MusicBlocks: An Innovative Tool for Learning the Foundations of Music

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Abstract: The Italian National Guidelines (Miur, 2012) and in particular the legislative decree no. 60 highlight the competencies in the artistic and expressive field which students must acquire by the end of the first cycle of education. Indire in collaboration with the Italian Ministry of Education started research activities in order to support music teachers in the teaching activities and in the implementation of best practices in their classes. The research presented in this paper results from listening to teachers' needs. It describes the ideation, realisation and future developments of the experimentation of MusicBlocks: a tool patented by the research group, which enables tangible music production, overcoming the difficulties deriving from learning how to play a musical instrument. MusicBlocks is an easy-to-use tool due to its structure especially conceived to be used by students as a stand-alone tool. Students can compose their own melody and listen to its execution by laying Lego® bricks. If this does not provide practical help to learn how to play an instrument, it surely helps to acquire the propaedeutic competences: rhythm, melody, and harmony, which are necessary in order to develop an interest in playing a musical instrument. Experimentations with MusicBlocks are currently undergoing in lower secondary schools, receiving a high degree of interest and appreciation from students and teachers.

1 INTRODUCTION

According to the "National guidelines for the curriculum of infant schools and the first cycle of education" (Miur, 2012), some of the basic concepts of foundations of music: rhythm, melody, and harmony can be studied and understood since the first cycle of education. Clearly, these are abstract concepts that can be exemplified only by direct participation and experience. In this context, supported by a wide literature about hands-on activities (Papert, 1984) and ludic didactics (Rogers, 1973), the development and design of an innovative device for the learning of music concepts has been carried out. In the first part we are going to present the theoretical basis of active and music didactics and an excursus on the regulations and initiatives promoted by the research group in collaboration with the Italian Ministry of Education for the acquisition of skills in the field of music and the promotion of innovative teaching methods. In the second part we will deal with the development and design of a device called MusicBlocks. Through a simple and interactive interface it enables students to compose their own melody without the need to be able to play musical instruments, giving them the possibility to focus on the theoretical basis underlying music. Therefore, the strength of MusicBlocks is its capacity to make musical composition visual, which helps to become acquainted with the fundamental principles of music in an intuitive and engaging manner.

1.1 Laboratory Teaching as a Method to Develop Music Competences

Referring to Piaget's theory of cognitive development already at nursery school and in the first years of primary school, children are able to use symbols and refer to symbolic play as a tool to socialize and represent the world. They are therefore capable of substituting an object to represent other things and their playful activity is enriched with symbolic addition capacities. According to Piaget, older children, up to lower secondary school, in the "concrete operational" stage, show the ability to operate logically on previously acquired symbolic mental structures, and what is more, they also acquire the principle of reversibility so that it is possible to go back from certain actions with the same but inverse operations. In this sense, it seems important to consider the practical and theoretical structure of con-

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structivism that originates from Piaget's works, according to which knowledge is actively constructed by the learner and cannot be passively transmitted by the teacher. The concept of "learning by doing" is especially powerful. This is justified in Piaget's studies, according to which formal thinking, acquired from the age of 11 onwards, retraces the stages of concrete thought, which is characteristic of the previous cognitive stage, but at a hypothetical-deductive, non-verbal level. From this analysis emerges that the concrete operations are a previous conquest with respect to the hypothetical-inductive operations, and therefore more deeply rooted in the individual (Valentini and Tallandini, 1998). In 1984, Papert proposed an evolution of Piaget's constructivism according to which the learners themselves contribute to building concepts by interacting with appropriate materials, called cognitive artefacts, which, used in a cooperative environment under the guidance of the teacher, facilitate learning (Papert, 1984). The manipulation and use of artefacts enable to face up to the problem of the contextualization of knowledge (Merlo, 2017). As further confirmation of what stated above, in the 1960s, cognitive didactics developed, and Ausubel's theory of "meaningful learning" was developed (Ausubel, 1968). Capuano and colleagues, describe the effect of a deep learning "In short, meaningful learning enables students to become strategic, through the development of skills of a metacognitive (learning to learn), relational (knowing how to work in a group) or attitudinal nature (autonomy and creativity)" (Capuano et al., 2018, p. 9). The meaningful construction of knowledge occurs when students are placed in a position to experiment, move autonomously within a discipline, act together in a relationship of mutual exchange, shared reflection, dialogue and negotiation with others (Jonassen et al., 2007).

