A Mobile Serious Game to Foster Music Sight Reading with Different Clefs

Adriano Baratè[a], Andrea Brugaletta and Luca A. Ludovico[b]
Laboratory of Music Informatics (LIM), Department of Computer Science "Giovanni Degli Antoni", University of Milan, via G. Celoria 18, 20133 Milan, Italy

Keywords: Music, Education, Mobile Applications, Serious Games, Clefs.

Abstract: This work introduces a mobile app that aims to promote the sight-reading of music with different positions of the clef on the stave. Relying on the principles of game-based learning, the app offers applications primarily in the didactic field: by facilitating and encouraging the learning of this challenging aspect of music, the app on one side contributes to the preservation of intangible musical heritage and, on the other, serves practical educational purposes such as the preparation for Conservatory exams. The results of early experimentation show a general appreciation by test users as it concerns engagement, but also highlight a number of interaction aspects to be improved.

1 INTRODUCTION

A game refers to a structured play with rules, goals, and challenges for the purpose of entertainment (Cheng et al., 2015). The term "gamification" first emerged in the first decade of the 2000s and gained increasing relevance since the 2010s. In contrast to games, gamification is characterized by its serious purpose. Gamification is closely related to the concepts of *serious games* and *game-based learning* (Krath et al., 2021). The latter locution refers to the achievement of defined learning outcomes through game content and play and enhancing learning by involving problem-solving spaces and challenges that provide learners, who are also players, with a sense of achievement. Serious games, being designed to have a primary purpose other than pure entertainment, are the means to achieve game-based learning.

Serious games have gained increasing attention in recent years as a promising tool for education and training. By leveraging the motivational power of games, serious games offer a unique opportunity to engage learners in a fun and interactive way while still delivering meaningful content. The serious and the game parts have to be carefully balanced in order to meet quality criteria, as explained in (Caserman et al., 2020).

Serious games demonstrated to be effective in various domains, such as health (Sharifzadeh et al., 2020), military (Gace et al., 2019), and corporate training (Larson, 2020). Moreover, it is worth mentioning the research on the effects of serious games on people with intellectual disabilities, autism spectrum disorder, developmental disabilities, and cognitive and physical impairments (Tsikinas and Xinogalos, 2019; de Vasconcelos et al., 2020; Kokol et al., 2020; Vieira et al., 2021).

However, despite the growing interest in serious games, there is still a need for more rigorous research to investigate their effectiveness in different learning contexts, as well as to identify best practices for their design and implementation (Backlund and Hendrix, 2013; Bellotti et al., 2013; Giessen, 2015; Zhonggen, 2019).

This paper is the evolution of a previous work that provided only the guidelines for the implementation of a serious game in the form of an app (Baratè and Ludovico, 2013). With respect to the mentioned work, the main aspects of novelty concern the availability of a working prototype and, consequently, the possibility to report on an early test phase. After completing the beta testing and passing the required privacy, security, and content verification by Apple, the prototype will be made freely available in the App Store.

In this work, we first present a systematic review of the existing literature on serious games in music-

[a] https://orcid.org/0000-0001-8435-8373
[b] https://orcid.org/0000-0002-8251-2231

Baratè, A., Brugaletta, A. and Ludovico, L.
A Mobile Serious Game to Foster Music Sight Reading with Different Clefs.
DOI: 10.5220/0012059500003470
In *Proceedings of the 15th International Conference on Computer Supported Education (CSEDU 2023) - Volume 1*, pages 397-403
ISBN: 978-989-758-641-5; ISSN: 2184-5026

oriented learning environments, examining the evidence base for serious games as a tool for learning and considering the factors that contribute to their effectiveness. We also explore the design principles that have been proposed for music-oriented serious games. Then, we propose a mobile app that implements a serious game to encourage the practice of music sight reading in a number of clefs, an activity often considered boring and uninteresting by young music learners. After an early test phase, we discuss the limitations of current research and identify directions for future research.

The rest of this work is structured as follows: Section 2 addresses the adoption of computer-supported systems in music education, focusing in particular on mobile apps for sight reading; Section 3 introduces the music theory behind the problem we want to solve, namely the development of abilities in sight reading with different clefs; Section 4 describes the technical details, the graphical interface, and the gameplay of the proposed serious game; Section 5 reports on early experimentation conducted on a small number of test users; finally, Section 6 discusses the applicability of such an approach to music education and draws the conclusions.

