EUROPEAN JOURNAL OF STEM EDUCATION

European Journal of STEM Education,
2023, 8(1), 02
ISSN: 2468-4368

lectito

Examination of STEAM-based Digital Learning Applications in Music Education

Zeynep Özer [1]*, Rasim Erol Demirbatır [1]

[1] *Bursa Uludag University*, TURKEY

***Corresponding Author:** 811941004@ogr.uludag.edu.tr

Citation: Özer, Z. and Demirbatır, R. E. (2023). Examination of STEAM-based Digital Learning Applications in Music Education. *European Journal of STEM Education*, 8(1), 02. https://doi.org/10.20897/ejsteme/12959

Published: February 12, 2023

ABSTRACT

STEAM is an interdisciplinary educational approach. Based on the idea that different disciplines can meet on a common ground, the STEAM approach aims to give students the habit of working together, to provide rich learning experiences and to focus on real-world problems. This study investigates STEAM-based digital learning applications used in music education, their contents and age group suitability. For this purpose, the method of the research is the narrative review study. In this context, we analyzed the Chrome Music Lab, Scratch Music, Groove Pizza, earSketch, UPISketch and iMuSciCA applications. Studies have proved that digital-based STEAM applications used in music education increase students' creativity, improve their music learning, and increase their interest in the lesson because they offer fun learning. With the development of technology, it has become necessary to adapt the methods and techniques used in music education to the age. By integrating art education, which has an important place in STEAM education, with other disciplines, music lessons can be effective and more permanent. The study shows that the more effective use of related applications by music teachers will contribute to music education and it is important in this regard.

Keywords: STEAM education, digital learning, music education

INTRODUCTION

The digitalization trend that continues unabated today affects learning approaches and environments. With the development of technological tools, terms such as web-based education and online education have emerged (Lin et al., 2017). The collection of these terms under a single title has brought the digital learning approach to the agenda. Especially with the global epidemic in recent years, the digital learning approach has gained more importance, and it has become inevitable to use digital learning in order to respond to the needs of new generations who have behavioral and perceptual differences and to improve their educational environment (Ünlü, 2019; Kocaman Karaoğlu et al., 2020). In addition, the idea of how this tendency can be used effectively for the development, benefit and welfare of societies has also been a matter of curiosity (Fukuyama, 2018).

Digital learning is a complex phenomenon associated with many things, and although there are different interpretations in the literature, it is generally defined as an unplanned and implicit process with the help of smartphones, tablets, computers and similar technological devices. In addition, digital learning often takes place unconsciously, without predetermined goals regarding learning outcomes (Sousa and Rocha, 2019).

Digital learning is also widely used in STEAM education. STEAM education is an interdisciplinary educational approach in which more than one of the fields of science, technology, engineering, art and mathematics are used together. In the literature review, studies show that digital learning, combined with STEAM education, has positive effects on students' interests and motivations (McDonald, 2016; Hawkins et al., 2019; Starkey, 2012). In a study investigating the effects of digital game-based STEM applications on students' interest in STEM fields and their scientific creativity, it was stated that positive results were obtained in terms of variables in the measurements performed before and after the application (Sarıçam, 2019). In another study, it was seen that socioscientific subject-based online STEM education carried out within the scope of digital learning supported students to transform their knowledge into skills and to use their achievements for different courses in an interdisciplinary way (Uyanık, 2021). Valko et al. (2020) stated that STEM applications used only in lessons are not sufficient for effective learning, the connection between digital learning and expected results should be deeply understood and this situation should be integrated into the learning process.

In the face of new teaching conditions and rapid development of technology, computer assisted music education serves as an important method in modern music teaching (Zhou, 2020). Gouzouasis and Bakan (2011) examined the potential impact of creative, digital technologies on music pedagogy in the 21st century. They stated that in the last decade digital technologies have fundamentally changed how to make, share, teach and learn music, and that digital music games and apps are an unprecedented revolution in social music making. In addition, they emphasized the need for music educators to be up-to-date on emerging trends in order to adapt their students to the era. Nart (2016), on the other hand, emphasized that digital learning applications in music education are important in terms of effective and efficient education process, and as a reflection of this, educators should closely follow the technological developments in their fields.

