



Modern piano teaching technologies: Accessibility, effectiveness, the need for pedagogues

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Abstract. The article deals with certain approaches and methods using the latest technology to improve the results of piano teaching. The aim of the study is to analyze and compare the most popular and latest technologies of learning to play the piano in terms of their availability, effectiveness and the need for a teacher. In the work, methods of synthesis and analysis, comparisons were used, with the help of which various technologies of learning to play the piano were studied. As a result, two approaches for introducing modern technologies have become apparent in piano teaching: making group lessons more interactive and increase the scope of individual learning along with the gradual withdrawal of the teacher. However, some new technical solutions are far from being ready for use by educational institutions and individuals; therefore, it currently seems relevant to combine modern technology with conventional music teaching practices.

Keywords: Piano pedagogy, online learning, computer software, augmented reality, music e-learning

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INTRODUCTION

Music education is divided into three types: general music education, amateur music education, and professional music education. Professional music education is given to individuals who want to be trained as professional musicians (Akbulut, 2010). Analysis of pedagogical and psychological literature 2019 has provided some data about the modern form of teaching connected with the recognition of younger pupils' subjectivity, with the support of their cognitive self-reliance by teachers, and with attention to the development of pupils' motivation. Piano, being a class of keyboard instruments, requires a careful and consistent approach to teaching, because students must develop a number of skills that, only when used together, can make it possible not only to achieve a high level of playing musical compositions by notes but also to develop the ability to improvise. For a long time, piano teaching required interacting based on the "face-to-face" principle (Ryan, 2004), that is, direct close contact between the teacher and the student. But the specificity of musical education means that the wrong relationship with the teacher can prevent even the most gifted pupils to reach their full potential. For this reason, very high demands are placed on the teachers of the instrument both with their specialization and about their psychological and pedagogical abilities (Chmurzynska, 2012).

Music pedagogy, like other fields of the "art of teaching", does not stand still and actively improves the classical methods of mastering the instrument, involving the latest technology. To understand the full picture of its progress, one needs to study the experience of individual countries or authors in the innovation-intensive teaching to play keyboard instruments.

A significant advantage of keyboard instruments over others is their versatility. Black and white keys are used both in classical acoustic harpsichords, grand pianos, pianos, organs, accordions, and in electronic synthesizers, keytars, and the like. Therefore, it should be noted that the latest technology of teaching to play the piano is also applicable to the above-mentioned instruments.

The First Keyboard Instrument

The first stringed keyboard percussion instruments – harpsichords – appeared in the fourteenth century in Italy. This instrument has a long history; a huge contribution to its

literature and design was made but there never was, nor can be a standard harpsichord (Irvin, 2019). As a result of improvements and new approaches to acoustics, the first clavichords, virginals, and spinets appeared later, which, starting from the seventeenth century, were equipped with two rows of keys for convenience: five keys in each octave, which gave higher or lower semitones, were made shorter and placed above the main seven keys (the modern three black keys and two pairs of black keys). The color of the keys played a significant role, although, until the nineteenth century, the traditional seven whole tone keys were black, and those that gave a semitone were white, opposite to their current colors. It was since then that the first classical techniques of teaching to play this class of instruments emerged. At the end of the eighteenth century, an Italian master B. Cristofori invented the piano, and during the next century, several pipe organ masters introduced revolutionary innovations in the instrument: the three-pedal system and the double repetition mechanism invented by S. Érard (Harding, 2014). The creation of a unified piano mechanism contributed to the emergence of the first systematic approaches to teaching to play this instrument.

The Formation of “Piano Pedagogy”

The entry of Ukraine as an independent entity into the European educational space ensures the national identity of musical and educational phenomena, as well as actualizes the significance of the Ukrainian Piano School as a world heritage, determines the introduction of its pedagogical achievements to the general scientific community (Guralnyk & Xinyan, 2019).