2 RELATED WORKS

Serious games that use computer technology to teach and learn music have been widely researched and implemented. The scientific literature on computer-based serious games related to music is extensive and covers a wide range of topics, including simulated instrumental practice, advanced ear training, music composition, graphical representation and analysis of scores, and motion-tracking techniques for controlling music and audio parameters. Baratè *et al.* provide a number of significant examples (Baratè et al., 2013).

To our goals, the field can be narrowed to mobile-oriented applications related to music edutainment and ear training.

There are software tools aiming to simulate traditional musical instruments or implement brand-new ones. Examples documented in the scientific literature include the *Smule Ocarina* (Wang, 2009) and *PhonHarp* (Presti et al., 2021). A more recent investigation about the state of the art and the future perspectives of mobile devices employed as musical instruments is provided in (Essl and Lee, 2018).

Social interaction in music-making through mobile devices is the basis of projects such as *Momu*, a music toolkit for mobile devices (Bryan et al., 2010), *MoPhO*, the Stanford Mobile Phone Orchestra (Oh et al., 2010), and the *Mobile Device Marching Band*, a revised version of the Princeton Laptop Orchestra (Snyder and Sarwate, 2014). Mobile devices can also be used to implement audience-participation techniques based on social mobile computing (Oh and Wang, 2011).

Zhou *et al.* describe the experience of *MOGCLASS*, a collaborative system of music to perform in a classroom context (Zhou et al., 2011). Another relevant early example is provided by *Rhythmatical*, an educational application designed for iPhone and iPod Touch that conveyed mathematical topics via musical, rhythmic, or movement interactive techniques (Moorefield-Lang and Evans, 2011).

Particularly relevant to our goals are mobile apps for sight reading (Loman and Wiradinata, 2014; Larasati and Sukmayadi, 2021). Even if not documented in the scientific literature, it is worth mentioning applications such as *Music Tutor (Sight-Reading)* by Jsplash Apps, *Music Crab: Easy Music Theory* by Eric Zorgniotti, *Notes Teacher* by Yannis Richard, *Note Flash Music Sight Reading* by Pranoy Chowdhury, and *Note Brainer* by James Buchanan. These products are similar to our proposal as it concerns the general goals and the graphical interface, but they mainly address standard music notation and, as such, are not aimed at sight reading with multiple alternating clefs.

3 THE 9-CLEF SYSTEM

In Western Music Notation, a clef is a musical symbol that fixes which notes are represented by the lines and spaces on a musical stave. Music theory, based on the evolution of European music across the centuries, currently recognizes three clef symbols: the C-clef, F-clef, and G-clef. The placement of a given clef on a specific stave position assigns a particular pitch to one of the five lines, consequently defining the pitches on the remaining lines and spaces. For example, the G-clef on the second line of the stave states that the pitches on that line are G notes of the central octave, thus the pitches on the lower line are E notes and those on the upper line are B notes.

The use of different clefs, concerning both the music symbol and its placement on the stave, makes it possible to write music for all instruments and voices, taking into account differences in their range. Using different clefs for different instruments and voices allows each part to be written comfortably on a stave with a minimum of ledger lines.

In fact, the mentioned clef symbols not only iden-

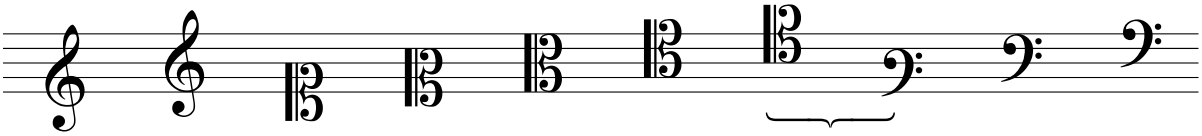

Figure 1: Clefs commonly in use in musical practice. From left to right: French violin, Trable, Soprano, Mezzo-soprano, Alto, Tenor, Baritone (two versions), Bass, and Subbass.

tify different reference notes but can also be theoretically placed on each stave line, thus moving the specific reference note across the stave. The combination of 5 lines and 3 clefs originates 15 possibilities for clef placement, but 6 would be redundant since they would result in an identical assignment of the notes to lines and spaces. For the sake of clarity, a G-clef on the fourth line achieves the same note placement as a C-clef on the second line. As a consequence, historically only 9 distinct clefs have been in use (see Fig. 1): the G-clef on the two bottom lines, the C-clef on any line, and the F-clef on the three top lines. Even if the C-clef on the top line is equivalent to the F-clef on the third one, both options have been employed in music notation.