Music education, which is included in art education, is a versatile science that creates positive effects on students' cognitive, affective and social development and can interact with different disciplines.

Statement of the Problem

There are studies showing the importance and positive effects of STEAM education in art education (Liao, 2016; Jeon and Lee, 2014; Guyotte et al., 2015; Andreotti and Frans, 2019; Phanichraksaphong and Tsai, 2021; Morton at al., 2017). Hasanova (2021), drawing attention to the importance of aesthetic education in the full development of young generations, emphasized the invaluable contribution of music education in this direction. For this reason, music education emerges as an indispensable phenomenon in education systems. As these studies show, enriching music education with different approaches in a way that adapts to the era will further increase its effectiveness. An example of this is a study in which students are provided with an environment where they can rearrange their music within the scope of digitalization in learning environments, and positive results were obtained in their attitudes towards learning (Engelman et al., 2016). Especially with the Covid-19 epidemic, the difficulties experienced in different areas globally have deeply affected the education world. Hernandez (2021) conducted a study on how the Covid-19 epidemic affected computer-assisted teaching in Texas middle school choir classrooms. According to the results of the survey conducted before and after March 2020, he concluded that computer-assisted teaching in choir classes increased after March 2020. However, it is an undeniable fact that developed societies in the field of technology have overcome this process more easily. In this process, the importance of digitalization in education has once again come to the fore. For the stated reasons, it is important to introduce STEAM-based digital music applications to music educators and individuals who are interested in the field.

Research Question

In this research, we tried to introduce STEAM-based digital learning applications in music education. The aim is to ensure that music teachers create awareness of these applications in students by enriching their lessons and strengthening the bond of music science with different disciplines.

In this context, we seek answers for the following questions:

1. What are STEAM-based digital learning applications used in international music education?
2. What is the content of STEAM-based digital learning applications used in international music education?
3. For which age groups are these STEAM-based digital learning applications used in international music education suitable?

RESEARCH METHODOLOGY

In this research, literature review was conducted in order to present examples of STEAM-based music education digital learning applications and a narrative review was carried out in this direction. Narrative review is used for the purpose of making a general evaluation by organizing the studies found after the literature review on the subject (Çepni, 2018a; Snyder, 2019). Narrative review method, also known as unsystematic narrative review, is a summary of published studies on the subject under investigation (Green et al., 2006). In this context, we have compiled the tools obtained by examining the studies carried out in the databases with the keywords "STEAM", "Music Education" and "Digital Applications".

RESEARCH RESULTS

In this section, STEAM-based digital learning applications in music education are presented and evaluated under sub-headings.

Math, Science and Music Website

Mika Shino, director of the International Jazz Program at the Thelonious Monk Institute, has argued that music can be used successfully with mathematics and science. For this purpose, in 2016, Herbie Hancock Can Institute launched a website application to enable teachers to access music-based education programs to improve their STEM skills and perceptions (Huang, 2020). The program addresses the growing need for students to acquire skills, gain knowledge and learn to think creatively in science, technology, engineering, mathematics and music. The Institute collaborates with math, science, music and education experts at leading universities and the private sector to develop a wealth of free engaging curricula, games, apps, and other interactive online components. The Math, Science and Music website serves as an exciting and engaging repository of free, interactive tools for learning STEM subjects through music to prepare students for a world where technological skills are a necessary and important part of life. It is a platform with free applications that appeal to students of all age groups, from kindergarten to university (MathSciencesMusic, 2022 October 2).

