presented, serving also as a possible outline of the learning process among the participants.

4.2 User Sessions and Their Overall Structure

Reviewing the recorded sessions, we were able to divide each group session into three steps or phases. As hinted above, the mentioning of these steps serves as a description of the actual use of the I-BLOCKS as well as a framework for the later mentioning of perspectives in regard to music-making and musical experimentation with new technology. The three steps observed in the experimental sessions are as follows:

1. Exploratory use. Together as a group the children explored different ways of connecting the I-BLOCKS and the different musical segments and variations that resulted from this. This step was characterized by the children's fascination of the technology itself and the fact that by combining the I-BLOCKS they were able to initiate music. Everyone in the group would at this point actively connect and disconnect blocks and turn the structure around in an exploratory manner. No particular interest in the qualitative musical output and the actual combination of instruments and musical loops was apparent. The main interest among the children at this point was to activate and "check out" the different loops, and - to a certain degree - find out which colors represented which instrument or sound.

As in many other regards, exploration of something - for instance a toy that one is not familiar with - is a natural approach. Therefore the explorative way in which the participating children approached this new toy was to be expected. What we saw was children employing the basic learning principles, which leading education theoreticians like Piaget, Dewey, and Vygotsky have described as, for instance, "active learning", "hands-on learning" and "experimental learning", and which they have pointed to as fundamental for children's learning. Of particular interest is the observation of cooperation as well as turn-taking among the participants during their further exploration and music-making, as described in the following.

2. Collaborative music-making. Following the exploratory phase, the children started to pay more attention to the actual musical output of their collaborative use of the I-BLOCKS. Typically this involved discussion among the participants regarding which instruments were audible during their construction of a structure and which variation of this particular instrument they preferred. Typically one participant would start off by connecting an I-BLOCK as a starting point, choosing a loop that they were particularly fond of. Another participant would connect another block, choosing a loop which they felt accompanied the first loop. From here on the group would experiment with the different loops and the structure of the blocks. At times this involved turning the entire structure around and thereby changing the entire musical output, and at other times turning single blocks, changing only the musical output of this particular instrument. The music-making and the learning approach in this phase was still very much a collaborative effort, but did, however, at this point involve a key element of turn-taking allowing the participants to single-handedly control the blocks and the position of the structure, having the other participants suggesting changes and supplying ideas.

3. Individual music-making. In each session we encouraged the participants to create their own musical piece or “mix”, having complete control over the blocks. At this stage it was particularly clear that I-BLOCKS served as a useful tool for musical expression, composition and performance. To a varying degree the participants would examine each block to choose the loop they wanted to use and be very selective in this process. Often they would leave one or two blocks out of the mix in order to receive the output or sound they wanted, avoiding the overall mix getting clustered or “muddy”. Some participants would start off by creating a combination of instruments and loops that they found fit together and subsequently change the entire structure, serving as another development of the song or tune. This resulted in a series of combinations of loops compromising not just a single mix but several developments of a tune.

A striking observation made during these experiments was that every participating child was able to create a well-sounding and personal musical piece within the short time of a session (lasting approximately 15 minutes). Everybody participated in collaborative as well as individual music-making and completed the task of creating a mix of their own regardless of their prior experience with instrumental music tuition.

5 Music-Making with New Technology

Traditionally, being able to express oneself musically and engage in musical activities involving the production of sound, is somewhat determined by one’s ability to play an actual instrument. In order to produce sound with an instrument one must possess a minimum of skills in regard to the actual handling of the instrument. In order to compose or in other ways carry out musical ideas a certain degree of craftsmanship and experience is needed [5] and this is a hindrance for most children, who for that reason might not experience the joy of musical performance and creation.

As technological development and research generates different possibilities in approaching music-making and musical experimentation, new paradigms of musical expression, comprehension and creativity are formed. While technology plays an important role among musicians, e.g. in regard to recording music or performing music utilizing different technological tools, the development of computer software designed for music production and creation (Steinerg Cubase, Apple Logic etc.) as well as different types of midi controllers (e.g. midi keyboards, electronic drum kits, Korg's Kaossilator and new interfaces such as The Samchillian, Monome, Beat Bugs etc.) has had an important impact in regard to musical play among children and in music teaching in general. In the following we wish to point out some of the possible advantages linked to the use of new music-making technologies, both in music education and out of school.