Concerning music notation, such a system has been in disuse for more than a century. Nowadays, leaving out the editions that use the ancient notation for philological reasons, the soprano, mezzo-soprano, and contralto parts are written in the treble clef, whereas the baritone and bass parts are written in the bass clef; for the tenor part, the suboctave treble clef is used, i.e. a standard treble clef accompanied by a sign to indicate the execution in the lower octave. Concerning musical instruments, the alto clef is still adopted by the viola and the alto trombone and the tenor clef is an auxiliary notation for the cello, trombone, bassoon, double bass, and contrabassoon. Modern instrumentation and orchestration texts still suggest their use for specific instrumental scoring (Blatter, 1997).

In the Italian formal music-education system, the study of this subject is known as *setticlavio*, an Italian word literally standing for "seven clefs". In fact, seven is the number of male and female tessituras used in vocal music (soprano, mezzo-soprano, alto, tenor, baritone, and bass) plus the Treble clef. Anyway, for extension, the study of *setticlavio* involves all the possibilities shown in Fig. 1.

Setticlavio, intended as a solfeggio alternating all the clefs, represents one of the sight-reading tests of the *Musical Theory and Solfeggio* license in Italian conservatories, both in a spoken and in a sung form. Fig. 2 shows an example of *setticlavio* taken from the final exam at the Conservatory of Brescia. Moreover, its use is required in *Composition* courses dealing with ancient music. Due to its infrequent use in contemporary music notation, the study of the *setticlavio* is often considered difficult and perceived as useless. This is particularly true for young music students who are the typical participants of *Musical Theory and Solfeggio* courses.

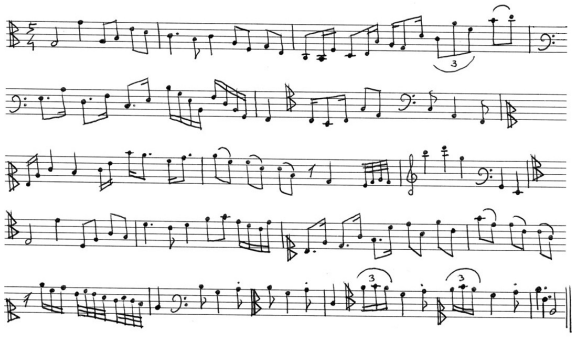

Figure 2: An example of handwritten *setticlavio* for the final test of *Music theory and solfeggio* at the Conservatory of Brescia.

4 THE APPLICATION

In this section, we describe in detail *iClef*, the serious game we developed in the form of an app for mobile devices. The application is currently available to developers as a beta release and runs on iOS devices only. A cross-platform implementation using *Kotlin Multiplatform Mobile*, *React Native*, *Xamarin*, or similar technologies is currently under study.

4.1 Design

During the design phase of *iClef*, we first analyzed the factors that make a serious game effective. It is important to consider the specificity and distinctive characteristics of each game, but it is possible to find in the literature some common components that involve an increase in the effectiveness of serious games, i.e. in their ability to achieve the intended purpose. From a study conducted on 63 serious games (Ravyse et al., 2017), five common factors emerged: storytelling, realism, adaptability, interactivity, and feedback. In the case of *iClef*, the first two items, typical of interactive and immersive games, can be overlooked. Rather, we focused on the last three, namely adaptability, inter-

activity, and feedback.