The so-called piano pedagogy emerged relatively recently, along with the advent of the piano, which rapidly replaced its forerunners in the eighteenth century (Alekseev, 1974). However, some theoretical works describing the rules of sitting behind keyboard instruments, the position of fingers while playing, etc. had already existed in Europe before. This was due to the popularity of pipe organs, which in the Old World were the main musical instrument of the Roman Catholic religious cult. The Spanish organist J. Bermudo was among the first to thoroughly approach the theory of fingering charts, which resulted in his *Declaración de instrumentos musicales* in five volumes published in the middle of the sixteenth century (Alekseev, 1974). The author proposed to train all the fingers, as each of them can be used in various positions when performing various melodies and the performer must be prepared for it. Strangely enough, this seemingly logical method is not ubiquitous currently, and its followers are at odds with the classical approach to standardizing the fingering. Under the influence of the court etiquette of France and other countries, the rules of playing predecessors of the piano were saturated with special rituals that were supposed to present the musician as a gallant personality in high society. However, this ritual had no practical significance. In addition to the rules of finger positioning, the first publications on the teaching theory mainly dealt with considerations on the benefits of music and playing music for the human soul, physical health, paying much attention to the emotional unity of the performer and the melody to deliver all melodic shades properly.

The first fundamental educational works solely for the piano were published in the first half of the nineteenth century. Those were the publications by Austrian virtuoso pianists: J. N. Hummel's *A Complete Theoretical and Practical Course of Instruction on the Art of Playing the Piano Forte* (1828) and K. Czerny's *School of Practical Composition* (Rassel & Lynne, 2018).

In the nineteenth century – the era of the scientific and technological revolution – the attitude toward playing the piano also changed. Ordinary music teachers consciously or unconsciously began to focus on the playing technique, ignoring the improvisational side of piano education. This was quickly noticed by the then leading music teachers, in particular, F. Kalkbrenner, who was the first to criticize various mechanisms developed by “innovative” teachers who were supposed to teach students how to play the piano properly (Alekseev, 1974). The well-known Polish pianist and composer F. Chopin played a significant role in the development of the so-called “natural playing.” He insisted on using fingering performances natural for human hands and certainly influencing the harmony of melodies.

METHODS

This study analyzed the most popular modern technologies for teaching the piano to play in terms of their availability, effectiveness and the role of teachers in the process of their application. Using the method of synthesis and analysis, the main trends in the development of modern piano teaching technologies have been identified, their importance in teaching younger students. To determine the "ideal technology" for modern high-tech piano lessons, a comparison method was used.

RESULTS

The Essence of Piano Education is the Education of Music Quality

The effects of music art on the human spirit, emotion, soul, and character make music education become an important part of quality-oriented education. Therefore, piano teaching becomes increasingly popular in society. It is necessary to reform the traditional methods in piano teaching, to meet the requirements of more people in receiving the piano education and arouse the interests of children in learning the piano. In the internet era, mass teaching on intelligent piano becomes more superior (Xu, 2016). There are reasons to believe that with the popularization of intelligent mass teaching, piano education will prosper and develop, and the aesthetic ability and comprehensive quality of people will improve greatly.

In the education field, modern technologies have a significant advantage in facilitating education development and cultivating young students' interests. The application of modern technologies in piano teaching has great potential, which can optimize the presentation effect of teaching materials and promote the interaction between teachers and students. The application of modern technology to education is also a meaningful attempt for the reform of teaching mode and the development of education.

The Most Popular Features of Modern Piano Teaching Techniques

Modern piano teaching techniques are based on interdisciplinary approaches that use the latest achievements in anatomy, acoustics, neurology, IT technology, etc. Music pedagogy received the notion of "music technology," which unites all studies of the scientific community in the field of improvement of the training methods, between them and pianists (Gorbunova, Pomazenkova, & Tovpich, 2015). The community of music teachers does not accept all modern solutions equally, as they often are purely technical, such as, for example, the proposal to abandon musical notation in favor of chart-like tables (Gorbunova & Zalivadny, 2013). But some solutions harmoniously correlate with conventional music education. Ukrainian researchers, including Yu. F. Dvornik (2011), N. A. Zavgorodnyaya and P. A. Zavgorodnyy (2009), A. A. Baritskaya (2014), Yu. I. Oleinik (2013), and others, dealt with issues of music technology.