Norwegian professor of musicology and music education, Petter Dyndahl, has emphasized how "new" technology, for instance sequencing software or the midi standard as such, has made new ways of approaching musical creativity possible. According to Dyndahl a digital representation of music on a computer allows us to "mould directly" in the authentic, timbral substance [6], which brings to mind conceptions of music as a physical, moldable object. Like modeling-wax – flexible and manageable in the hands of the user. Sequencing software, for instance, allows us this kind of flexibility. We can record music of our own, sample existing recordings and manipulate sounds in an infinite amount of ways. Utilizing technology in the creation of music, we may experience a shortening of the distance between an idea and its actual aural representation. In fact, technology may even allow the non-musician access to a creative process involving music in ways previously unimaginable.

Professor of music education and technology Peter Webster has described creative thinking in music as a creative process in which we engage via either enabling skills or enabling conditions or both [7]. Webster's thinking can help us illustrate how music technology may help us gain access to a creative process which may reveal certain talents otherwise hidden. By using the term 'creative' we are referring to the process of creation as such and not focusing on the actual end product and any form of valuation of this. 'Creative' is not to be mistaken for 'original' or 'unique'. This view is informed by Ignacio L. Götz's definition of creativity [8] which describes creativity as the very process of making, placing it at the final stage of Graham Wallas' famous four stages describing the creative process: preparation, incubation, illumination and verification [9].

Webster uses Wallas' stages as well: in order to gain access to this creative process we need a way in. Traditionally, what we need in order to be able to be musically creative is *enabling skills*. This could be a range of aptitudes such as certain sensitivity towards rhythmic or tonal patterns and movements or the ability to express ourselves in an original manner or be very flexible in our approach to music making and our playing. Another enabling skill is craftsmanship; the ability to sing or play a musical instrument at a certain level, which is perhaps the main enabling skill in this regard, while the above mentioned aptitudes serve as further developments of our musicality alongside craftsmanship. Yet another enabling skill is a well developed aesthetic sensitivity.

Another way of gaining access to the creative process is through the *enabling conditions*. These may be certain aspects of our personality or motivational factors. The environment is a crucial element as an enabling condition as it contains a long list of outside factors that may influence us, inspire us, motivate us or in other ways enable us to be musically creative. Parents, friends, teachers, equipment and technology are parts of this category.

Looking back at some of the results we obtained from our user experiments, a key discovery was that every participant, regardless of his or her musical background, was able to engage in the creation of a musical piece and apparently feeling joy doing so. The blocks served as a piece of music technology which made it possible for the users to be musically creative – to make music, certainly within the limits of the pre-recorded music we made for the blocks, but still they were able to make their personal musical pieces. An interesting aspect in regard to this is the question as to how children who normally do not engage in music making activities at home or in school may reveal certain aptitudes such as originality or flexibility in their musical expression or a well developed aesthetic sensitivity when utilizing musical toys or other kinds of music technology. When the need of a certain kind of craftsmanship in order to make music is eliminated certain aptitudes and skills otherwise hidden may reveal themselves. The music teacher may realize that pupils, who have troubles developing instrumental skills or may lack interest in taking up an instrument, actually possess skills in regard to knowledge of musical genres, having a well-developed sense of aesthetics in music or being very original in their musical expression when utilizing “untraditional” tools in their creation of music. While our user experiments hinted towards this as a possible outcome additional studies which focus on this exact issue are needed in order to draw further conclusion in relation to this.

While projects such as the aforementioned Beat Bugs or ReacTable allow the user to create rhythmic patterns or experiment with harmonic and timbral sound material, the RoboMusicKids project aims at allowing children to experiment and manipulate with pre-recorded musical sequences or elements, reminiscent of the way a DJ remixes existing tracks. The I-BLOCKS serve as a multi-track mixer giving the user complete control over the progression and overall mix and arrangement of the track. Furthermore, I-BLOCKS allow the user to isolate the separate elements of a musical piece, making it possible for him or her to understand the sound and musical role of different instruments, both in regard to musical arrangement and mix and in regard to music history, traditions of musical genres and sub-genres, technological possibilities in connection to studio equipment and the recording of music and so forth.

6 Perspectives on Learning from a Constructivist Viewpoint

In the development of the idea behind the RoboMusicKids project a main inspiration in regard to creating educative experiences for children has been Seymour Papert’s writings and experiments in the field of computers as an educational tool and his LOGO programs and concept. We find his use of Jean Piaget’s theories about learning and understanding to be a key element in a theoretical foundation for a constructivist approach to the development of educational learning products.