Applications on the math, science and music website are listed below:

1. Chrome Music Lab

Aiding the transition from iconic technology to recording technology and standard notation, the Chrome Music Lab app is Google's hub for providing music-related experiments and activities, and is particularly useful in virtual and simultaneous teaching environments (Griffin, 2021). Chrome Music Lab is a website launched in 2016 that makes learning music more accessible through fun and hands-on experimentation. This digital learning platform, which consists of hands-on experiments including visualizers, can be used as a source of entertainment by immersing the student in an imaginary world, as well as a tool for teaching music to beginners (Garg, 2013). Many music teachers use the Chrome Music Lab app as a tool to combine dance and instruments with music to explore its connections to science, math, art and more (Chrome Music Lab, 2022 October 2). Especially music educators all over North America benefit from this practice to stimulate students' musical curiosity through visual interaction (Kosasih, 2021).

In the Chrome Music Lab, students can be asked to create their own rhythms, and inquiry skills based on mathematical concepts in rhythm can be developed. In addition, students gain by exploring mathematical concepts such as pattern, one-to-one equivalence, ratio and proportion, spatial thinking of fractions, row-column representation through music (Mishra, 2021).

The names and figures of the activities in the Chrome Music Lab application are given in **Table 1**. There are 14 activities in the Chrome Music Lab digital learning platform. The Kandinsky activity interprets the movements of the user as pitch, texture and rhythm. On the other hand, The Song Maker activity uses iconic notation as a piano roll showing students the relationship of pitches on a diatonic scale. By adding notes (boxes) to the grid, students can play their compositions and create melodies by revising them when necessary (Clauhs, 2021).

Table 1. Activities in the Chrome music lab app (Chrome Music Lab, 2022 October 2)

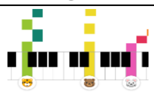
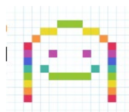
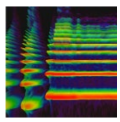
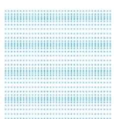
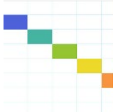
Name of the activity	Figure	Name of the activity	Figure
Shared Piano		Song Maker	
Rhythm		Spectrogram	
Sound Waves		Kandinsky	

Table 1. Activities in the Chrome music lab app (Chrome Music Lab, 2022 October 2) (continued)

Name of the activity	Figure	Name of the activity	Figure
Harmonics		Arpeggios	
Voice Spinner		Piano Roll	
Melody Maker		Chords	
Oscillators		Strings	

2. Scratch Music

Coding education has an important place in the STEAM approach. Educators in many countries of the world provide coding training in STEAM approaches. (Çepni, 2018b). Launched in the United States in 2013, Project Tynker is a creative computing platform where students organize games and apps through coding (Tynker Review, 2022). Another project is the Code Club Project for children aged 9-13 in England. This project was developed to enable children to follow computer technologies throughout their lives (Code Club, 2022 December 7). In addition to the exemplary studies, there are also STEAM-based music education applications with the help of coding.

Scratch is a programming environment designed and developed at the Lifelong Kindergarten Group at the MIT Media Lab. First launched in 2007, Scratch 1.0 is a native runtime application for Mac and Windows. Since 2013, Scratch 2.0 version has been coded to run in the web browser in Adobe's Flash environment. With the deprecation of Flash as a supported web environment, the new version 3.0 of Scratch has been reprogrammed using JavaScript and the Web Audio API. This version was made available for free to all users in January 2019 (Payne and Ruthmann, 2019). In addition, Scratch offers users different language options. Scratch allows users produce meaningful projects such as animated stories and games with the help of coding. One of the main aims of this program is to support learning through peer collaboration (Maloney et al., 2010).

While there are numerous studies examining Scratch in the context of children's creating games and coding interactive environments in general, little is known about its creative sound or its music-specific functionality. Music and sound are an important part of children's lives, but their ability to easily create music in coding environments is limited by the deep knowledge needed in music theory and computation to easily realize musical ideas (Payne and Ruthmann, 2019). This application, which all age groups starting from primary school age can use, teaches students the concepts of mathematical and computation, and provides them with 21st century skills as well as creative thinking, reasoning and working in collaboration (Resnick et al., 2009).

