Fostering Piano Keyboard Proficiency Through Interactive Minigames on a MIDI Controller

Andrea Tarondo, Susanna Brambilla[a] and Luca Andrea Ludovico[b]
Department of Computer Science, University of Milan, via G. Celoria 18, Milan, Italy

Keywords: Education, Gamification, MIDI, Music.

Abstract: This article presents a digital platform comprising eleven minigames aimed at deepening the use of a musical keyboard by young learners. Specifically, the platform requires the use of a MIDI controller, and some games aim to familiarize users with typical controls found on digital pianos, such as wheels and sliders. The platform is freely available from an online repository. An initial experimentation involving nine users was conducted, where two questionnaires were administered: the first before the gaming activity for user profiling purposes, and the second after the gaming activity to evaluate the experience. The tests carried out reveal positive results concerning satisfaction, engagement, and skill improvement, simultaneously indicating a low level of tension and annoyance.

1 INTRODUCTION

The acquisition of proficient piano skills in young students is a multifaceted challenge that demands innovative and engaging educational approaches. In response to this challenge, we have designed and developed a set of interactive minigames designed to foster and enhance piano keyboard abilities in young learners. The key objective of our study is to make the learning process enjoyable and effective, leveraging the inherent appeal of interactive minigames to captivate the interest of users. By combining entertainment with education, we strive to create an engaging learning environment that encourages consistent and motivated practice.

In traditional piano education, students often face difficulties transitioning from theoretical understanding to practical application. Recognizing this gap, our research aims to bridge it by creating a computer application featuring a series of targeted minigames. Central to our approach is the utilization of a keyboard-like MIDI controller, a versatile instrument that extends beyond conventional piano keyboards by incorporating additional components such as sliders and wheels. Thus, the minigames are crafted to facilitate a comprehensive learning experience, covering not only the traditional piano keys, but also incorporating the sliders and wheels found on a MIDI controller.

This paper provides an overview of our research methodology, the design principles behind the minigames, and the potential impact of our approach on the acquisition of piano proficiency among young students. As we explore the specifics of our game-based learning application, our goal is to shed light on how the integration of MIDI controllers and interactive gameplay can revolutionize the way piano education is approached, offering a promising avenue for the enhancement of musical education in young learners. The rest of the paper is organized as follows: Section 2 will cite some key approaches and relevant scientific papers dealing with gamification and music education, Section 3 will provide the technical details and a detailed description of the minigames collected on the *Midigames* platform, Section 4 will report on the results obtained in preliminary experimentation, and finally Section 5 will draw the conclusions.

2 GAMIFICATION AND MUSIC EDUCATION

The intersection of music and video games is a promising idea for educational purposes within the realm of music theory and practice. By allowing an easy comprehension of musical concepts, the devel-

[a] https://orcid.org/0000-0002-7975-8724
[b] https://orcid.org/0000-0002-8251-2231

Tarondo, A., Brambilla, S. and Ludovico, L.
Fostering Piano Keyboard Proficiency Through Interactive Minigames on a MIDI Controller.
DOI: 10.5220/0012743200003693

In *Proceedings of the 16th International Conference on Computer Supported Education (CSEDU 2024) - Volume 1*, pages 597-605
ISBN: 978-989-758-697-2; ISSN: 2184-5026

opment of awareness toward music parameters, and the acquisition of practical skills, this field is gaining significant attention from researchers.

When students find learning enjoyable and motivating, they tend to progress quickly and comprehend concepts more efficiently, rather than engaging in repetitive tasks. An interactive approach that merges music learning with video game interactivity maintains the motivation of the learner and enhances overall productivity. The term "gamification", which denotes the integration of game-like elements into a workflow to increase motivation and productivity by satisfying rewards, becomes relevant in this context (Caponetto et al., 2014).