The main role of **adaptability** is to adjust the training pace, with the goal of avoiding frustration on one side and keeping the engagement level high on the other. Specifically, in this scenario, adaptability can be seen as the ability to adjust the difficulty of the game according to the skill displayed by the player during the gameplay. To this end, a user-performance analysis mechanism has been implemented, with particular reference to response times. Within the app, there are four elements that make the game more or less complex:

- the time available to guess a note, which naturally decreases during the gameplay, unless a mistake occurs;
- the number of keys which, is chosen before the game starts (see Section 4.3);
- the width of the interval between two consecutive notes, which normally increases during the gameplay, unless a mistake occurs;
- the number of accidentals applied to the notes. At the beginning of the gameplay, only natural notes are proposed, but soon single and even double accidentals can appear.

Adaptability is implemented by making all the mentioned parameters change to either increase or decrease the difficulty in relation to the user's behavior.

Interactivity is strictly connected to the game mode proposed to the player, which implies the timed presentation of a sequence of notes written in different clefs and the consequent choice of the pitch considered correct by the user through a point-and-click action to perform on the device. Interactivity is multimodally reinforced through the use of sound, as shown below.

The **feedback** component is mainly conveyed through two factors: the score, whose progression is closely related to the user's performance, and some simple visual and audio cues. In particular, in the case of success, the graphical representation of the note is colored in green, and the pitch is aurally performed; in the other case, the note is colored in red, and an audio icon remarks on the mistake. The feedback component allows players to immediately perceive a cause-and-effect link between their actions and the game result.

4.2 Graphical Interface

The graphical interface of the app during the gameplay is shown in Fig. 3. The screen is roughly divided into two areas: the upper one is aimed to contain the

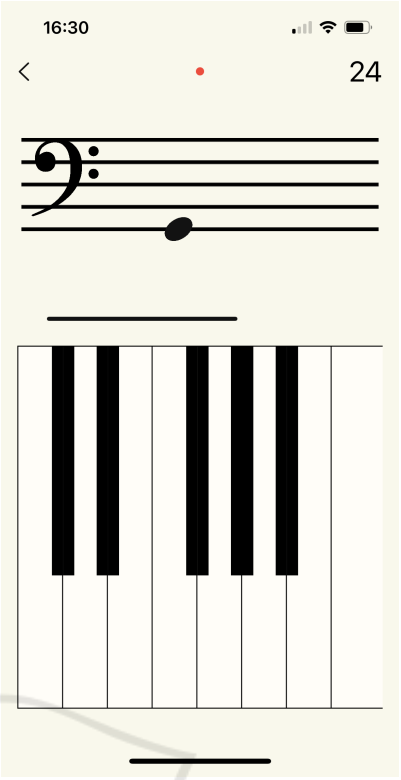

Figure 3: The graphical interface of *iClef*.

music notation to recognize, while the lower one is a one-octave keyboard to input results.

Right below the stave, there is an indicator that provides feedback about the time left to guess the pitch.

In addition, in the upper area, there is a control to go back to the main menu (left position) and two indicators for the number of mistakes made by the user (middle position) and the score achieved (right position).

The graphical interface is intentionally very plain and clean, so as not to distract the player from the main goal, which is guessing the pitch. The notation is represented as widely as possible. Unfortunately, the horizontal dimension of the screen limits the width of keys; nevertheless, during the early test phase, the pointing mechanism proved to be adequate to allow precise identification of pitches.

4.3 Gameplay

The aim of *iClef* is to guess the pitch of the notes proposed on a stave and shown for a limited time. Such a choice is done using the on-screen representation of a piano keyboard, the range of which is limited to one octave. The pitches must therefore be recognized on the basis of their name and independently of the oc-

tave information. The notes can be altered and the accidentals must be correctly recognized by the user.

iClef was conceived as a potentially infinite game. The game ends either by the player's decision or by reaching the maximum number of errors allowed in a match, namely three mistakes.

The start menu of the app lets the user select one of four levels. The main difference between them lies in the number of clefs that will randomly appear:

- the first level – *Beginner* allows the user to practice in the Treble clef only;
- the second level – *Intermediate* presents notation in the Treble and Bass clefs;
- the third level – *Advanced* contains the four most used clefs, i.e. Treble, Bass, Alto, and Tenor;
- finally, the last level – *Expert* lets the user practice on all clefs.