1.2 Ludic Didactics

Playing and its more scientific and pedagogical framework as ludic didactics is one of the ways in which "meaningful learning" takes place (Rogers, 1973; Cairo, 2012; Rizzo, 2014). With this term we intend to refer to holistic learning (that is, investing the affective and emotional dimension of the subject, not only the knowledge sphere), which is strongly based on experience and capable of stimulating the learner's interests. Being this kind of learning directly linked to the learner's interests, it is also self-motivated and self-evaluated: the interest is in playing itself and the objective is to play. Ilaria Sudati presents the application of the ludic theory to Italian language teaching and learning in adults (Sudati, 2014). Caon and Rutka define the ludic method as, in essence, able to create meaningful learning, by stimulating aspects of motivation, learning by doing, collaboration and implicitly autonomy, reflection, and cultural difference (Caon and Rutka, 2004). Krashen, as reported in (Sudati, 2014), states that "one learns a language better if he/she forgets that he/she is learning" (Krashen, 1983, p. 213). Making a parallel between language and music is easy, as well as regarding the variables in their learning process: language has the alphabet, music has notes; language is written according to syntactic and logical rules, music has a grammar made up of the duration of notes and beats. Therefore, the same considerations expressed before find a correspondence in the learning style of music; and the ludic component and learning by playing are relevant also in this context.

1.3 The Evolution of Music Teaching

The 1980s saw important changes in the field of music pedagogy and didactics. An innovation in teaching, focusing on creativity, enhancing the musical improvisational and compositional act as fundamental for an organic development of musicality and skills can be find in (Delfrati, 1979; Porena, 1979; Piazza, 1979; Piazza, 1984; Addessi et al., 1996). Music education was seen from different angles, such as the linguistic connotation (Della Casa, 1985), semantic-cultural (Stefani, 1982), and semantic-communicative perspectives (Baroni, 1978). In (Addessi and Piras, 2020) a recent analysis of the evolution of teaching starting from the 1980s is reported. More recently Enrico Bottero and Irene Carbone proposed Bianchi's experience and his vision of creativity and didactics of music that "aim to form the bodily, sensorial and perceptive foundations of basic education. They aim to strengthen the pre-categorical foundations that are also useful for other school disciplines and activities: the learning of reading and writing, linguistic expression, mathematics, etc." (Bottero and Carbone, 2003, p. 15).

1.4 Application of Ludic Tools (Lego) to the Didactics of Music

In the 90's, on the basis of Piaget's constructivist theory, Papert's constructionism and Frank R. Wilkons's hand-mind relationship, Lego proposed the method Lego Serious Play, a transversal method which starting from a real problem guides students, but also adults, in the construction of a narrative experience which leads to the personal solution of the problem. The Lego bricks work as a catalyst, as a tool to "think through your hands" which is in fact the slogan of the method. Thus, we find examples of the use of bricks for the study of science and physics in (Campbell et al., 2011; Börner, 2007; Celli and Gonella, 2015). In (Salmaso, 2013) and (Salmaso, 2014) experiences in primary school - where Lego bricks have been used for the development of visual-spatial and planning skills, also in an inclusive and gender-equal perspective - are presented. Lego bricks are then routinely used in coding and educational robotics activities, while online different experiences of using bricks in grammar and logical analysis are told, as personal initiatives of teachers[1], as well as in the animation of stories and storytelling[2]. Oestermaier and colleagues presented an application for an interactive multi-touch table, which exploiting transparent grids and Lego bricks enables children to create a music composition: the "LEGO music learning composition with bricks" (Oestermeier et al., 2015). A software approach which encourages computational thinking was designed by the University of Milan, (Ludovico et al., 2017; Baratè et al., 2017). They developed a "Multimodal LEGO - Based learning activity" where elements of the domain of music and information technology are mixed together. The learning activity includes also a web application to support this approach which foresees the disposition of bricks in a delimited area, including also the third dimension, in order to organise multiple melodic lines. Matthew Shifrin, (Mattheij, 2022), a visually-impaired English musician and singer, has devised a methodology for the study of rhythm, pitch and duration of sounds which involves the use of Lego bricks arranged on a plate of variable dimensions, used as an alternative stave in which the abscissa represents the passage of time and the ordinate the pitch of the sounds. The dimensions associated with the colours of the bricks represent the durations of the sounds.

