An Ensemble of Tangible User Interfaces to Foster Music Awareness and Interaction in Vulnerable Learners

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Abstract: This paper describes an educational and creative experience based on tangible user interfaces for making music together. The learners involved in the initiative, aged 7 to 50, presented various forms of social disadvantage and, in some cases, also physical and cognitive impairment. The methodology consisted in building a number of user-tailored experiences to let participants acquire basic musical skills by a hands-on approach implemented through an ensemble of digital instruments. Aspects such as peer-to-peer collaboration, usability, and accessibility had to be addressed. The achieved results included not only the improvement of music competences in vulnerable users, but also the acquisition of social and soft skills. After analyzing the state of the art, this paper aims to investigate all the aspects of the initiative, starting from the design phase (devices, organizational aspects, learning subjects, etc.), then describing the experimental setting, and, finally, documenting the achieved results.

1 INTRODUCTION

In the field of sound and music computing, a relevant research question is how technology can bridge the gap between musical creativity and expressiveness on one side, and physical and cognitive user impairment on the other. Not only disability, but also a condition of social disadvantage can hamper the development of musical skills (Harrison, 2013; McAnally, 2013; Bates, 2018). For example, in a context of educational poverty due to economic conditions or geographical isolation, even the availability of a musical instrument can be a critical issue.

Digital technologies can help in a number of heterogeneous ways: just to mention a few examples, a computer-based system can substitute and/or augment a standard musical instrument (Gabrielli et al., 2011; d'Alessandro et al., 2015; Ko and Oehlberg, 2020), can pave the way for unleashing creativity (Mellor, 2008; Riley et al., 2009; Morreale et al., 2014), can provide alternative interfaces suitable to overcome impairments (de Oliveira et al., 2015; Gorbunova and Voronov, 2018; Frid, 2019), can encourage the development of music-related skills (Avanzini et al., 2019b; Baratè and Ludovico, 2020; Pesek et al., 2020). According to Li et al. (2019), music teaching through information technology can also affect behavior relating to learners' online learning attitudes, music learning motivation, and learning engagement. The ubiquity of portable devices (notebooks, tablets, smart phones, etc.), equipped with ad-hoc hardware accessories, suitable software tools, and easy-to-use interfaces, can represent a solution even in vulnerability contexts.

As stated by Barton and Riddle (2021), music is learned and taught in multiple ways depending on the socio-cultural contexts in which learning occurs, and musical activities should be culturally responsive and meaningful so as to respond to diverse learning contexts. In the scenario described in this paper, critical aspects such as user-friendliness, usability, accessibility, affordability, and a suitable use of multimodality must be considered.

The experience described in this work makes use of multiple tangible user interfaces, acting as the musical instruments, connected via Bluetooth to a mobile device, acting as both the synthesizer and the configuration center. The goal is to foster musical expressiveness and interaction between young users living in a condition of social disadvantage, due to educational

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poverty or cognitive/physical impairments.

The key research questions we aim to answer are:

RQ1. How can a tangible user interface encourage the acquisition of basic musical skills in socially distressed subjects?

RQ2. How can an ensemble of tangible user interfaces improve socialization and cooperation among peers?

RQ3. How can this experiment be extended and easily exported to other contexts?

The remainder of the paper tries to answer such questions, and is organized as follows: Section 2 will describe some previous experiences employing music therapy to overcome physical and cognitive impairments; Section 3 will introduce tangible user interfaces, focusing, in particular, on their applicability to music expressiveness; Section 4 will frame the activities in the context of the "Note Digitali" project; Section 5 will report some design choices and describe the experimental setting; Section 6 will focus on achieved results, assessed through the analysis of pre- and post-activity surveys and teacher observations; finally, Section 7 will draw the conclusions.

2 BACKGROUND

The current proposal is rooted in some previous music-therapy experiences conducted by the same working group with the help of digital technologies and documented by Baratè et al. (2018, 2019). Also in that case, the idea was to employ a computer-based interface in order to overcome the physical and cognitive impairments that often hamper musical activities in users with disabilities. Such a goal only partially overlaps the one of the "Note Digitali" project; in fact, in the scenario described below, not only impairments, but also conditions of social disadvantage will be considered.