Gamification proves beneficial in addressing challenges associated with music notation comprehension (Samat et al., 2022). The inherent difficulty in mastering the music notation often leads students to lose motivation to study. However, the incorporation of gamification, particularly within sight-reading exercises, serves to improve student motivation and participation in teaching and learning activities.

Music educators can start with an analysis of elements of flow in video gaming (such as being transported, mortal danger, limitlessness) to help students find motivation in learning music (Csikszentmihalyi, 1990; Nakamura et al., 2002; Wagner, 2017). According to the research mentioned, the phenomenology of flow can be a useful lens to look at ways to motivate students in their music learning.

A specific category of gaming experiences dealing with sound and music parameters is that of audio games, in which all information is conveyed mainly or exclusively through sound. Consequently, players need to use their sense of hearing to accomplish tasks and achieve goals. In addition to fostering sound and music awareness, this process promotes concentration, memory, fantasy, emotion, perception, data management, and cooperation (Rovithis et al., 2018).

A case study conducted with 2nd cycle students focused on the adoption of multimedia materials designed to provide support for instrumental and voice practice. The design of a game in which students were required to answer random questions to unlock desired multimedia materials proved to be effective both in promoting music-related topics and in developing skills in other adjacent areas (Gomes et al., 2014a).

In terms of instrumental practice, proficiency requires extensive training. Musicians participate in various technical exercises to refine their skills and mastery of instruments. These exercises often entail iterative tasks leading to repetitive actions essential for achieving expertise in performance. Examples for piano players include exercises on fingering, musical scales, and arpeggios.

Specifically focusing on gamification and piano education, research shows that the introduction of game elements such as rewards, badges, and achievements positively influences students' engagement in technical exercises (e.g., scales, chords, arpeggios), thus facilitating enhanced learning with reduced effort (Birch and Woodruff, 2017).

In this field, innovative approaches based on immersive environments and mixed reality are being experimented with. An example is *Musical journey*, a virtual world gamification experience for music learning that allows students to freely explore the most relevant sounds, musical instruments, and composers, ranging from the first century to the present time (Gomes et al., 2014b). A more recent application is *HoloMusic XP*, a multimedia tool designed to help students learn the fundamentals of music theory and how to play the piano (Molero et al., 2021).

As mentioned above, our proposal is centered on the use of a MIDI controller. The applicability of the MIDI protocol to educational activities has already been documented in the scientific literature (Ludovico, 2017). Early research works focused on the educational inroads forged by MIDI, described as "a positive element and environment to music education programs" (Hunter-Armstrong, 1996) and "a technology [that] helps to open the once-closed door to traditional note-oriented composition for students, as well as to offer limited opportunities for the composition of music that could not be realized in a traditional, human, acoustic setting" (Beckstead, 2001). There are studies on the potential of specific MIDI controllers to target music goals, e.g. composing with MIDI (Airy and Parr, 2001), improving singer training for live performances (Chousidis and Lipan, 2016), and allowing vulnerable users and people with disabilities to create aural and musical effects (Baratè et al., 2021; Swingler, 1998). As clarified in the next section, our proposal differs from those listed above because we are not using a MIDI controller to foster the development of music abilities, but rather a gamification approach to let users improve their proficiency on that specific controller type, i.e. a MIDI keyboard. The main advantages compared to a traditional piano are the greater availability, the lower cost, and the intrinsic ease of letting a MIDI controller communicate with a computer system.

3 THE *MIDIGAMES* PLATFORM

The approaches mentioned in Section 2 served as positive precedents in the development of *Midigames*, of-

fering promising prospects for an interactive gaming experience fused with music education. *Midigames* is a gaming platform that offers 11 short game experiences numbered 0 to 11, specially designed to practice the controls usually offered by a MIDI keyboard.

The taxonomy of digital musical learning resources reported in (Mandanici et al., 2023) mentions three hierarchical tiers, namely Domains, Dimensions, and Nodes. Referring to such a taxonomy, the platform can be classified as shown in Table 1.