1.5 Guidelines and Ministerial Initiatives

Since 2012, Indire (National Institute for Documentation, Innovation and Educational Research), a research body of the Italian Ministry of Education, has conducted research activities in the field of music education, through a series of projects in order to promote the dissemination of musical practice in schools of all levels: in particular vocal and instrumental practice for the first cycle of education, new technologies, and music for upper and lower secondary schools, documentation and dissemination of best practices on music teaching and skills related to the field of music listening. In the context of laboratory teaching and innovation of the curriculum in the artistic-expressive area, in recent years, Indire has achieved a series of significant experiences in terms of commitment and results: from the documentation and sharing environment "Music at school"[3] to the 31st National Music Festival "Music unites schools"[4]; from the imagination and development of innovative prototypes to the broader integration of music education in the context of the plan for the arts. The guidelines for experimentation led by the Ministry of Education have been clearly expressed in a series of legislative acts that have promoted the prospect of the gradual inclusion of musical practice in the core curriculum of all students: the Decree of the Minister of Education no. 8 of 31 January, 2011[5] , and the national guidelines for the curriculum of infant schools and the first cycle of education. More recently, the Legislative Decree of 13 April, 2017 no. 60, "Regulations on the promotion of humanistic culture, on the enhancement of cultural heritage and productions, and on the support of creativity"[6], introduced the "Themes of creativity" as fundamental components of school knowledge, of the wealth of intellectual knowledge of every human being, and therefore of the curriculum itself. They make use of the help of technological innovation and involve four areas: music and dance; theatre and performance; arts and visual arts; language and creativity.

2 RESEARCH FRAMEWORK

Starting from what Shifrin proposed in his research, i.e. the use of a Lego plate and bricks as placeholders for the notes, Indire conducted a study and technological research activity for the implementation of a computer-based tool that could automatically reproduce the melody starting from the reading of the plate duly populated with bricks. The research idea that guided the development of MusicBlocks derives from the analysis of the literature (as indicated in Section 1.1) and from the considerations that arise with respect to learning methods in collaborative and manipulative contexts, and also from the experience gained by the research group regarding the problems

[1] https://portalebambini.it/analisi-logica-con-i-lego/ and https://youtu.be/T2LdyYOdfoY

[2] https://codingerobotica.indire.it/uploads/CODINGEROBOTICA/CONTRIBUTI/galati_1.pdf

[3] https://musicascuola.indire.it/

[4] https://lamusicaunisce.indire.it/

[5] tinyurl.com/yddukmhp

[6] https://www.gazzettaufficiale.it/eli/id/2017/05/16/17G00068/sg

that music teachers must face in the classroom with respect to the teaching of certain concepts. With MusicBlocks, we tried to encourage the aspect of manual skills even in a field where the subject is actually purely abstract and not tangible, such as notes and melody, where the main sense involved is generally not the touch but the hearing. Therefore, just as a musical instrument needs hands (or other parts of the body) to produce music, MusicBlocks was created with the aim of making musical production tangible, trying to manage the difficulties that arise from learning to use a musical instrument. If this is not a practical help in learning to play an instrument, it is certainly helpful in acquiring the preparatory skills: rhythm, melody, harmony, necessary to develop interest in music. Starting from these premises, the research was based on two different aspects. The first concerns the technological realisation of an educational tool for learning the fundamental principles of music according to the goals, skill and competences as described in (Miur, 2012, pp. 71-75). It combines playful aspects (in particular the coloured bricks) with educational aspects (in particular, in addition to the musical aspects, problem solving and the learning by doing approach). The other aspect concerns the pedagogical application that the use of this tool can have in the classroom and the implications in terms of achieving specific competence goals and learning objectives for primary and secondary schools.

3 MusicBlocks

MusicBlocks (Fig. 1) is a tool based on an open-source architecture (Raspberry PI and software in Python) that uses Computer Vision software to transform the image of an alternative stave (acquired in real time) into a melody.

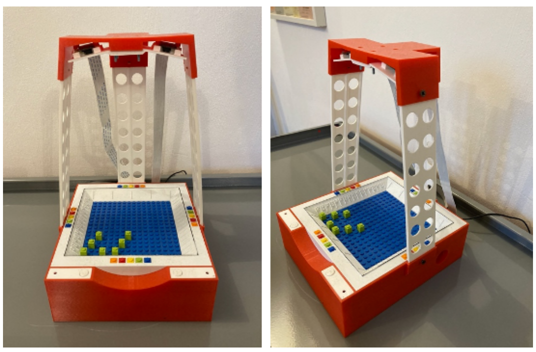

Figure 1: The final prototype of MusicBlocks.

This tool is designed to allow students to compose their own melodies, to activate the competences according to (Miur, 2012) and linked to the objectives to be achieved in the first cycle of education. The use of MusicBlocks is very simple and intuitive: the bricks represent the duration of the sounds, their position on the plate represents the notes (pitch) and the playing time. Once the students have placed the bricks on the board, by pressing the Play button, the MusicBlocks will process the composition and play it as a melody. This melody will be repeated cyclically until the Stop button is pressed. MusicBlocks consists of a base about 10 cm high that contains all the hardware of the device, well hidden to ensure adequate security. Housed on the base in full view and easily accessible, there is a removable plate which is the work area. It is the alternative staff on which students can work on creating their compositions. Finally, on the edge near the plate, there are two buttons and a LED light. Above the plate, at a height of about 30 cm, there are two cameras, mirroring the base and inclined by 30 degrees. Their function is to capture the plate on which the students will place the Lego bricks from two different angles, to obtain an adequate redundancy of the data in order to overcome the problems caused by light gradients or reflections. On the right side of the base are the connectors for recharging the battery that powers the device and for connecting it to the LAN network and the knob to increase or decrease the sound volume.