Other key differences with respect to the aforementioned experiences must be remarked. First, from a technical point of view, human-computer interaction occurred through the Leap Motion controller, an optical hand tracking module able to detect and capture the movements of user's hands with great accuracy (Weichert et al., 2013). The applicability of such a device to music recalls the concept of "air" musical instruments, i.e. virtual instruments employing depth cameras or other sensor systems to implement an interaction paradigm based on performing gestures in the air, without touching a physical interface (Godøy et al., 2005). Examples have been documented by Tarabella (2004), Fan and Essl (2013) and Dahl (2015). Conversely, the "Note Digitali" project will employ a specific tangible user interface called *Kibo* and described in Section 3. Needless to say, this kind of interfaces completely changes the human-computer interaction paradigm.

Moreover, in previous experiences the musical performance mainly involved only the impaired user – interacting through the Leap Motion controller – and the therapist – playing a traditional instrument. The social aspects typical of making music together were limited to the relationship between a single learner and the instructor. Conversely, the proposal detailed below will focus on peer-to-peer interaction between multiple young performers, and the main roles played by the instructor will be to explain, help, and propose new musical experiences.

The scientific literature reports many other experiences of ensemble music based on digital instruments. For example, the aspects of human interaction and communication in a digital music ensemble have been addressed by Hattwick (2011) and Hattwick and Umezaki (2012); Ben-Tal and Salazar (2014) propose a new model for collaborative learning based on the connections between the technological tools and the social frameworks in emerging digital music collectives; Cheng (2019) investigates the development of musical competency in a laptop ensemble.

With respect to other similar initiatives, our proposal presents novel features regarding the expressiveness of the selected digital device, the availability of a fine–tuned learning environment, and the attention paid to affective and emotional aspects. These characteristics will be better clarified in next sections.

3 TANGIBLE USER INTERFACES FOR MUSIC

In the digital domain, *tangible user interfaces* (TUIs) aim to overcome some limitations posed by classic computer interaction, offering, for example, intuitive ways to build complex structures, manipulate parameters, and connect objects. TUIs use physical forms that fit seamlessly into a user's physical environment, giving physical form to digital information and taking advantage of haptic-interaction skills (Ishii and Ullmer, 1997). TUIs make digital information directly manipulatable with our hands and perceptible through our peripheral senses through its physical embodiment (Ishii, 2008). Such an approach is particularly effective for young (Xu, 2005) and disadvantaged users (Farr et al., 2010; Aljaam et al., 2011; Carreño-León et al., 2020).

Another key concept to clarify in this context is the one of *music embodiment*: it can be defined as a corporeal process that enables the link between music as experienced phenomenon and music as physical energy, or the physical environment in general (Leman et al., 2008). This sense-giving process focuses on the cognitive relationship that ties musical subjects and objects. Such an idea has been critically analyzed and reworked by Schiavio and Menin (2013).

Music TUIs are a technological means able to support and encourage music embodiment, thus breaking down the barriers that hinder musical creativity and expressiveness especially in young people and in impaired performers. On one side, a tangible interface – implying something "real", "concrete" – offers a physical way to interact with music and sound parameters, somehow recalling the kind of interaction of traditional musical instruments; on the other side, it can simplify the process, e.g., making it more accessible and intuitive.

Many music TUIs are based on *fiducial markers*, or simply *fiducials*, namely objects placed in the field of view of an image-recognition system with functions of control, user input, reference or measure. Examples of fiducials include:

- 2D markers, e.g. barcode systems or pictograms (Fiala, 2005);
- basic 3D geometrical shapes, e.g. multi-faceted cubes (Rabbi and Ullah, 2014);
- 3D printed objects, e.g. diorama models of musical instruments (Avanzini et al., 2019a).