Table 1: Classification of *Midigames* with respect to the taxonomy reported in (Mandanici et al., 2023).

Domains	Dimensions	Nodes
Metadata	Material	Midigames
	Contribution	Case study
	Date	2023
Technological	Applications	Desktop
	Input Technologies	MIDI
	System Outputs	Audio, Video
Musical	Activities	Performing
Pedagogical	Learning Theories	Constructivism
	Users	Primary school
	Venues	Lab, Home

A primary consideration in the development of *Midigames* was the maintenance of high motivation and low levels of frustration throughout the learning process. These short experiences strive for simplicity and intuitiveness, adopting a minimalist graphical user interface. Each minigame is designed to be easily comprehensible yet inherently enjoyable, a pivotal aspect in fostering effective education.

These games are mainly intended for educational purposes, thus addressing young users and beginners, but can also be adopted in physical or cognitive rehabilitation contexts. Concerning the expected age of users in the educational scenario, the platform addresses primary school children. For younger users, the presence of a facilitator is strongly suggested. In fact, minigame goals are presented through short sentences and note names are spelled out according to alphabetical musical notation, i.e. A to G. For a student who is not able to read yet, minigames are not fully self-explanatory. For other use cases, there are no requirements about the player's age. Anyway, it is advisable to have an educator supervising game sessions even when using the platform for cognitive rehabilitation purposes.

Midigames offers three difficulty levels: normal, intermediate, and professional. These difficulty levels vary in the number of obstacles present, the time, and the number of lives available to the player. In the normal difficulty setting, players have four lives, while in the intermediate setting, they have two, and in the professional setting, they have only one. Moreover, a gameplay mode was developed specifically for training purposes but was not utilized during the testing phase described in Section 4. In this training-specific mode, players have access to more comprehensive in-game information compared to other modes, alongside the benefit of infinite lives. Additionally, there is an endless mode available where players have infinite lives, allowing for continuous practice and improvement.

Midigames has been compiled and distributed for MacOS and Microsoft Windows. The platform can be downloaded from https://silver978-dev.itch.io/midigames.

3.1 Technical Details

The platform is based on the Musical Instrument Digital Interface (MIDI), a standard communication protocol used in electronic musical instruments and devices. MIDI allows different musical instruments, such as keyboards, synthesizers, drum machines, and computers, to communicate with each other and control various aspects of music production. At its core, MIDI is a language that enables electronic devices to transmit and receive musical information. This information includes instructions for playing notes, changing the sounds of instruments, adjusting the volume levels, and controlling various parameters of sound synthesis. MIDI messages can be sent and received between MIDI-compatible devices via standard MIDI cables, USB connections, or wirelessly using MIDI-over-Bluetooth or other wireless protocols.

One of the fundamental applications of MIDI is controlling a synthesizer from a keyboard. When a key is pressed on a MIDI keyboard, it generates a MIDI note message that includes information such as the pitch of the note, the velocity (how hard the key was pressed), and the duration of the note. This MIDI note message is then transmitted to a MIDI-compatible synthesizer, which interprets the message and produces the corresponding sound. In addition to note messages, MIDI supports a variety of other messages that allow for control over different aspects of musical performance and sound synthesis. For instance, Control Change messages are used to adjust various parameters of sound synthesis, such as volume, pitch bend, modulation, and filter cutoff, thus they can be used to create dynamic and expressive musical performances. Another fundamental message is the Program Change, used to change the instrument or sound patch being used by a MIDI-compatible device. Each instrument or sound patch is assigned a unique program number, and sending a Program Change message with the desired program number

Figure 1: An example of a MIDI keyboard.

causes the device to switch to that instrument or sound patch.