Piano keyboard and computer software

One of the successful combinations of modern information technology and conventional musical instruments is the integration of a piano keyboard with computer software, which immediately shows the notation of the track being played. This allows conducting a more detailed analysis of the student's playing by comparing the musical notation of the original and the completed sample of the composition. This feature makes it possible to evaluate one's playing and correct mistakes, even without a teacher. On the other hand, there is a risk that this type of training can become automatic and affect the improvisational potential of the student. Also, a digital MIDI keyboard will not reveal the entire potential of the one of the traditional pianoforte, which takes into account the pressure force, sometimes the material it is made of, and the like (Tanimoto, 2017). Also, as a rule, the missing pedal mechanism in such devices makes it impossible to master the principle of playing the traditional piano in practice, which consists in developing a proper, but individually comfortable sitting position.

Video communication as the tool for the interactive e-learning

Video communication as the main tool for the most interactive e-learning in modern conditions also provides ample opportunities for teaching to play the piano. However, to achieve a high level of skills, this solution requires using appropriate technical means. Firstly, these are several webcams (rather than a single one), because the teacher must be able to see not only the position of fingers on the keyboard from above but also how correctly the keys are pressed, how properly the student is sitting, as well as how he uses the pedals, which requires other views to be shown by cameras. Secondly, both the student and the teacher need high-quality microphones and speakers, capable of reproducing all the subtleties of the compositions being played and allowing for remote solfège lessons. Thirdly, it is necessary to have a high-speed Internet connection to transmit audio and video signals in real-time without delays. Also, an issue for such lessons is that common video communication software like Skype, Viber, Discord, Tox, etc. cannot use several webcams by one of the interlocutors, although these restrictions can be solved by using conference calls. But in this case, both sides need to have certain skills to set up such online classes. Nevertheless, the software market is actively developing and, probably, there are certain proprietary, application-specific IT products in this market, which can solve the above-mentioned issues. Another recognized shortcoming of video conferencing as a means of learning is their poor capability of providing the teacher with metacognitive data, that is, the student's progress in mastering the material, which cannot be always seen and heard in music education. Also, such an "ideal case" of a piano lesson will be much more expensive than a conventional one due to using numerous devices. Also, long-term musical training causes important audio-visual-motor plastic processes (Delogu, Brunetti, Inuggi, Campus, Del Gatto, & D'Ausilio, 2019).

Since the 1970s, music researchers have been making efforts to shift away from the system of individual piano lessons in educational institutions in groups (Johnson, Dufour, Damian, & Tzanetakis, 2016), since, in their opinion, this contributes to the popularization of music skills and significantly reduces the price of expensive, especially in Western countries, face-to-face lessons. Practical results also demonstrated the high efficiency of group lessons (Schonberg, 1987), due to a more abstract and comprehensible manner of explaining the playing technique principles and, probably, due to the competitive nature of the classes, stimulating students to achieve better results.

The Piano Tutor system

The US-developed Piano Tutor system of piano teaching, which was successfully tested in the early 1990s, was based on the most innovative approach. The project featured an algorithm automatically turning pages on the PC screen simultaneously with the song played, included a multimedia interactive system that involved the student who could adjust the training program by making it simpler after failures or more difficult after successful completion of a certain stage. After Piano Tutor was tested, it turned out to be a solution, good enough to entail adjustments to the curriculum of many US music schools, even those that did not use any multimedia teaching tools (Dannenberg, Sanchez, Joseph, Joseph, Saul, & Capell, 1993).