3.1 Musical Applications of TUIs

Fiducials are the basis of the functioning of the *reacTable*, a digital musical instrument developed by the Music Technology Group at the Universitat Pompeu Fabra in Barcelona, Spain (Jordà, 2010). The *reacTable* employs fiducials to generate and control music and sound parameters. This device has a tabletop tangible user interface formed by a round translucent table used as a backlit display. Special blocks called *tangibles* (see Figure 1) can be placed on the table and moved by the user according to the intended result; their geometrical and spatial characteristics are detected in real time by the image-recognition system, that, in turn, pilots the virtual modular synthesizer to create music or sound effects.

Another fiducial-based framework for music is *D-Touch* (Costanza et al., 2003), defining a class of tangible media applications that can be implemented on consumer-grade personal computers. *D-Touch* fiducial markers for music-performance applications are shown in Figure 2.

Finally, it is worth mentioning the *TuneTable* (Xambó et al., 2017), a platform based on programmable fiducials for music coding (Figure 3). This approach was assessed in a computational musical tabletop exhibit for the young held at the Museum

Figure 1: Fiducial markers in use in the *reacTable*. Picture taken from (Dance Music Northwest, 2015).

Figure 2: Fiducial markers in use in *D-Touch*. Picture taken from (Costanza et al., 2003).

Figure 3: Fiducial markers in use in *TuneTable*.

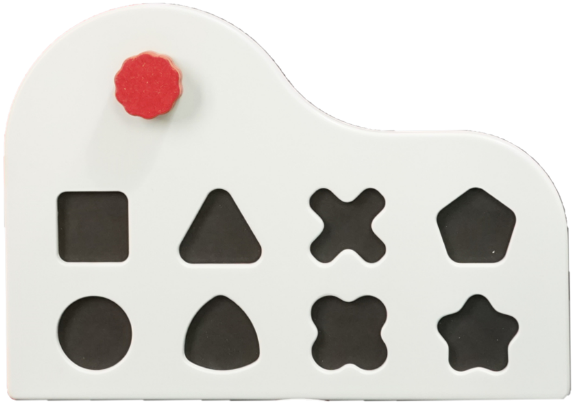

Figure 4: *Kibo*'s body and tangibles.

of Design, Atlanta (MODA). Workshop activities had the goal of promoting hands-on learning of computational concepts through music creation.

3.2 Kodaly *Kibo*

Kibo by Kodaly is a wooden board presenting eight unique geometric shapes that can be inserted into and removed from suitable slots. This device, also sensitive to pressure variations on single tangibles, returns the dynamic response of a polyphonic acoustic instrument.

The main control over music parameters is realized through a set of 8 easily-recognizable tangibles, shown in Figure 4. Each object has a different shape fitting in a single slot. Tangibles present symmetry properties so that they can be rotated and flipped before being inserted in their slots. They have a magnetic core, consequently they can be also stacked one on top of the other. The body of *Kibo* contains a multipoint pressure sensor that allows to detect the insertion and removal of tangibles. The characteristics of the sensor make the instrument both extremely sensitive and very resistant. Concerning the former aspect, it is sufficient to bring a tangible closer to the body to trigger a reaction; similarly, the gentle touch of fingers over an already plugged tangible is recognized as a pressure variation. Concerning robustness, *Kibo* has been designed to tolerate strong physical stresses, like fists and bumps. A distinctive feature is the possibility to detect pressure variations over tangibles.

Kibo can be connected via Bluetooth or USB to iOS and macOS devices running a proprietary app, that acts both as a synthesizer and a configuration center. Windows and Android operating systems are also supported via third-party drivers.

The communication between the controller and the app occurs by exchanging standard MIDI 1.0 messages. The MIDI engine integrated into the app supports up to 7 *Kibo* units simultaneously, without perceivable latency. Being a fully compatible controller, *Kibo* can also be integrated into any MIDI setup without the intervention of the app as a mediator.

The reasons why *Kibo* was chosen for the "Note digitali" project have been already anticipated by Amico and Ludovico (2020). In addition to the advantages of any music-oriented TUI, this device simplifies the establishment of a network of musical instruments working together like an orchestral ensemble.