In order to easily set these music and sound parameters, in addition to keys, MIDI keyboard controllers usually are equipped with other control devices, including wheels with central return position (a typical case is the pitch bend wheel used to finely detune pitches), some sliders, and other rotating controls (usable to set, e.g., channel volume, panning, chorus, and reverb). An example of a MIDI keyboard is shown in Fig. 1; in addition to velocity-sensitive keys, the left side of the device has a pitch bend wheel, a volume slider, and a modulation wheel.

The *Midigames* platform supports any form of MIDI inputs and, in particular, both virtual and physical MIDI keyboards. Virtual MIDI keyboards are software-based devices that allow users to play MIDI notes using their computer keyboard or mouse. Virtual MIDI keyboards can perfectly simulate the functionality of physical keyboards and they even present several advantages over the latter, including convenience (many free products can be retrieved from the Web), portability (they are software applications), and versatility (they can embed a number of configurable controllers). However, in this context, virtual keyboards are useful mainly for test or demonstration purposes and for the mere acquisition of basic musical concepts, e.g. the correct identification of keys associated with pitches. Since the experiences that we propose are tightly connected with musical practice, the adoption of a physical keyboard is strongly suggested.

3.2 Game Experience

In this section, we list the minigames on the platform, provide a short description of their features, and highlight their intended goals. Their graphical interfaces are shown in Fig. 2

- *Midigame 0* — This minigame presents a sequence of notes shown one at a time in the form of a colored text indication. The input interface to use is the piano keyboard. If the player presses the right note, the next note is shown. The process continues until the sequence is finished. The educational goal of this minigame is to strengthen associations between note names and the corresponding keys;
- *Midigame 1* — This minigame is based on the same concept as the previous one, but notes are presented all together, in a sequence that scrolls on-screen. The input interface to use is the piano keyboard. To win this minigame, the player has to press the notes in the correct order from left to right. The total length of the pitch sequence is variable depending on the level of difficulty. The educational goal of this minigame is, once again, to strengthen associations between note names and the corresponding keys;
- *Midigame 2* — This minigame presents two groups of emoticons randomly scattered on the screen: the former group aims to represent a happy emotion, the latter an angry feeling. The player is invited to press the keyboard keys associated with the notes of the angry emoticons, without pressing the notes of the happy ones, to make them disappear from the screen. When the player selects a note related to happiness, the minigame fails. Even if this experience relies once again on the associations between note names and keys, in this scenario there is no predefined sequence to follow; moreover, a quick response from the player is rewarded;
- *Midigame 3* — This minigame introduces a character that, starting from the left side of the screen, has to reach the goal on the right. The path is blocked by two rocks that have to be lifted by pressing a specific note on the piano keyboard. Each rock can be traversed as long as the corresponding key is pressed. Thus, in this minigame, not only the note pitch but also its duration is relevant for completing the game;
- *Midigame 4* — This minigame shows a bird-like character who has to fly and avoid obstacles coming from the right side of the screen. His vertical position is controlled using the pitch bend wheel. The flight height is also linked to a sound whose pitch depends on the wheel position. This experience differs from the previous ones as it is a survival game: the player has not to complete a challenge, rather she has to survive without touching any obstacles until the time is over. The goals of this experience are both to improve the ability to use the pitch bend will and to better understand the concept of micro-tuning typically connected to its use in musical performance;
- *Midigame 5* — In this minigame based on vertical scrolling, the player controls a car that can move

Figure 2: The graphical interface of *Midigames 0* to *10* (left to right, top to bottom).

left and right using two specific notes that are randomized each time the experience is restarted. The game goal is to avoid any contact with the enemy cars arriving from the top. This is another case of a survival game that fosters the ability to quickly alternate keyboard keys;