For example, West and Rostvall (2003) proposed a program of group detailed analysis of piano playing videos, divided into 11 lessons. In their opinion, it allows combining the advantages of an individual (more detailed study) and group (better coverage of the material) study models. The process of this method is complicated further with testing students by asking them to reproduce the demonstrated video materials with the instrument under the teacher's supervision. Also, according to West and Rostvall, this type of lesson deprives the teacher of excessive power and control, which has often resulted in even mocking the students who did not perform well, which is inadmissible for pedagogy. The authors of the mentioned teaching concept emphasize that their idea puts students in a "strong position along with better interactivity" (Seipp, 1976). Similar ideas are used in the Finnish music e-learning service Rockway, in which video materials are offered according to its pedagogical structure of education levels (Enbuska, Rimppi, Hietanen, Tuisku, Ruokonen, & Ruismäki, 2018).

The MIDI ensemble method

In the USA, the MIDI ensemble method has recently gained popularity. It is particularly popular among the so-called third-age students, that is, elderly people. This approach was tested in 2002 on 12,000 students of different age groups. In addition to those who had certain skills in playing the piano or similar instruments, there was also a subgroup of entry-level musicians. However, the group classes showed a fast pace of learning among the members of the latter subgroup. The classes were organized so that six students with personal MIDI keyboards were divided into three groups, which were responsible for their part of a technically simple musical composition. As the research results showed, about 90% of the students involved in this type of training tried to practice melodies taught at the classes outside the course. The main advantage of a MIDI ensemble consists of the regular training of the sense of rhythm and beat. In the future, the course developers are going to extend this experience to training programs for other instruments (Mora, Lee, Comeau, Shirmohammadi, & El Saddik, 2006).

Augmented reality technologies

Another promising direction of piano pedagogy is the use of augmented reality technology; whose developers seek to completely replace the teacher and even the instrument itself with technology in the future. For example, in the second half of the 2000s, the project VICON MX 3D was developed to train the proper sitting position and visualize sitting mistakes. Up to 79 sensors are attached to the student, in real-time showing on the PC screen the position of the student's spine and other parts of the skeleton when sitting at the piano. The PC program shows certain mistakes or offers various options for the proper positions of the pianist. The software also collects statistical data that allow monitoring the progress in developing the proper position when sitting at the instrument (Keraus, 1973). However, it is doubtful whether this technology can be used daily, as the equipment is quite expensive and the very presence of the sensors on the pianist's body causes a certain psychological discomfort affecting the playing quality, especially during improvisational exercises.

The detector of the correct position of the hands and piano gloves

Difficulties in learning to play the piano are well known. Finger coordination, rhythm, the ability to press the right keys and, especially, decryption of the abstract text of musical notes are difficult tasks (Blumenstein, Turova, Alves-Pinto, & Lampe, 2016). Modern innovations in correctional piano pedagogy no longer require any direct contact with the pianist. In Canada, a detector of the correct position of the hands while playing the piano with a deep inspection camera was tested in 2016. The previously needed numerous sensors were replaced with a heuristic software analysis of the hand position caught on video (Hwang, Son, & Kim, 2017), making it more convenient and less costly for common users and music education institutions.

In 2009, S. Garner invented piano gloves, which most accurately simulate playing the piano without using an actual instrument (Quick, 2010). The device accounts for the pressure force and quality of playing and records the collected data to a PC. But a large number of connected cables and sensors make hand movements uncomfortable, in contrast to the conventional option (Pike, 2011).

The "markerless teaching" method

A group of engineers from China worked with pianists to develop the AR Piano system (Augmented Reality Piano), which uses the so-called markerless teaching method. It combines a camera and software to locate the fingers when playing a particular melody on a special MIDI keyboard and lights up certain keys for playing piano solo or chords. The student only needs to press the backlit keys and adjust the tempo as needed, changing it along with his skill improvement (Harding, 2014). This system is suitable for a real educational process, as well as for amateur attempts to play the piano. However, this project does not yet train to position fingers properly to play conveniently and dynamically.