Scratch is a great environment to explore and create music. Scratch makes the first steps of creating music easy and accessible. Unlike many music programming languages, it provides instant audio feedback to the student with a single block of code that can be clicked and activated at any point. Often other music encoding programs require more complex structures to play a sound, such as starting a new instrument, finding and loading a sample, and turning on the sound output before producing a result (Payne and Ruthmann, 2019). To write a script that makes things happen from scratch, you should use code blocks. Scripts are associated with the stage background or individual animated characters. A new project starts with a blank background and a Cat sprite named Sprite 1 (Brown and Ruthmann, 2020). The sample usage of Scratch application is given in **Figure 1** (Scratch, 2022 December 2).

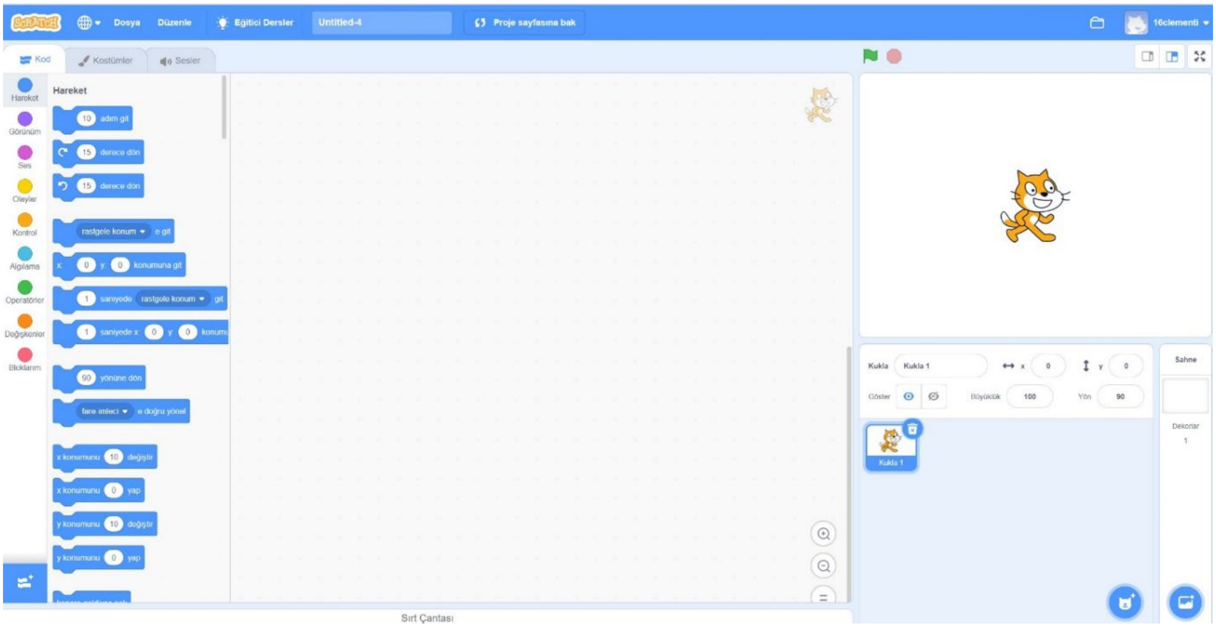


Figure 1. An example of scratch application

3. Groove Pizza

The starting point of Groove Pizza application coincides with Ethan Hein's Master's thesis written in 2013. Then, the first web prototype was created in collaboration with Adam November in 2015. Currently Groove Pizza is a comprehensive application reaching 1.5 million users in 216 countries (Groove Pizza, 2022 October 2).

Groove Pizza is a widely used web application that allows users to program drum rhythm patterns on a circular grid for creative music making and learning. This visualization scheme supports the creation of fun rhythm patterns using mathematical concepts such as shapes, angles and patterns. In this application, the symmetrical patterns in the visual field correspond to those in the auditory field (Holland et al., 2019). It's also a fun tool for creating music using math concepts like shapes, angles, and patterns.