Moreover, the app natively embeds three operating modes that are particularly useful in educational, rehabilitative, and therapeutic fields:

1. Musical Instrument Mode — In this scenario, *Kibo*'s tangibles are usually mapped onto pitches. Associations between shapes and notes can be customized; in this way, the device is not bound to a fixed association (e.g., a C-major scale), but it support key changes, other scale models, non-standard note layouts, etc. Through a suitable processing of MIDI messages, a single key could also trigger multiple musical events, e.g. custom chords or arpeggios. The metaphor of a keyboard controller is further extended by the *aftertouch* effect, namely the possibility to detect pressure variations over tangibles after note attacks;
2. Beat Mode — In this scenario, tangibles are mapped onto single percussive instruments. The pressure sensor, presenting a high level of resistance to strong mechanical stresses but also a noticeable sensitivity, allows effects ranging from hard mallet beats to delicate brush rubbing. With respect to the previous one, such an operating mode greatly simplifies interaction and makes the performance more intuitive for beginners; for example, the melodic and harmonic dimensions of music are absent, and a number of musical parameters (e.g., the release time for notes) are ignored;
3. Song Mode — In this scenario, *Kibo* is employed as a controller to trigger already available music loops. Tangibles are associated with mutually synchronized but independent tracks, like in a multi-track environment. When tangibles are inserted, the corresponding tracks are activated; when they are removed, tracks are muted (but they keep running silently, so as to preserve global synchronization). This type of interaction with music content is particularly suitable to engage users who are not able or do not wish to create their own music.

The configurability of *Kibo*, coupled with the adoption of standard communication protocols, enables numerous and heterogeneous scenarios. Multiple *Kibo* units in an ensemble can be set to cover distinct note ranges and timbres, or even to work in different operating modes, thus providing the teacher with great flexibility. Additional operating modes could be easily implemented by assigning other meanings, even extra-musical ones, to the MIDI messages generated by *Kibo* via ad-hoc software interfaces.

4 THE "NOTE DIGITALI" PROJECT

The initiative described in this work was launched in response to "Bando 57", a call promoted and funded by *Fondazione di Comunità di Milano - Città, Sud Ovest, Sud Est e Adda Martesana ONLUS*. In this framework, a number of workshop activities under the common umbrella of the "Note digitali" (i.e. Digital Notes) project has been proposed. The project directly involved 3 partners:

1. *Laboratorio di Informatica Musicale* (Laboratory of Music Informatics), Department of Computer Science, University of Milan. Established in 1985, it is one of the most relevant Italian research centers dealing with sound and music computing;
2. *Casa di Redenzione Sociale* (House of Social Redemption), Milan. Founded in 1927, this institution has been conducting activities in both the social and cultural fields, specifically addressing problems linked to the context of the northern suburbs of Milan: fragmentation of the social fabric, widespread educational poverty, and lack of public spaces;
3. *Fondazione Luigi Clerici*, Milan. In operation since 1972, this foundation offers vocational courses and apprenticeship initiatives, also for adult and impaired students. The mission is to create a network able to integrate education and organizational skills in collaboration with public and private authorities, local institutions, trade associations, and social organizations.

The project was conceived as an experiment of cultural citizenship where music turns into a means of self-empowerment and social cohesion. The goals included providing basic musical competences and skills, fostering creativity, and, above all, encouraging interaction and socialization in vulnerable young students. The expected results included the promotion of participation in the socio-cultural life of the community by people with different types of disabilities, the perception of music as a means of aggregation,

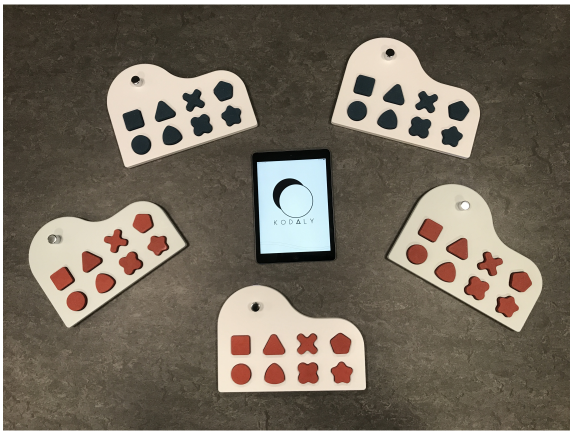

Figure 5: The hardware equipment used during the experimental activity: 5 *Kibo* units and an *Apple iPad*.