The KeynVision system

The aforementioned systems are too expensive and sophisticated to use, but they have laid a solid practical and theoretical basis for developing applied and simple concepts for a common user. Modern augmented reality concepts rely on VR-glasses (Virtual Reality), a portable and convenient device that allows access to the augmented reality quickly. The KeynVision system was developed to learn how to play the piano specifically for Microsoft HoloLens goggles. Its operating principle is similar to AR Piano, but the main focus is on transforming the learning process into a game process, i.e. gamification. The game-based method for teaching to play the piano not only is suitable for younger students but also is a universal approach for mastering certain skills quickly, as well as developing the pianists' potential for improvising. The interface of VR-goggles allows choosing from a large number of modes that visualize and synchronize the study of musical notation with fingering, train the performer's head positioning and movement without a real piano, etc. (Birhanu & Rank, 2017). The AirPiano system, designed by Korean experts, is similar but does not require a MIDI keyboard and a surface for simulation. Its advantage is the realistic tactile feedback of the fingers with fully virtual piano keys and the relative simplicity of the project technology (Huang, Zhou, Yu, Wang, & Du, 2011).

The system Andantino

Quite interesting is the British-American system Andantino, which combines virtual reality and gamification. Its name derives from the subtype of the music moderate tempo andante. The concept of this system is to visualize the indicators on the piano keyboard in the form of human silhouettes that move, dance, etc. (Xiao, Puentes, Ackermann, & Ishii, 2016). The developers note that such styled illumination of the required keys makes playing the piano more interesting for young pianists. However, Andantino does not distract the children but instead creates conditions for the child to focus on the keyboard, as the silhouettes react to correct/incorrect key presses, turning the learning process into an exciting and interactive game. Intensive tests of this system give hope that it will improve and become available for practical use (Tanimoto, 2017).

DISCUSSION and CONCLUSIONS

Thus, no ideal technology of piano teaching yet; each of them have its advantages and disadvantages. Having analyzed the most popular modern piano teaching techniques (Table 1), we can conclude that these technologies are not effective. The main disadvantage is the high cost of equipment, which is necessary for the use of one or another technology. It should also be noted that in 6 out of 10 studied technological systems, a student can do without a teacher.

Modern telecommunication and information technologies have become so global and widespread that they have penetrated even into the field of music education. Piano as one of the most popular instruments among students is no exception. IT technology has influenced the structure of piano lessons. With technical and communication tools, individual lessons become group lessons and involve as much interaction as possible, leveling their price down and eventually popularizing piano learning. The personal technique research of stringed keyboard instruments is improving intensively and dynamically. The first attempts to develop devices facilitating and automating piano teaching were made at the beginning of the nineteenth century, but they failed. The modern approach combines the principles of compactness, convenience, and practicality. Augmented reality systems stand out thanks to the revolutionary advancements in mobility that have taken place in recent years, making it possible for most people to enjoy their advantages.

Table 1. *The investigated characteristics of modern piano teaching techniques*

Piano Teaching Techniques	Characteristics		
	Accessibility	Effectiveness	Need for pedagogue
Piano keyboard and computer software	Depends on the software price	Partially	Not needed
Video communication	The equipment is quite expensive	Partially	Need
The Piano Tutor system	The equipment is quite expensive	Partially	Need
The MIDI ensemble method	The equipment is quite expensive	Effective	Not needed
Augmented reality technologies	The equipment is quite expensive	Partially	Not needed
Detector of correct position	The equipment is quite expensive	Partially	Need
Piano gloves	The equipment is quite expensive	Partially	Need
The “markerless teaching” method	Depends on the software price	Partially	Not needed
The KeynVision system	The equipment is quite expensive	Effective	Not needed
The system Andantino	The equipment is quite expensive	Partially	Not needed