- *Midigame 6* — The scenario of this experience is a garden with plants that have to be watered to grow, The initial position of plants is random. Water is sprayed from a tube placed in the center of the scene. To complete the task, the player has to master one of the rotative controls or sliders present on the MIDI controller, whose position changes the direction of the water. Also in this example, the practical use of the control tool is reinforced by a musical meaning, e.g. volume settings, vehiculated through MIDI Control Change messages;
- *Midigame 7* — In this activity, the goal is to move a rectangle-shaped fictional shield to defend the Earth from space meteors. Like the previous minigame, this experience invites the player to use either a rotative or a slider control to achieve the result;
- *Midigame 8* — This minigame presents a group of people asking for some candies; some of them are hungry, others are not. The player is invited to press the notes shown below to people who want candies, avoiding the notes associated with the other characters. This minigame is similar in its goals and approach to *Midigame 2*;
- *Midigame 9* — This activity proposes a list of notes in ascending order to be played as a sequence within a given time interval. Since the random sequence recalls a fragment of a musical scale, the underlying goal is to foster the learning of fingerings;
- *Midigame 10* — In this minigame, the player has to defend her house against incoming rockets. Each weapon is associated with a pitch and the user has to press the corresponding key to neutralize it. Once again, the idea is to encourage a prompt response from the user on the keyboard.

Let us analyze the games from different perspectives, summarized in Table 2. First, they encourage the player to use different controls of a typical MIDI keyboard: the keys, the pitch bend wheel, the sliders, and other rotating controls. In order to keep minigames simple from a physical and cognitive point of view, such controls are never used together. One deliberately overlooked aspect is the use of the pedal. Although it is an essential component of a traditional or digital piano, it is not common to find this control associated with a MIDI keyboard controller.

Table 2: Comparison between different minigames.

Game id	Control	Type	Story
0	keys	time	no
1	keys	time	no
2	keys	time	yes
3	keys	time	yes
4	pitch bend wheel	survival	yes
5	keys	survival	yes
6	slider / rotating	time	yes
7	slider / rotating	survival	yes
8	keys	time	yes
9	keys	time	no
10	keys	survival	yes

All games have a limited play time in the range of 10 to 60 seconds. The number of seconds available changes according to the difficulty level. But some of the games are time challenges, i.e. the task has to be completed before the time expires (the shorter the time taken, the better the result), whereas others are survival games, i.e. the player has to reach the end of the challenge with no mistakes.

From the point of view of storytelling, some games offer purely musical challenges, whereas some others have characters or present extra-musical goals. In our intentions, in a supervised experience, this multiplicity of approaches should allow the educator to choose the most suitable experiences to encourage the player, e.g. starting from fun scenarios like watering plants or defending the Earth and gradually moving toward note sequences, chords, and scales. In an unsupervised gaming experience, heterogeneity should improve engagement and avoid frustration, letting the player choose the most suitable challenges with regard to the goals to achieve.

4 EARLY EXPERIMENTATION

4.1 Test Protocol

The testing phase to evaluate the gaming platform involved several key steps. Participants were supervised by an expert while they downloaded and played the minigames. To ensure a level playing field, participants were provided with a comprehensive guide, including instructions, which is beneficial for those unfamiliar with the mechanics and musical notes. They then proceeded to engage directly on the keyboard, employing a trial-and-error approach to familiarize themselves with the gameplay. Each gaming session lasted approximately thirty minutes, during which participants exclusively played in the normal

difficulty mode. To mitigate potential biases, the order of the minigames was randomized.

The testing phase involved administering two questionnaires, the former to be administered before the game experience and aimed at profiling players and the latter to be administered after the game experience and aimed at gathering user opinions and remarks. The test activity involved 9 users in total.

The first questionnaire investigated aspects such as the player's gender, age, and level of musical experience. Profiling the participants allowed some assumptions to be made in the analysis of the results provided below.