Figure 6: The classroom for workshop activities.

and self-empowerment, namely the self-discovery for the participants of their skills and abilities.

5 EXPERIMENTAL SETTING

Workshop activities were conducted in small groups under the guidance of an experienced tutor in a time span from December 2020 to May 2021.

In this section we will describe the design choices made when planning the workshop activities, concerning the type and number of hardware devices, the expected structure of the course, the characterization of the subjects involved, and the learning materials prepared to guide participants towards the acquisition of both musical and social skills.

The basic hardware equipment used during the experimental activity included 5 *Kibo* units connected to an Apple iPad via Bluetooth Low Energy (BLE), as shown in Figure 5. The room where most activities took place (Figure 6) was also equipped with traditional and digital musical instruments, such as drums and an electric piano. This setting provided the tutor with many options, including the exclusive use of *Kibo* units (with or without involving the tutor herself) or mixed performances involving also traditional instruments, specifically the piano and the ukulele. In the latter scenario, the tutor was the only performer enabled to play a non-digital instrument, since most participants had no previous music knowledge, and the function was basically to explain musical concepts and guide learners towards an autonomous performance.

The technical limitations of the BLE communication protocol currently limit to 7 the total amount of *Kibo* units simultaneously connected to a single mobile device. In case of an expanded *Kibo* orchestra, such a constraint can be easily overcome by employing a higher number of devices suitably configured to communicate with a subset of *Kibo* units. Moreover, these TUIs can be used as standard MIDI controllers, thus operating in conjunction with other compatible hardware equipment.

As the participants admitted to the workshops were expected to present different types of impairment or distress conditions, the idea was to create small and homogeneous groups. Participants were subdivided into teams made of 4 people, in order to guarantee a number of peers sufficient to foster social interaction on one side, and let the tutor easily supervise and guide the experience on the other. The tutor had background experiences both in music therapy and in digital music technologies.

Participants belonged to 3 categories: 1. young students aged 12 to 18 with psycho-social support needs; 2. adults aged 25 to 50 with cognitive and/or physical impairment; 3. children with special needs (in particular due to dyslexia, dyspraxia and dyscalculia) aged 7 to 10. In total, participants were 20 (12 males, 8 females) and they formed 5 teams: 2 teams (8 participants, 2 females) for the first category, 2 teams (8 participants, 4 females) for the second category, and 1 team (4 participants, 2 females) for the third category.

Each 4-people team attended a complete cycle made of 4 didactic units; units were administered once a week and lasted 2 hours each. In this way, any cycle was completed in the time span of one month.

Table 1 shows the tentative program of each educational cycle, divided into units and tasks. Depending on the characteristics of the team (age, type of impairment, previous music knowledge, level of attention, etc.), some adjustments were made on the fly by the tutor in order to finely tune the educational activities. The basic idea was to drive learners along two parallel growth paths: on one side, improving their musical skills by gradually introducing new dimensions (rhythm, melody, harmony, timbre); on the other side, encouraging their interaction aptitudes through music (listening to the tutor's performance, playing alone, playing with the tutor, playing in an ensemble, playing together and improvising in front of an audience). Some tasks implied theoretical investigations, other tasks focused on practical activities.

The adoption of a TUI was fundamental to break down the initial barriers (physical impairments, lack of instrumental practice, sense of insecurity or shame) and let participants be involved in a musical performance in a very limited amount of time. It is worth underlining the importance and the outcome of some tasks. Task 2.3 implied the ability to translate a sequence of musical events (possibly available in Common Western Notation format) into a sequence of pictograms referring to fiducials. In other words, the TUI pushed learners to develop soft skills (team work, problem solving, etc.) and the ability to reason abstractly. Task 3.3 asked participants to perform a music piece together by playing different roles: two leading voices, a rhythmic base and a harmonic accompaniment. This task encouraged synchronization abilities, information exchange and peer-to-peer cooperation. Finally, Tasks 4.1 and 4.2 explored the field of music improvisation, both mixing already available materials and playing freely under the influence of visual artworks. In the latter case, the portability of the system (the *Kibo* units and the tablet) was a key aspect to conduct such an experience in a museum with a collection of paintings. Not only the TUI is an enabling technology for impaired users unable to play a traditional instrument, but it can also unleash creativity and support musical expressiveness after a very short exploration phase.