After the initial choice, there is no level advancement. In other words, a good performance, say, in the *Beginner* level does not take the player to the *Intermediate* level after a while. Anyway, during the gameplay, the level of difficulty increases according to the factors illustrated in Section 4.1. Beating the top score should provide enough motivation to perform better and better. The score awarded for each guessed note changes from level to level, ranging from 2 at *Beginner* level to 32 at *Expert* level.

iClef can be used both for sight-reading practice and for teacher assessment in game-based learning. Please note that multiple gameplay modes can be conceived. Basically, *iClef* is a single-player endless runner game, but it can be easily adapted to become a time-challenge game, as we did in our early experimentation (see Section 5). Moreover, even if a multiplayer mode is not available, user scores and performances can be easily compared in a class environment, thus fostering competition, motivation, and engagement (Cagiltay et al., 2015).

5 EARLY EXPERIMENTATION

A session of tests has been conducted with a small number of users. The employed devices included an iPhone 12 Pro and an iPhone 13 Pro. Ten test users have been involved in the test campaign, aged 30 to 50, with formal/informal music education and some experience in musical scores. For reasons of space, we have selected three particularly significant cases in order to represent different categories of potentially interested users:

- *User A* is a 46-year-old professional in the field of sound and music computing, with past formal studies in piano and composition. He/she can represent users interested in this application to prepare for a Conservatory exam;
- *User B* is a 48-year-old musician who is used to reading sheet music (in particular, he/she plays the trumpet in a jazz band) but has never had the need to learn clefs other than the G-clef. He/she can represent users willing to improve orchestral score sight-reading;
- *User C* is a 40-year-old amateur musician who plays the saxophone in small ensembles for fun in his/her spare time. He/she can represent a population of users who is completely unaware of the 9-clef system.

The test campaign focused on single-player matches organized as time challenges. The tests were sized considering two conflicting needs: they had to be short enough to keep the attention high, but long enough to provide players with non-trivial challenges. The maximum duration for each game session was 90 seconds, but the game could stop even earlier in the case of 3 errors achieved. Each player was subjected to 4 game sessions of increasing difficulty, spaced by 1-minute-long rests: one match at the *Beginner*, *Intermediate*, *Advanced*, and *Expert* levels. There was no previous training about the use of the app since this campaign was not intended to assess learning effects. Rather, the goal was to test the functions of the software, the effectiveness of the gameplay, and the level of engagement. Moreover, we retrieved some useful comments and remarks from the test users.

The results achieved by selected users during the gameplay are shown in Table 1. Not surprisingly, *User A* achieved a better success rate and a higher number of correctly recognized notes in each round. Anyway, *User A*, more skilled in sight-reading due to his/her formal studies, was overconfident and used a frantic approach, trying to guess the highest number of notes in the smallest time, but this brought him/her to commit a high number of mistakes (for example, at the *Beginner* level he/she concluded the match in advance due to mistakes). Conversely, *User B* and *User C* spent more time reading the notation, thus slowing down the pace but also paying more attention to some game pitfalls. A typical example, in this sense, is the presentation of two successive notes with the same position on the stave but corresponding to different pitches due to the occurrence of a clef change: at a glance, this situation can be misinterpreted by a frantic player.

Now, we summarize the main remarks and suggestions emerging from post-activity interviews.

Table 1: Results achieved by Users A, B, and C in 90-second time challenges for each of the 4 levels.

User	Level	Nr. of right notes	Nr. of mistakes	Elapsed time (s)	Success rate (notes/s)
A	1	87	3	78	1.12
B	1	70	0	90	0.78
C	1	56	3	65	0.86
A	2	61	3	66	0.92
B	2	45	3	84	0.54
C	2	26	3	50	0.52
A	3	63	2	90	0.7
B	3	36	2	90	0.4
C	3	8	3	44	0.18
A	4	13	3	21	0.62
B	4	3	3	24	0.13
C	4	12	3	55	0.22

User A was not completely satisfied with the graphical interface, in his/her opinion poor in information about game progression during the gameplay. According to *User A*, a lacking option is the number of subsequent notes to be read in the same clef, in accordance with solfeggio exercises in use in Conservatories; nevertheless, *User A* recognized that being able to sight-reading notes in everchanging clefs would provide a good test bed for easier tasks.