The post-game survey followed the guidelines proposed in the *Game Experience Questionnaire* (GEQ) from the Eindhoven University of Technology (IJsselsteijn et al., 2013). The structure proposed by such a document consists of three modules and an additional part:

- **Core Module**, which measures the game experience using various components. The most relevant for *Midigames* are competence, flow, tension, and challenge;
- **Social Presence Module**, which analyzes the interaction between the player and other social entities, like in-game characters or other online players;
- **Post-Game Module**, which takes into account how the player felt after playing the game. This part consists of four components: Positive Experience, Negative Experience, Tired- ness and Returning to Reality;
- **In-Game Version** of the questionnaire, which represents a more compact version of the core module, presented to the player inside the game itself.

The general schema was adapted to suit our goals, particularly by limiting the Core Module to focus on the most relevant components for our minigames. In this adjustment, the component of Sensory and Imaginative Immersion, which is primarily related to the aesthetic aspects of the game and less relevant in our context, was omitted. The included components consist of Flow, Competence, Negative Affect, Positive Affect, Challenge, and Tension/Annoyance. Furthermore, being all the activities in *Midigames* single-player games without virtual characters, the Social Presence module was omitted, too. Finally, the nature of *Midigames* suggested to avoid the In-game Version of the questionnaire.

In order to gather objective evaluations, players completed the questionnaires without being monitored, thus reducing potential biases that could arise from the presence of a supervisor.

4.2 Pre-Game Questionnaire Results

The gender was well balanced in the group, with 5 males (55.6%) and 4 females (44.4%). Concerning age ranges, 1 participant was 17 or younger (11.1%), 1 participant was 18 to 20 (11.1%), 2 participants were 21 to 29 (22.2%), 2 participants were 41 to 49 (22.2%), and 3 participants were 50 to 59 (33.3%). It is important to highlight that the age distribution is skewed towards older users, an aspect to keep into account if the main target of these games is young learners.

On a 5-point Likert scale, most of the participants declared that they had no musical education (2 participants, 22.2%), a low level (3 participants, 33. 3%), or a medium level (3 participants, 33.3%); only 1 responder self-assessed her abilities as 4, no one scored 5. In this perspective, the characteristics of the experimental group are consistent with the intended audience of *Midigames*. Among the 6 users who have some experience in instrumental practice, 50% declared playing the keyboard as the main instrument, the others indicated guitar, drums, and wind instruments.

All respondents declared to have some experience with gaming. On a 5-point Likert scale where 1 means "no experience" and 5 means "high experience", 1 participant scored 2 (11.1%), 2 participants scored 3 (22.2%), 3 participants scored 4 (33.3%), and 3 participants scored 5 (33.3%). The preferred category was adventure games, but, noticeably, one vote went to rhythm games.

The pre-game questionnaire also investigated participants' opinions on the adoption of video games in an educational framework. Four respondents out of 9 declared to have the highest consideration toward gamification in education, whereas one of them was completely against this approach. Finally, six participants stated that they had never participated in a gamification activity.

4.3 Post-Game Questionnaire Results

As mentioned at the beginning of the section, this part of the experimental activity focused on the Core Module and the Post-Game Module of the *Game Experience Questionnaire*.

In order to present the findings of the GEQ, violin plots and box plots derived from all participants in the study were employed. These graphical representations serve to provide a depiction of the data distribution. The violin plot offers insight into the den-

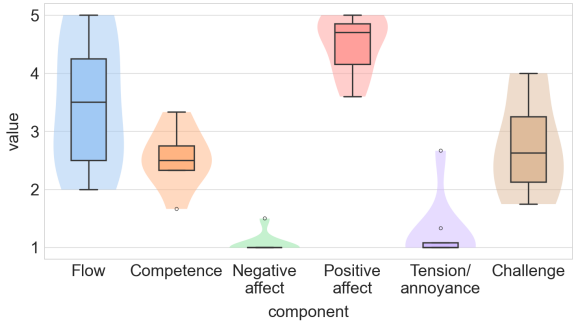

Figure 3: Violin plots, computed from the Core GEQ data of all participants. Each plot focuses on one specific component of the GEQ.