MusicBlocks is not just a physical device, it also comes with a cloud platform on which every performance is stored and easily accessible via a web browser. The online environment, as well as acting as a repository for the teacher, who can therefore control the students' work from the image of their composition to its sound performance, also has the characteristic of reproducing the composition virtually, showing the progress of the performance through a timeline and also its transposition into traditional musical notation.

3.1 MusicBlocks Features

For the realisation of the working area it was decided to use a Lego plate of 16x16 pins. Imagining the plate as a system of classical Cartesian axes, the y-axis shows the notes (16 possible notes considering the semi-tone) that vary gradually from C at the lowest point of the diagram to D#, of the next octave, at the highest point, depending on the height the brick is placed, while the second (x-axis) represents the time on which the notes unfold, expressed as 4 bars of 4/4 each (Fig. 2).

The bricks used in the musical composition represent a duration and are therefore of different lengths:

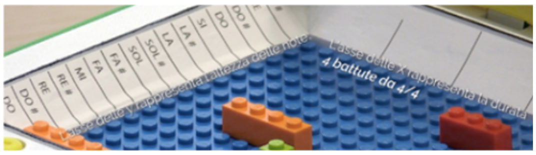

Figure 2: Detail of the plate and musical notes in Italian notation.

1/4, 2/4, 3/4 and 4/4. In addition, to make the recognition of their duration visually faster, it was decided to use different coloured bricks for each type (Fig. 3).

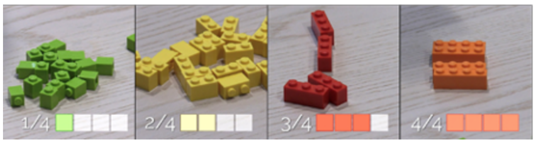

Figure 3: Examples of bricks.

The arrangement of the bricks in the MusicBlocks plate makes it possible to transform durations into sounds. As soon as they are placed in relation to the base representing time, at a specific pitch, they acquire the meaning of musical notes. Once students have completed the free arrangement of the bricks on the plate, i.e.on the alternative stave, pressing the Play button allows you to immediately listen to the performance in a continuous loop. The Stop button, on the other hand, interrupts music playback. MusicBlocks is then automatically ready to handle changes to the arrangement of the bricks and a new playback. As indicated in Section 3 and in Section 3.3, a cloud environment has been created, accessible through the WiFi network connection provided by MusicBlocks itself (i.e. even without an active Internet connection), in order to store every single compositional "performance" and eventually to be able to:

- view an image of the plate and the bricks as it was composed by students;
- listen to it again or download it in mp3 audio format;
- listen to the melody by displaying on the plate the timeline of the notes played and at the same time the transposition of the melody using traditional musical notation (stave);
- rename the performance and change the musical tempo (bpm) of the playback.

3.2 Design and Technological Solutions

The research activity relating to the technological development of MusicBlocks involved two phases of work. The first concerned the construction of a prototype device, i.e. the design of the object, which involved various development phases aimed at optimising the final result, and the choice of the most convenient hardware solutions in terms of cost and performance. The second phase concerned the development of the software for transforming the physical composition into a melody, which also involved various phases of refinement in order to be able to model even less efficient lighting situations. In the development of the software since we were working on images intended as a matrix of pixels without any information at the context level, we used advanced techniques of image processing and Computer Vision as object detection operations and image classification.

3.2.1 Design Phase

The design of MusicBlocks and its realisation represented an important work of research and development because there was no device similar neither for functionality nor for architecture in literature and in the market. Consequently, the physical design of the instrument was a long process of realization and revision, starting however from some considerations shared by the research group on the characteristics that it should have satisfied. In particular, the following requirements were identified:

- ease of use;
- the reduction of the complexity for users;
- a wide and practical access to the area of manual interactions;
- the use of standard bricks that do not require any modification with respect to those on the market;
- total safety in the use of the product;
- high ease of transport;
- the possibility of operating without any kind of physical connection (i.e. without connection to the electricity network or a LAN);
- open-source architecture and software;
- low implementation costs.