Research and engineering centers constantly present innovations in piano playing using data from other sciences such as acoustics, bionics, psychology, etc. Although most of them are experimental and not yet ready for wide use, their ideas are a good basis for further development of hardware and software for individual use. Current trends in the development of artificial intelligence and technology testify to the fact that augmented-reality music education systems will be integrated into smart homes in the future, turning homes into full-fledged educational platforms. On the other hand, the rapid development of the technology behind piano education and popularization of group lessons can cause the piano teacher job to disappear or the number of piano teachers to significantly reduce. But so far, the conventional music pedagogy can successfully combine classical experience with modern technology in teaching to play the piano, since most multimedia applications and approaches to piano teaching are based on the interaction between the teacher and the student.

REFERENCES

- Akbulut, S. (2010) The use of extended piano techniques at conservatories in Turkey. *Procedia - Social and Behavioral Sciences*, 2(2), 3080–3087. <https://doi.org/10.1016/j.sbspro.2010.03.469>
- Alekseev, A. D. (1974). *Review of the piano teaching history*. Kyiv: Muzychna Ukrayina.
- Baritskaya, A. A. (2014). *Methods for the formation of professional competence in future music teachers by means of multimedia technologies*, Unpublished Doctoral Dissertation, Dragomanov National Pedagogical University, Kyiv, Ukraine.
- Birhanu, A., & Rank, S. (2017). KeynVision: Exploring Piano Pedagogy in Mixed Reality. *CHI PLAY '17 Extended Abstracts- Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*. <https://doi.org/10.1145/3130859.3131336>
- Blumenstein, T., Turova, V., Alves-Pinto, A., & Lampe R. (2016). Sensorimotor piano system for people with disabilities. *Journal of Sensors*, 2016. <http://dx.doi.org/10.1155/2016/9825905>
- Chmurzynska, M. (2012). How (not) to discourage youngsters from playing the piano. On bad and good piano teaching. *Procedia - Social and Behavioral Sciences*, 45, 306–317. <https://doi.org/10.1016/j.sbspro.2012.06.567>