When students program the drums in pop and dance idioms, they can embody rhythmic abstracts through direct multi-sensory experience. Groove Pizza has some unusual features designed to support intuitive rhythmic exploration. Rhythms appear as geometric shapes that can be applied directly. For example, users can change patterns rhythmically by rotating the corresponding shapes on the circle (Holland et al., 2019). The sample usage of Groove Pizza application is given in **Figure 2** (Groove Pizza, 2022 October 2).

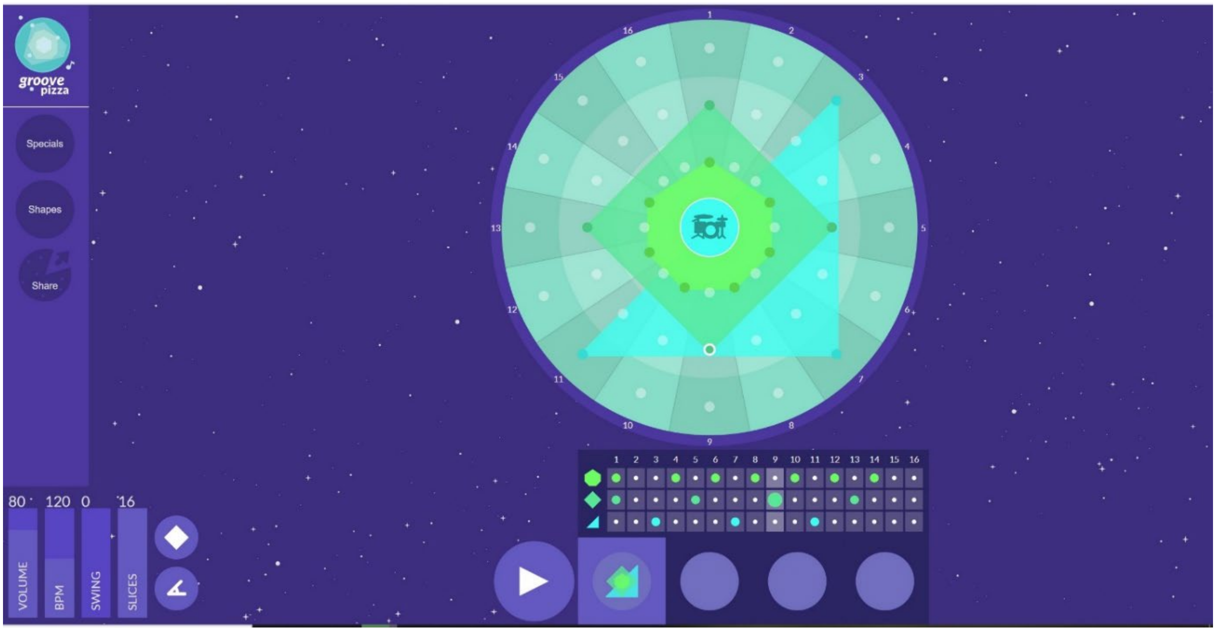


Figure 2. An example of groove pizza application

earSketch

earSketch is a free program that offers students a collaborative and authentic learning environment that introduces students to programming through music remixing in commonly used programming languages such as Python and JavaScript. Since the development of EarSketch began in 2011, more than 10000 users have been reached for use in many schools, summer camps, academic courses and other educational programs from primary schools to university (Mahadevan at al., 2015). The purpose of EarSketch is to offer users the opportunity to create music with the help of coding in a digital learning environment (Engelmen et al., 2017). EarSketch consists of an integrated curriculum, software toolset, audio loop library and social media website. The software toolset enables students to create music by manipulating loops, creating beats, and applying effects with Python code. On the other hand, the social media Web site allows students to upload their music and source codes, view other students' work, and create musical remixes derived from students' codes (Magerko et al., 2016). McKlin et al. (2018, February) stated that the EarSketch program attracted students' attention by providing the opportunity to start coding and creating music quickly in an environment perceived as authentic.