Ease of use is the requirement that has guided the entire design in practice. In fact, the product is extremely simple and designed for minimal user interaction: in addition to the positioning of the bricks, there are only three buttons to interact with (power, play, stop), while the technology is hidden from the user. In order to meet the other criteria, MusicBlocks was designed as a stand-alone product, i.e. autonomous and without the need for additional third-party supports to operate or special maintenance and/or precautions. In the initial prototype, to make it easily transportable and safe to use, a box-shaped structure with a lid was designed, later replaced by an open version without a lid to better manage reflections due to external lighting. MusicBlocks was born as an open-source device that could be easily replicated by anyone. With a common 3D printer, it is possible to print the various parts that make up the external structure of the device: in particular, the lower part, consisting of a hollow base with accommodation for hardware and the Lego composition plate. In the lower part of the box are housed (invisible to the user) all the hardware components necessary for operation. In order to share the project with schools and teachers, each component has been chosen to be easily available on the market and at a relatively low cost. As mentioned above, the design of the MusicBlocks has undergone many changes over time, as the experiments conducted on each sample led to the identification of some defects that could not be overcome by software.

As shown in Fig. 4 we passed from a very first example of a stand-alone plate with camera support (Fig. 5), to a closed version with lid and one camera (Fig. 6), to a version with lid but two cameras, to the final version without lid and with two cameras perpendicular to the base and positioned in the middle symmetrical to the plate (Fig. 1).

The final prototype adopted in the first phase of experimentation, therefore, consists of a Raspberry Pi 3B+, an Arducam shield for the dual camera, 2 Raspicams, an audio amplifier, two mini speakers and a power bank.

3.2.2 Hardware Equipment

Among the requirements identified in the early stages of design, as indicated in Section 3.2.1, particular importance was given to these three aspects: the selection of hardware components especially regarding to the speed of execution, i.e. the time that elapses between when the play button is pressed and when the melody is played; the ability to use MusicBlocks even without connection the mains ; and the design in order to have a device easily to be transported. Although the possibility of using an Arduino-type electronic prototyping board as the core of the project was initially considered, as it allowed for the management of a number of external devices, it soon became clear that in order to optimise the execution time of the image-to-sound transformation software, i.e. the processing time, higher performance in terms of computing power and different hardware set-ups were required. For this reason, the choice fell on SBC (Single Board Computer) solutions, which have been on the market for several years and have already been partly tested in other Indire research projects. The board chosen to implement the software and manage the hardware components was the Raspberry Pi 3B+ because it has a series of fundamental characteristics: first of all the possibility to be powered by a standard power bank (like those for mobile phones), moreover with 1.4GHz frequency, 64 bit, 4 cores and 1GB of RAM it guaranteed a computing power adequate to the needs of the project, it had limited size and cost, a wide range of connection types (WiFi, Bluetooth). Raspberry has a very active online community and therefore has a wide range of software, libraries and documentation that have been extremely useful to support the development of MusicBlocks facing problems in the development. Starting from this board, therefore, all the other needed components were identified: the cameras are Raspicam v.2.1 (natively compatible with the main board), a 20,000 mA power bank sufficient to power the circuit for many hours and an audio system consisting of a small amplifier and two speakers. In addition to this, other electronic components were used to build the interface, such as the two main buttons, the two LEDs, cables and resistors. Since the Raspberry Pi board does not have a power button but the system starts up when it receives power and the shutdown phase has to be initiated by software interface, the problem had to be addressed and in the last prototype it was solved by software. While the development of the first prototypes, which included a single camera, did not bring any particular complications at the hardware level, the development of the last model with a double camera has involved a further phase of study and experimentation because the Raspberry Pi board provides for the management of a single webcam through a hardware interface and, in order to keep costs down and still ensure a good execution speed (which in the case of stereo image acquisition involves a double processing), the possibility of using USB webcams, which are generally slower, more expensive and with lower definition levels, was excluded. The problem was overcome by using the Arducam shield, which, born in the context of video control systems, is able to connect up to 4 Raspicam directly to the only port available on the Raspberry Pi board.

3.2.3 The Implementation Phase

The software of MusicBlocks can be divided into three parts: the first concerns the management of hardware components (i.e power on, power off and connection with the webcams), the second concerns the processing of images and the encoding of the stave in a MIDI file (Fig. 7), the third one manages the execution of the MIDI file.