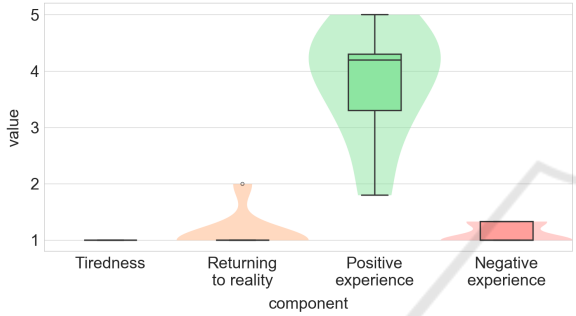

Figure 4: Violin plots, computed from the Post-Game GEQ data of all participants. Each plot focuses on one specific component of the GEQ.

sity estimation of the empirical distribution, while the accompanying box plot delineates key statistical parameters including quartiles, median, maximum and minimum values (whiskers), with outliers depicted as individual data points.

The distribution of average scores among various components of the core module is depicted in Fig. 3.

The median values of the *flow* and *positive affect* components are approximately 3.5 and greater than 4.5, respectively. This implies that the players were immersed, enjoyed the game, and felt pleasure in the experience. Conversely, the medians of the *negative affect* and *tension/annoyance* components are 1, the minimum value on the scale. The players did not feel pressure or frustration, and negative experiences were minimal. The *competence* component is close to 2.5. This value suggests that players did not perceive themselves as highly skilled. This is especially true for less experienced players who had to understand music-related requests and learn to play. It also suggests that more initial training will be necessary in the future. Similarly, the median of the *challenge* component is around 2.5, indicating a moderate level of challenge for the players.

For the Post-Game Module, the violins and box plots are shown in Fig. 4. The components under analysis are *positive experiences*, *negative experiences*, *tiredness*, and *returning to reality*.

As can be seen from the data, the *positive experience* component consistently yields a median exceeding 4. Conversely, the medians of the *negative experience* and *tiredness* components hover around 1, the lowest value permitted. These findings suggest that the activities offered in *Midigames* were positively evaluated by the participants, and the notion of presenting brief gaming activities likely mitigated the fatigue of the players. Moreover, the process of *returning to reality* was perceived as effortless, with a median of approximately 1.

5 CONCLUSIONS

This paper has described a platform to foster proficiency in the use of a MIDI keyboard, focusing on different musical parameters and employing different interaction tools typically offered by a keyboard-like controller.

The software platform exhibits several advantages that stem from its versatility, which caters to diverse user demographics, including children without prior knowledge of music, individuals with physical or cognitive impairments, and those simply seeking recreational enjoyment.

While the preliminary tests conducted so far on the software platform may have involved a limited number of users, their significance lies in establishing a robust investigation methodology and generating valuable insights through the application of established evaluation guidelines such as the Game Experience Questionnaire. Moving forward, these findings serve as a foundation for further research, iterative development, and optimization efforts aimed at enhancing the platform's usability, accessibility, and overall user experience.

In the gameplay, aspects of reinforcement have been integrated so that actions on the keyboard achieve not only the apparent goal of the game (for example, reproducing a sequence of gestures to overcome an obstacle) but also aid in understanding the musical parameters typically controlled through those gestures. This integration of reinforcement mechanisms serves to deepen the player's engagement with the game by aligning gameplay objectives with musical learning outcomes. By requiring players to interact with the keyboard in ways that directly impact musical parameters, such as pitch, tempo, or rhythm, the gameplay experience becomes inherently educational. Players not only progress through the game's

challenges but also develop a nuanced understanding of musical concepts and techniques. Furthermore, by linking gameplay actions to musical parameters, the gameplay experience becomes more immersive and meaningful. Players are not just pressing keys to advance in the game; they are actively shaping and manipulating musical elements, thus enhancing their musical comprehension and appreciation.