User B noticed a lack of continuity when (not) passing from one level to another: in his/her opinion, a good performance at Level n should automatically bring to Level $n+1$. Concerning the interface, some elements typical of gamification, such as stars or awards, are missing. Regarding the automatic selection of pitches, the distribution of notes is not considered optimal compared to the limited keyboard range. Furthermore, *User B* pointed out that game performances are influenced by the type of controller the instrumentalist is used to: a keyboard interface is more intuitive for a pianist than for a trumpet player. Finally, he/she would have appreciated the presence of a dashboard with historical scores, trends, and some diagrams.

Finally, *User C* considered the game engaging and its interface fit for the goals of the app. Nevertheless, if intended for non-expert users, the game needs a tutorial and some theoretical explanation. A shortcoming detected in the gameplay, especially in the initial phase of each level, is the repetitiveness of pitches, which causes a decrease in the player's interest. In conclusion, *User C* pointed out that he/she would use the game again if he/she had to learn sight-reading in different clefs (which, anyway, was not his/her intention at the moment of the interview).

6 CONCLUSIONS

In this work, we presented an app for mobile devices whose purpose is to encourage the study and learning of reading at the first sight of music written with multiple alternating clefs. The main applicability fields have a didactic nature and range from the enhancement of intangible musical heritage (for example, the development of the ability to read ancient music) to practical educational purposes (for example, the preparation of specific Conservatory exams).

The effectiveness of game-based learning in this scenario must be verified in an experimental context, while, at the moment of writing, we have investigated mainly implementation and gameplay aspects. Concerning the experimental phase, one of the critical aspects to consider is the difficulty of conducting massive test campaigns due to the niche of users the app is aimed at. In fact, the expected audience for this kind of serious game is made of musicians or music students interested in sight reading with alternating clefs, which is not a common scenario in music practice or even in basic music education. For this reason, we hope that the described solution will be brought into conservatories and music schools, so as to analyze learning results and retrieve comments and suggestions from a more numerous and differently characterized pool of users.

REFERENCES

Backlund, P. and Hendrix, M. (2013). Educational games-are they worth the effort? a literature survey of the effectiveness of serious games. In *2013 5th international conference on games and virtual worlds for serious applications (VS-GAMES)*, pages 1–8. IEEE.

Baratè, A., Bergomi, M. G., and Ludovico, L. A. (2013). Development of serious games for music educa-

tion. *Journal of e-Learning and Knowledge Society*, 9(2):93–108.

Baratè, A. and Ludovico, L. A. (2013). Serious games for music education. a mobile application to learn clef placement on the stave. In Foley, O., Helfert, M., Restivo, M. T., and Uhomoibhi, J., editors, *Proceedings of the 5th International Conference on Computer Supported Education (CSEDU 2013)*, pages 234–237, Setúbal. SCITEPRESS - Science and Technology Publications, Lda.

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., and Berta, R. (2013). Assessment in and of serious games: an overview. *Advances in human-computer interaction*, 2013:1–1.

Blatter, A. (1997). *Instrumentation and orchestration*. Schirmer Books.

Bryan, N. J., Herrera, J., Oh, J., and Wang, G. (2010). MoMu: A mobile music toolkit. In *NIME*, pages 174–177. Citeseer.

Cagiltay, N. E., Ozcelik, E., and Ozcelik, N. S. (2015). The effect of competition on learning in games. *Computers & Education*, 87:35–41.

Caserman, P., Hoffmann, K., Müller, P., Schaub, M., Straßburg, K., Wiemeyer, J., Bruder, R., Göbel, S., et al. (2020). Quality criteria for serious games: serious part, game part, and balance. *JMIR serious games*, 8(3):e19037.

Cheng, M.-T., Chen, J.-H., Chu, S.-J., and Chen, S.-Y. (2015). The use of serious games in science education: a review of selected empirical research from 2002 to 2013. *Journal of computers in education*, 2:353–375.

de Vasconcelos, D. F. P., Júnior, E. A. L., de Oliveira Malaquias, F. F., Oliveira, L. A., and Cardoso, A. (2020). A virtual reality based serious game to aid in the literacy of students with intellectual disability: Design principles and evaluation. *Technology and Disability*, 32(3):149–157.