Leaving aside the algorithms for the management of parts one and three, which do not present interest-

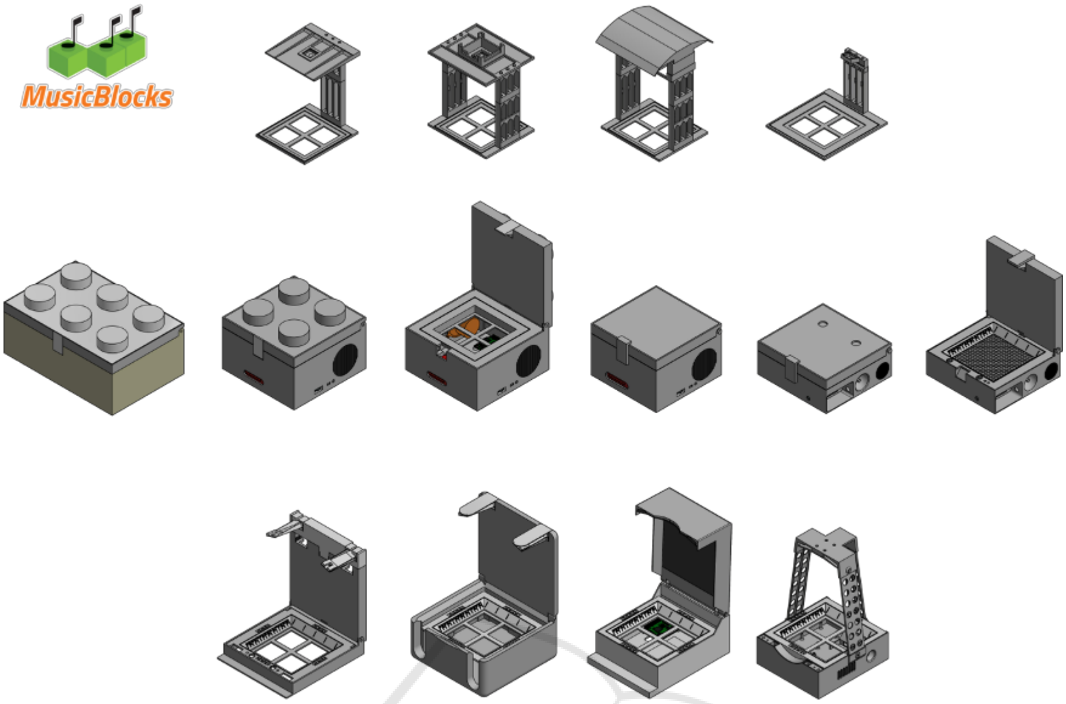

Figure 4: Evolution of MusicBlocks design.

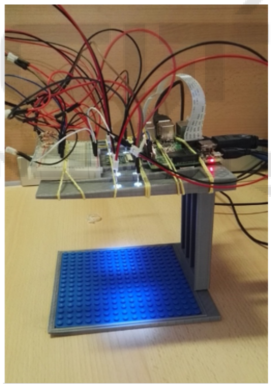

Figure 5: First example of MusicBlocks.

Figure 6: MusicBlocks with lid.

ing research elements, but are simply operational, let us see in detail the functioning of the processing starting from the acquisition of a left (ImL) and a right (ImR) image of the plate, that are specular in position and perspective distortions. Fig. 7 shows a high-level but exhaustive diagram of the software blocks and operations involved. Before proceeding to the actual processing, the images are binarized, processed by means of the Canny Edge detector (Canny, 1986) in order to identify the edge of the plate and cut out its contour, and finally a rectification of the images is applied to remove the perspective distortion introduced by the lateral position of the webcam, by means of homography. As it is evident from Fig. 8 and Fig. 9 it is possible to identify on each plate two grids that are shifted between them but, given the fixed position of the plate, they are calculated a priori and stored as initial parameters. The first grid is calibrated with respect to the plate and each position corresponds to the central point of each pin. The second one is calibrated with respect to the height of the brick. It is precisely because these two matrices of points are identified a priori and considered valid for each processing, that it is very important that the cameras always acquire the images from the same position, since a shift of even a few pixels could invalidate the correct superimposition of the grids.

Using two images, each of which is analysed on two levels, has produced benefits in terms of accuracy of results compared to previous prototypes where processing was on a single image and single grid, which repaid the greater processing time required. Following the scheme of Fig. 7 before proceeding to the actual analysis of the plate, an algorithm was imple-

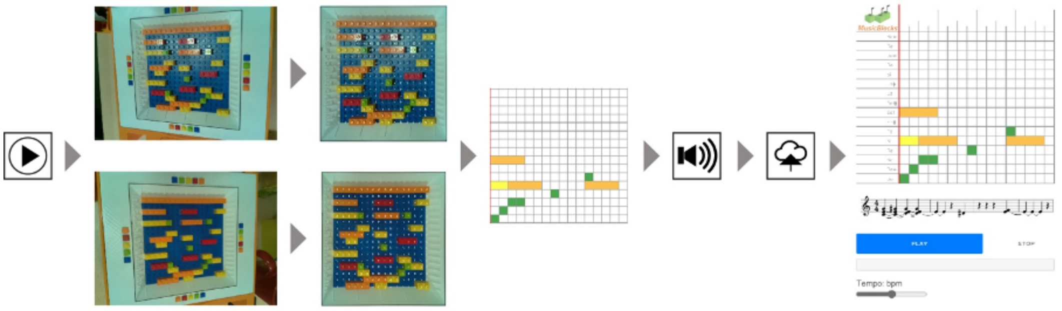

Figure 7: MusicBlocks process.