- Dannenber, R. B., Sanchez, M., Joseph, A., Joseph, R., Saul, R., & Capell, P. (1993). Results from the piano tutor project. *Proceedings of the Fourth Biennial Arts and Technology Symposium*, 143–150.
- Delogu, F., Brunetti, R., Inuggi, A., Campus, C., Del Gatto, C., & D'Ausilio A. (2019). That does not sound right: Sounds affect visual ERPs during a piano sight-reading task. *Behavioural Brain Research*, 367, 1–9. <https://doi.org/10.1016/j.bbr.2019.03.037>
- Dvornik, Y. F. (2011). The issue of using computer technologies in musical creativity. *Bulletin of Taras Shevchenko LNU*, 7(218), II, 44–49.
- Enbuska, J., Rimppi, A., Hietanen, L., Tuisku, V., Ruokonen, I., & Ruismäki, H. (2018). E-learning environments, opportunities and challenges to play the piano in student teacher education. *The European Journal of Social and Behavioural Sciences*, 21, 2562–2569. <https://doi.org/10.15405/ejsbs.226>
- Gorbunova, I. B., & Zalivadny, M. S. (2013). On mathematical methods in music studies and musician training. *Music Scholarship*, 1(12), 272–276.
- Gorbunova, I. B., Pomazenkova, M. S., & Tovpich, I. O. (2015). Tablet and music-computer technologies in the system of professional music education. *Theory and Practice of Social Development*, 8, 211–219.
- Guralnyk, N., & Xinyan, M. (2019). Tradition as a factor in modern school formation in Ukrainian piano pedagogy. *Journal of History Culture and Art Research*, 8(1), 212–222. <http://dx.doi.org/10.7596/taksad.v8i1.1959>
- Harding, R. E. M. (2014). *The piano-forte*. Cambridge: Cambridge University Press.
- Huang, F., Zhou, Y., Yu, Y., Wang, Z., & Du, S. (2011). Piano AR: A markerless augmented reality based piano teaching system. *Third International Conference on Intelligent Human-Machine Systems and Cybernetics*, 47–52. <https://doi.org/10.1109/IHMISC.2011.82>
- Hwang, I., Son, H., & Kim, J. R. (2017). AirPiano: Enhancing music playing experience in virtual reality with mid-air haptic feedback. *IEEE World Haptics Conference (WHC)*, 213–218. <https://doi.org/10.1109/WHC.2017.7989903>
- Irvin, P. Y. (2019). About harpsichords. *Instrument Maker*. [Online]: Retrieved on 23-December-2019, at URL: http://www.pyirvin.com/about_harpsichords.htm#Top.
- Johnson, D., Dufour, I., Damian, D., & Tzanetakis, G. (2016). Detecting pianist hand posture mistakes for virtual piano tutoring. *Proceedings of the International Computer Music Conference*, 166–170.
- Keraus, R. (1973). *An achievement study of private and class Suzuki violin instruction*, Unpublished Doctoral Dissertation, University of Rochester, Rochester, New York.
- Mora, J., Lee, W.-S., Comeau, G., Shirmohammadi, S., & El Saddik, A. (2006). Assisted piano pedagogy through 3D visualization of piano playing. *IEEE International Workshop on Haptic Audio-Visual Environments and Their Applications (HAVE 2006)*, 157–160. <https://doi.org/10.1109/HAVE.2006.283791>
- Oleinik, Y. I. (2013). Information and communication technology in music: digital musical instruments. *Part 1: Study guide for art students of universities (major: Musical Art)*. Kherson: Shtrikh.
- Pike, P. D. (2011). Using technology to engage third-age (retired) leisure learners: A case study of a third-age MIDI piano ensemble. *International Journal of Music Education*, 29(2), 116–123. <https://doi.org/10.1177/0255761410396965>
- Quick, D. (2010). Piano Gloves let you tinkle the virtual ivory. *New Atlas*. [Online]: Retrieved on 21-May-2019, at URL: <https://newatlas.com/piano-gloves-virtual-piano/15273/>.
- Rassel, S., & Lynne, F. (2018). The 3D-printed robot hand that can play jingle bells on the piano made by Cambridge University. *Cambridgeshire Live*. [Online]: Retrieved on 25-January-2019, at URL: <https://www.cambridge-news.co.uk/news/cambridge-news/cambridge-university-robot-hand-piano-15570814>.
- Ryan, D. (2004). Innovations in piano teaching: a small-group model for the tertiary level. *Music Education Research*, 6(1), 23–43. <https://doi.org/10.1080/1461380032000182911>
- Schonberg, H. C. (1987). *The great pianists*. New York: Simon and Schuster.
- Seipp, N. (1976). *A comparison of class and private music instruction*, PhD Thesis, West Virginia University, West Virginia.
- Tanimoto, S. (2017). Challenges for livecoding via acoustic pianos. *3rd International Conference on Live Coding*. Morelia, Mexico.
- West, T., & Rostvall, A.-L. (2003). A study of interaction and learning in instrumental teaching. *International Journal of Research in Music Education*, 40, 16–27. <https://doi.org/10.1177/025576140304000103>
- Xiao, X., Puentes, P., Ackermann, E., & Ishii, H. (2016). Andantino. *Proceedings of the 15th International Conference on Interaction Design and Children*, 16, 37–45. <https://doi.org/10.1145/2930674.2930689>
- Xu, Q. (2016). Research on Children's Collective Smart Piano Teaching. *Proceedings of the 2016 2nd International Conference on Economy, Management, Law and Education (EMLE 2016)*, 20, 543–545. <https://doi.org/10.2991/emle-16.2017.124>
- Zavgorodnyaya, M. A., & Zavgorodniy, P. A. (2009). Modeling the process of teaching to play a musical instrument. *Pedagogical Sciences*, 2, 55–65.