Essl, G. and Lee, S. W. (2018). Mobile devices as musical instruments-state of the art and future prospects. In *Music Technology with Swing: 13th International Symposium, CMMR 2017, Matosinhos, Portugal, September 25-28, 2017, Revised Selected Papers 13*, pages 525–539. Springer.

Gace, I., Jaksic, L., Murati, I., Topolovac, I., Zilak, M., and Car, Z. (2019). Virtual reality serious game prototype for presenting military units. In *2019 15th International Conference on Telecommunications (ConTEL)*, pages 1–6.

Giessen, H. W. (2015). Serious games effects: an overview. *Procedia-Social and Behavioral Sciences*, 174:2240–2244.

Kokol, P., Vošner, H. B., Završnik, J., Vermeulen, J., Shohieb, S., and Peinemann, F. (2020). Serious game-based intervention for children with developmental disabilities. *Current pediatric reviews*, 16(1):26–32.

Krath, J., Schürmann, L., and von Korflesch, H. F. (2021). Revealing the theoretical basis of gamification: A systematic review and analysis of theory in research on gamification, serious games and game-based learning. *Computers in Human Behavior*, 125:106963.

Larasati, M. T. L. and Sukmayadi, Y. (2021). Mobile learning design for sight reading. In *3rd International Conference on Arts and Design Education (ICADE 2020)*, pages 70–73. Atlantis Press.

Larson, K. (2020). Serious games and gamification in the corporate training environment: A literature review. *TechTrends*, 64(2):319–328.

Loman, C. T. and Wiradinata, T. (2014). Design and development of sight-reading application for kids. *ICITECHS*, 1:51–55.

Moorefield-Lang, H. and Evans, M. A. (2011). Rhythmatical: A game to combine music and mathematics for mobile devices. *Music Reference Services Quarterly*, 14(1-2):46–51.

Oh, J., Herrera, J., Bryan, N. J., Dahl, L., and Wang, G. (2010). Evolving the Mobile Phone Orchestra. In *NIME*, pages 82–87. Sydney.

Oh, J. and Wang, G. (2011). Audience-participation techniques based on social mobile computing. In *ICMC*.

Presti, G., Adriano, D., Avanzini, F., Baratè, A., and Ludovico, L. A. (2021). Phonharp: A hybrid digital-physical musical instrument for mobile phones exploiting the vocal tract. In *AM'21: Proceedings of the 16th International Audio Mostly Conference: Sonic experiences in the era of the Internet of Sounds*, ACM International Conference Proceeding Series, pages 276–279. ACM.

Ravyse, W. S., Seugnet Blignaut, A., Leendertz, V., and Woolner, A. (2017). Success factors for serious games to enhance learning: a systematic review. *Virtual Reality*, 21(1):31–58.

Sharifzadeh, N., Kharrazi, H., Nazari, E., Tabesh, H., Edalati Khodabandeh, M., Heidari, S., and Tara, M. (2020). Health education serious games targeting health care providers, patients, and public health users: scoping review. *JMIR serious games*, 8(1):e13459.

Snyder, J. and Sarwate, A. (2014). The mobile device marching band. In *Proceedings of the International Conference on New Interfaces for Musical Expression*.

Tsikinas, S. and Xinogalos, S. (2019). Studying the effects of computer serious games on people with intellectual disabilities or autism spectrum disorder: A systematic literature review. *Journal of Computer Assisted Learning*, 35(1):61–73.

Vieira, C., da Silva Pais-Vieira, C. F., Novais, J., Perrotta, A., et al. (2021). Serious game design and clinical improvement in physical rehabilitation: systematic review. *JMIR Serious Games*, 9(3):e20066.

Wang, G. (2009). Designing smule's ocarina: The iphone's magic flute. In *NIME*, pages 303–307.

Zhonggen, Y. (2019). A meta-analysis of use of serious games in education over a decade. *International Journal of Computer Games Technology*, 2019.

Zhou, Y., Percival, G., Wang, X., Wang, Y., and Zhao, S. (2011). MOGCLASS: evaluation of a collaborative system of mobile devices for classroom music education of young children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 523–532.