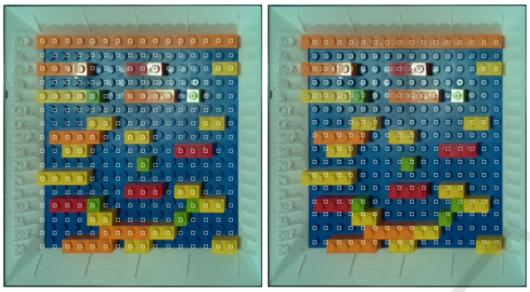

Figure 8: Right Image: grid calibrated with respect to the bricks (on the left) and to the plate (on the right).

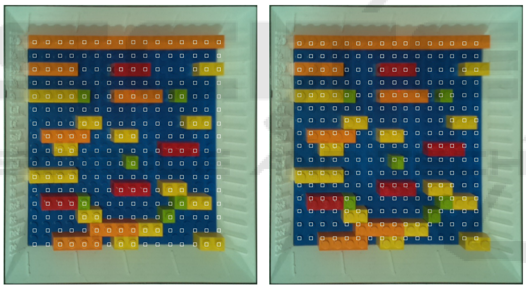

Figure 9: Left Image: grid calibrated with respect to the bricks (on the left) and to the plate (on the right).

mented for the calibration of the colours relative to the bricks, mainly to take into account the lighting context in which the MusicBlocks are positioned. In the first prototypes a static reference RGB colour matrix was used, which was the result of an analysis of about 100 colour samples in different lighting conditions, but the results were not adequate. In order to implement the dynamic colour matrix, five reference bricks were inserted on the edges on the four sides of the reading plate. The process then starts by taking a small portion of the coloured bricks at pre-set positions from the two images in Fig. 10 on the right and left.

For each image, each colour will have four different reference samples to compensate for any differences in plate illumination: the average RGB of each colour channel is then averaged. Each of the four

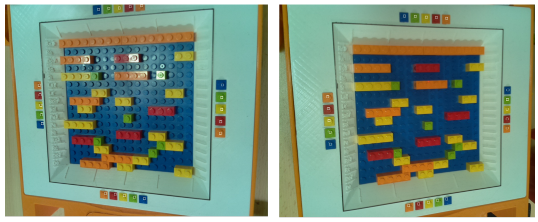

Figure 10: Samples of coloured bricks in right and left images.

reading areas undergoes a quality check before being assessed as suitable for inclusion in this average. In practice, to avoid cases in which there are reflections and therefore areas that are not suitable for processing (white pixels), the number of white pixels (according to a pre-set threshold) is evaluated. If this number exceeds a certain threshold, the entire area is excluded from the calculation of the channel average. If a colour has 2 or more areas excluded due to the presence of reflections, the processing will be interrupted, and an error message produced. Once the RGB averages of the reference colours have been calculated, we move on to the actual image processing. Let us consider ImR and ImL images and their grids at plate and brick level (Fig. 8 and Fig. 9): for each of them we have 256 areas of interest (portions of 3x3 pixels) that must be analysed. The evaluation of the colours associated with each portion is carried out first globally for the right image and then for the left image, first for the grid at plate level and then for the grid at brick level. Scrolling the sections from left to right and from top to bottom, each element is subjected to the same quality control as previously mentioned. If the number of white pixels exceeds a certain threshold, that section is discarded and the section in the other grid is evaluated or otherwise only the section in the other image is evaluated. For each suitable section, the average colour is calculated and the distance in three-dimensional Euclidean space from each of the sample colours is determined. The section is then assigned the colour with the smallest Euclidean distance from the samples. For each side (left and right), at the end of this process, each of the 256 sections of the plate in the two images will be associated with a colour: if the two grids identify the same colour, there is no further work to be done, otherwise the one with greater reliability is chosen.