6 ACHIEVED RESULTS AND CRITICAL DISCUSSION

6.1 Answering Research Question 1

RQ1 aimed to investigate the applicability of a TUI-based approach to the acquisition of basic musical skills in vulnerable learners. This research question focused on individual experience, acquisition of knowledge, and development of music-related skills.

From classroom observations and user feedback, *Kibo* proved to be a suitable tool to let users with no previous knowledge develop "musical intelligence", namely abilities in the field of perception and au-

Table 1: The program of the workshop, with details about didactic units and tasks.

Unit	Task	Description
1	1.1	Presentation of participants and pre-test
	1.2	Introduction to *Kibo* and its features
	1.3	*Kibo* and piano interactive performance
	1.4	All participants playing the same rhythmic pattern
2	2.1	Theoretical fundamentals of melody and rhythm
	2.2	Playing a short piece as an ensemble
	2.3	Writing and reading a simplified score
3	3.1	Theoretical fundamentals of harmony and timbre
	3.2	Playing a piece with different musical instruments
	3.3	Making music together with a *Kibo* ensemble
4	4.1	Playing a song mixing *Kibo*'s operating modes
	4.2	Music improvisation inspired by paintings

tonomous production of music. The results achieved by all participants, including very young as well as impaired ones, included the ability to understand the main dimensions of music (melody, rhythm, harmony, timbre), recognize variations in some parameters (e.g., dynamics, tempo, instrumentation), and autonomously reproduce a simple tune. These achievements have been assessed through instructor's observations.

If compared with the pre-workshop situation, the best results have been obtained by those participants who presented both physical and cognitive impairments (specifically, the second team of the second category). The members of this team had started from a lower level of knowledge, whereas other participants had recently studied music at school. Moreover, using an enabling technology was the only opportunity for them to make music, and in most cases this workshop was their first active musical experience. For these reasons, their reaction to the use of a TUI was enthusiastic. Figure 7 shows one of the wheel-chaired participants.

Another observation is more tightly related to the specific features of *Kibo*. The geometric shapes of the

Figure 7: A physically impaired user making music with *Kibo*.

fiducials proved to be suitable both to overcome visual impairments (tangibles were easily recognizable to the touch and pluggable into the slots) and cognitive ones (sequences of shapes were easy to remember also in case of memory deficit or inability to read a score).

6.2 Answering Research Question 2

RQ2 measured the achievement of non-musical results. One of the goals of the workshop was to emphasize a series of soft and transversal skills through the creation of a shared musical performance. Making music together as an ensemble requires the development of social skills, encourages cooperative aptitudes, promotes the ability of listening to the other and perform in front of an audience.

For most teams cooperation did not represent a problem, rather it encouraged the relations and strengthened the ties inside each group. For the first team, conversely, playing together was a real challenge. Let us recall that the members were children aged 12 to 14 with a difficult background, coming from a context of social fragility and educational poverty. The problems encountered with them were mostly behavioral: respecting the others, listening without talking over, playing the instruments at the right time. Luckily, the engagement due to making music together and the interest towards the playful interface of *Kibo* let them overcome internal conflicts and focus on a common goal.

The adoption of a TUI also encouraged problem-solving and abstraction skills, that are two key aspects of computational thinking. The problem to solve was how to reinvent a music score suitable both for people with no music knowledge and for impaired users. The solution was to translate music notation into *Kibo*'s symbols (see Figure 8).