A keystone in this approach is the notion that in order to learn and gain knowledge about something children must be able to experiment with different materials and be able to construct meaningful artifacts as part of this. Papert himself showed this in his many experiments involving children's use of the well-known LOGO programs and their construction of different technological inventions and aggregates [10].

Piaget's theory on adaption as a learning principle and learning as an individual process is the point of departure in Papert's work and a theoretical base upon which educational practice can stand. What we learn and how we learn depends on what we know and what we have experienced. According to Papert, we should make room for our pupils to address problems in various ways in the classroom, making use of what they know and do in order to solve problems and gain new experiences and knowledge as part of the process. Being able to use the enormous amount of knowledge and experiences obtained in 'informal' learning situations out of school is important in this regard. Papert points to drawing as an example of a practice that often is a part of children's play which they may use to solve different kinds of problems and tasks in a school context when given the opportunity to do so, and in the LOGO program drawing is used brilliantly as an entry point to math learning [11].

The I-BLOCKS used in the RoboMusicKids project share similarities with certain kinds of toys, such as building blocks or LEGO, which children typically have had experiences playing with, hence our description of the interface as 'intuitive'. While computer software may require quite a bit of practice to get used to using, the blocks are self-explanatory, inviting the user to start building. We need not explain to the children how to use the blocks to build a structure. They already know; it is a part of their play culture. As a result of this, their attention is drawn towards the music making and the musical choices they make as part of this creative process. Not towards the technology or tool itself.

While Papert has served as an inspiration to our research, the RoboMusicKids project differs from Papert's work in (at least) one significant way: The Logo program is based on an approach which involves planning and programming as stages to be completed before achieving an actual result: write code first, watch the result afterwards [10]. When using the blocks to make music you receive an immediate result while you change the direction of the blocks or the entire structure that you have built, hence the "sampling in real-time" mention earlier. This approach is also the reason why one can talk about the music as a parallel to "modeling-wax".

7 Conclusions

I-BLOCKS make it possible for the user to rearrange and manipulate musical elements and create a musical output. In our experiments we found that the participants were aware of how they wanted their finished musical piece to sound, and were very selective in the process of "building" this.

While music technology in some cases holds the risk of allowing us to simply generate a musical product and bypass the actual creative process, our experiments showed that even when utilizing prerecorded music in a basic setup of six variations on six different instruments, the participants were still able to express themselves creatively.

Utilizing music technology in music education and out of school may give children, or adults, the opportunity to be musically creative and create understanding of musical phenomena and structures. I-BLOCKS represent an intuitive approach to music, both in regard to musical expression as well as musical comprehension and understanding. In the hands of the user, the I-BLOCKS turn music into a moldable element, allowing the user to explore its possibilities in a creative and playful way and serve as an intelligent tool that is manageable and flexible in regard to its user's approach to creativity and learning.

References

1. Nielsen, J., Bærendsen, N.K., Jessen, C.: RoboMusicKids - Music Education With Robotic Building Blocks. In: Proceedings of the 2008 Second IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, pp. 149–156 (2008)
2. Weinberg, G.: The Beatbug – Evolution of a Musical Controller. *Digital Creativity* 19(1), 13–18 (2008)
3. Jordà, S., Geiger, G., Alonso, M., Kaltenbrunner, M.: The reacTable: Exploring the Synergy between Live Music Performance and Tabletop Tangible Interfaces. In: Proceedings of the first international conference on Tangible and Embedded Interaction (2007)
4. Sony Computer Science Laboratories, Inc.,
<http://www.sony CSL.co.jp/IL/projects/blockjam/>
5. Folkestad, G.: Computer Based Creative Music Making: Young People's Music in the Digital Age. *Acta Universitatis Gothoburgensis, Göteborg* (1996)
6. Dyndahl, P.: Music/Technology/Education. On Digitised Music Education, its Discourse and (Self-)Irony (in Norwegian) University of Oslo, Oslo (2002)
7. Webster, P.R.: Conceptual Bases for Creative Thinking in Music. In: Peery, J.C., Peery, I.W., Draper, T.W. (eds.) *Music and Child Development*. Springer, New York (1987)
8. Götz, I.L.: On Defining Creativity. *The Journal of Aesthetics and Art Criticism* 39(3), 297–301 (1981)
9. Wallas, G.: *The Art of Thought*. Harcourt Brace Iovanovich Inc., New York (1954)
10. Papert, S.: *Mindstorms - children, computers and powerful ideas*. Basic Books, New York (1980)
11. Papert, S.: *The Children's Machine*. Havester Wheatsheaf, Herthfordshire (1993)