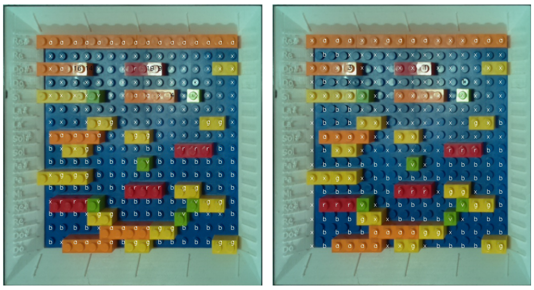

Figure 11: On the left: identified colours of bricks at plate level; on the right identified colours of bricks at pin level.

In Fig. 11 an example for the right images is shown: in the first row at plate level more bricks had been identified with the right colour ("a" that is orange) while at pin level some bricks had been identified as "x" which means "background". The final configuration of the bricks will then be obtained by a merge between the colours identified on the right and left side, together with considerations regarding the number of consecutive coloured bricks, considering that each type of brick has different lengths as well as different colours.

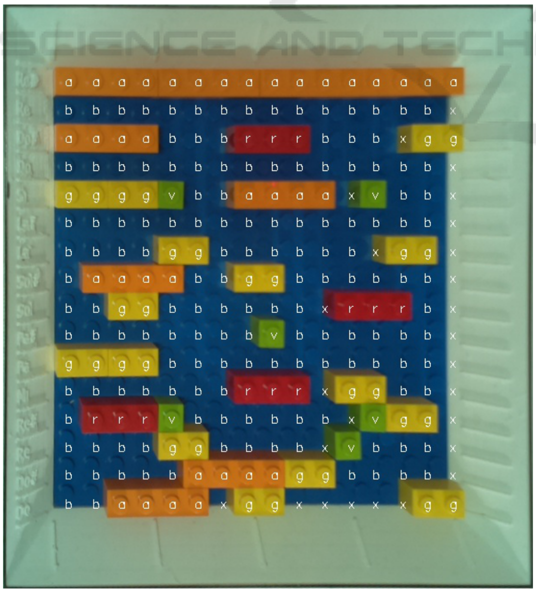

Figure 12: Final configuration.

Finally, once the final configuration has been defined as shown in Fig. 12, starting from the position of the bricks and their colours, the MIDI file is reconstructed through the MIDIUtil library and then sent for execution by means of the PyGame library which provides a player.

3.3 The Cloud

The functions of MusicBlocks are not limited to the reading, analysis and audio reproduction of the compositions created. Parallel to this main activity, an archive is populated in a completely autonomous way, capable of storing all the compositions created. Access to this archive is via an external device, such as a computer, tablet or even a smartphone with a WiFi connection. MusicBlocks is also a web server with its own WiFi network that teachers and students can connect to in order to perform certain actions. In this mode, it is possible to review all the compositions created, listen to them again and analyse them in more detail. Each composition is displayed with an image representing the position of the bricks. By clicking on the desired image, it is possible to access specific functions for in-depth analysis of the composition: in addition to the image of the plate with the bricks, there is also a stave (created using the open-source JavaScript library VexTab) where the bricks are translated and transcribed into musical notation, and a MIDI player that can play the composition again, also being able to modify the BPM speed. While listening, the bricks that are producing the sound and the relative note on the staff will be highlighted to improve understanding of the sound-brick-notation association. In this screen it is also possible to tag the composition by entering useful information for teachers such as the author, the date, the class that can identify the type of exercise or other information deemed important that allow them to create subsets of compositions, related to a particular topic or exercise, and make it easier to search for them later. Finally, each composition includes buttons for downloading the corresponding images or the generated MIDI file to your device. From this panel you can also access through an administrator user and thus have functions dedicated to the maintenance of MusicBlocks such as, for example, the possibility of updating the software with the versions that will be released over time, or share compositions considered particularly interesting with the Indire repository, or receive assistance, via log files, from the Indire project group, in case of hardware malfunctions. To access these functionalities there is a login that will allow the person in charge of managing MusicBlocks (generally the teacher himself) exclusive access. The authentication login serves both to ensure awareness of the execution of certain procedures, but also to maintain a simple interface for pupils.

4 CONCLUSIONS

Learning how to play a musical instrument is not easy, it requires great commitment and a good knowledge of the theoretical foundations and fundamentals of music. Currently, the "Italian National Indications" propose activities and competence goals mainly oriented towards secondary schools. MusicBlocks is an instrument that can also be used from the first cycle of schooling and can help to bring students closer to the concepts of rhythm, harmony and composition in a playful and active way, overcoming the steep initial step that there is in learning to play an instrument. MusicBlocks has been tested in a low secondary school and the results of this research will be published shortly. Anyway, it is evident, from a preliminary analysis, that the impact on learning and teaching was significant and the students' satisfaction very high.

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