However, it is important to acknowledge a known limitation of our approach: the necessity of having a physical controller capable of handling MIDI communication. This requirement may pose challenges for some users who do not have access to such hardware or face barriers to its use. Moving forward, addressing this limitation could involve exploring alternative control methods or providing support for a broader range of input devices, thus ensuring greater accessibility and inclusivity in the gameplay experience.

REFERENCES

Airy, S. and Parr, J. M. (2001). MIDI, music and me: Students' perspectives on composing with MIDI. *Music Education Research*, 3(1):41–49.

Baratè, A., Korsten, H., Ludovico, L. A., and Oriolo, E. (2021). Music tangible user interfaces and vulnerable users: state of the art and experimentation. In *International Conference on Computer-Human Interaction Research and Applications*, pages 1–25. Springer.

Beckstead, D. (2001). Will technology transform music education? although technological advances make composing easier, music educators tend to use these tools to make traditional methods more accessible rather than explore new possibilities in composing. *Music Educators Journal*, 87(6):44–49.

Birch, H. J. and Woodruff, E. (2017). Technical exercise practice: Can piano students be motivated through gamification? *Journal of Music, Technology & Education*, 10(1):31–50.

Caponetto, I., Earp, J., and Ott, M. (2014). Gamification and education: A literature review. In *European Conference on Games Based Learning*, volume 1, page 50. Academic Conferences International Limited.

Chousidis, C. and Lipan, L. (2016). The application of a novel voice-driven MIDI controller in music education and training. In *ICICTE 2016 Proceedings*.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*, volume 1990. Harper & Row New York.

Gomes, C., Figueiredo, M., and Bidarra, J. (2014a). Gamification in teaching music: Case study. *International Journal on Advances in Education Research*.

Gomes, J., Figueiredo, M., and Amante, L. (2014b). Musical journey: A virtual world gamification experience for music learning. *International Journal on Advances in Education Research*, 1(1):1–21.

Hunter-Armstrong, C. K. (1996). *MIDI applications in music education*. California State University, Long Beach.

IJsselsteijn, W. A., De Kort, Y. A., and Poels, K. (2013). *The game experience questionnaire*. Technische Universiteit Eindhoven.

Ludovico, L. A. (2017). The Web MIDI API in on-line applications for music education. In Ludovico, L. A. and Yousef, A. M. F., editors, *Proceedings of the Ninth International Conference on Mobile, Hybrid, and On-line Learning (eLmL 2017)*, pages 72–77. IARIA XPS.

Mandanici, M., Spagnol, S., Ludovico, L. A., Baratè, A., and Avanzini, F. (2023). A taxonomy of digital music learning resources. In *Digital Music Learning Resources: From Research to Educational Practice*, volume 1211 of *Springer Briefs in Education*, chapter 4, pages 53–66. Springer Science and Business Media B.V.

Molero, D., Schez-Sobrino, S., Vallejo, D., Glez-Morcillo, C., and Albusac, J. (2021). A novel approach to learning music and piano based on mixed reality and gamification. *Multimedia Tools and Applications*, 80:165–186.

Nakamura, J., Csikszentmihalyi, M., et al. (2002). The concept of flow. *Handbook of positive psychology*, 89:105.

Rovithis, E., Floros, A., and Kotsira, L. (2018). Educational audio gamification: Theory and practice. In *European Conference on e-Learning*, pages 497–505. Academic Conferences International Limited.

Samat, J., Baharum, A., and Andin, C. (2022). Identifying elements of gamification for reading music notation in music education. In *2022 13th International Conference on Information and Communication Technology Convergence (ICTC)*, pages 563–567. IEEE.

Swingler, T. (1998). "that was me!": Applications of the Soundbeam MIDI controller as a key to creative communication, learning, independence and joy. In *California State University Northridge Conference on Technology and Persons with Disabilities*.

Wagner, C. (2017). Digital gamification in private music education. *Antistasis*, 7(1).