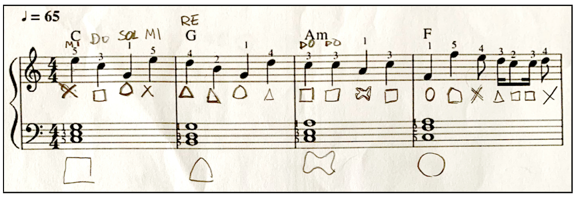

Figure 8: A music sheet for *Kibo* with fiducial symbols added by hand.

The cooperation of each team member was fundamental to complete Task 3.3. Learners had to form a small musical ensemble where everyone should play an important part. The tutor guided the process so as to promote personal abilities without causing frustration in participants. Each team was able to apply the principles of self-regulation, also thanks to the distinguishing features of the TUI in use. For example, a blind girl who demonstrated a great, unexpected sense of rhythm could perform her part using *Kibo* in Beat Mode; two young students autonomously decided to share the leading voice of a piece by playing it in turn in Instrument Mode; and less skilled users were able to participate taking benefit from the Song Mode.

More time would have been helpful to consolidate this work, but all the learners understood the meaning of working together and contributing actively to the achievement of a shared purpose.

6.3 Answering Research Question 3

RQ3 focused on the extensibility and reproducibility of this workshop activity in other contexts, for example with different types of participants or a different time schedule. To answer such a question, some critical aspects must be highlighted.

A first consideration concerns the choice of the device. *Kibo* proved to be a good solution from many points of view, from technical aspects (e.g., easy device connection and communication) to physical ones (e.g., user-friendliness and robustness). Unfortunately, it is not an affordable product. At the moment of writing, in Italy this device is sold for 900 to 1000€. Building an ensemble of *Kibo* units, including the need to have an Apple mobile device, is not a low-cost operation. From this point of view, a mixed approach that includes other traditional or digital instruments can help.

Concerning organizational aspects, a team composed by up to 5 participants was a good compromise. Conversely, the presence of a single tutor in the classroom did not guarantee a fluid conduct of educational activities. In fact, she had to explain theoretical concepts, play an instrument, support impaired users and, sometimes, even solve technical issues simultaneously.

The 2-hour lesson length was adequate and generally appreciated by participants, but the number of units per cycle should be increased in order to better cover the high number of music-related subjects. For instance, the intriguing relationship between music and visual arts was confined to Task 4.2, but it could become the focus of a whole educational cycle.

Finally, in our experimentation teams were not formed according to previous musical knowledge but considering social conditions and impairments. On one side, this choice facilitated the cooperation between users sharing similar problems and the consequent fine-tuning of the program, but, on the other side, it merged in a single team people with different expectations. *Kibo*, as well as many other music-oriented TUIs, is a facilitator for people with no music knowledge, but its limited possibilities can easily cause boredom and disengagement in more skilled users.

In conclusion, answering RQ3 requires to take some critical issues into consideration. The experience described in this paper represents a pilot study that will hopefully guide both the authors and the interested readers in better designing future initiatives.

7 CONCLUSIONS

In this paper, we have described the achievements in terms of increased musical, social, and soft skills for vulnerable users obtained by organizing ensemble music sessions with a TUI.

A not surprising result is that a TUI can help solve the typical issues of accessibility posed by traditional musical instruments for physically impaired users. In the experience documented here, most participants belonging to the second category presented motor impairments, and some of them had also visual impairments. For this kind of users, a TUI is an enabling technology fundamental to let them experience musical performance. Many participants had the opportunity to play music for the first time, and they were able to do it together. From this point of view, the experience was very positive, and reactions from learners were enthusiastic.

Moreover, a TUI can bridge the gap between cognitive impairment and a full comprehension and experience of musical dimensions. In this scenario, the ability to read and memorize a score is not trivial. Not only these critical issues were successfully tackled, but participants were able even to produce new scores, thanks to a simplified language and a gamification approach.

In conclusion, we realized that engagement can push the limits of users, making them obtain unprecedented results. A music-oriented TUI, employed under the guidance of an experienced tutor, can foster engagement bringing down the initial barriers and limiting the sense of frustration that often hinders music creativity and expressiveness in disadvantaged users.

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