The user can access the application for free. The application consists of 4 main parts. These sections are 'Content Manager', 'Digital Audio Workstation', 'Code Editor' and 'Curriculum'. You can access the sound browser by selecting sounds in the content manager just below the EarSketch logo. You can search for sounds by artist, genre, and instrument. The sound collection menu will also have suggestions for sounds suitable for the music you want to create, or sounds used by others looking for similar sounds. You can create your music by performing the coding process in the code editor section. In the Digital Audio Workstation section, you can listen to the music you have encoded. Explanation and explanation video about the use of the application can be found under the Curriculum. The sample usage of earSketch application **Figure 3** (EarSketch, 2022 October 2).

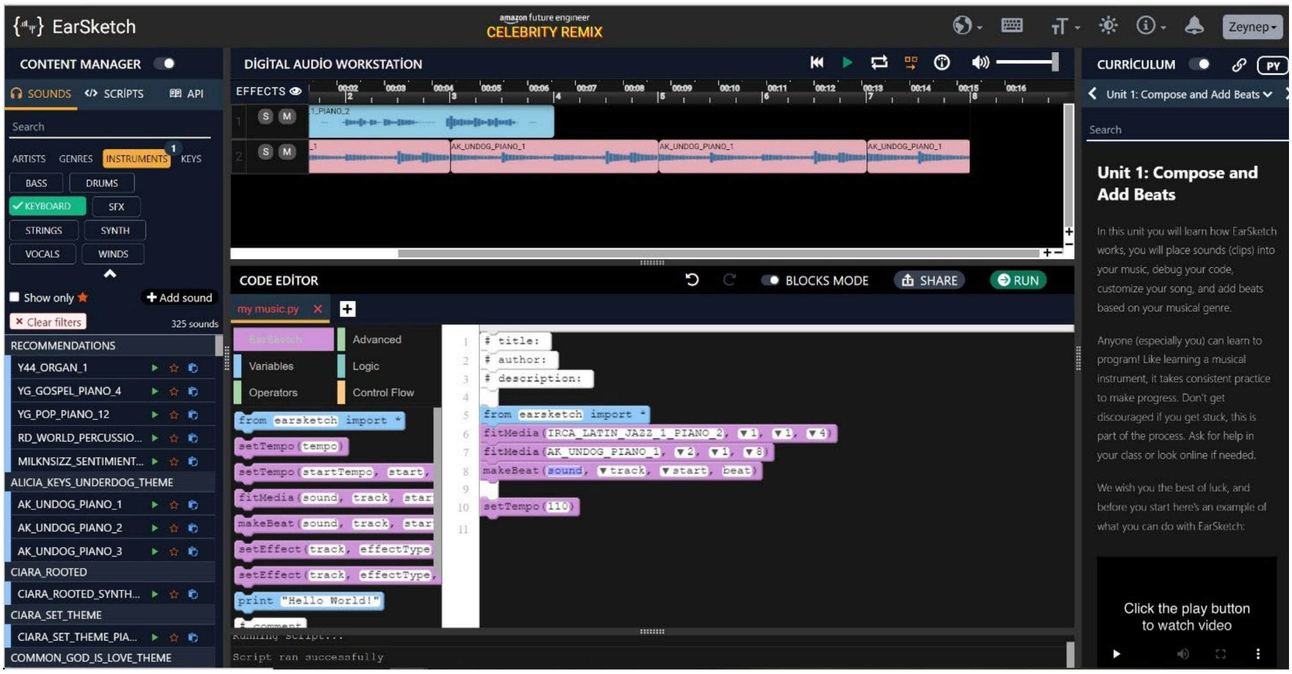


Figure 3. An example of earSketch application

iMuSciCA

Within iMuSciCA, combining Science, Technology, Engineering, Arts and Mathematics (STEAM) in a unified pedagogical framework enables students to directly identify the connections between abstract concepts and real-world elements. iMuSciCA is a European-funded project that provides a web-based work environment with several educational tools to connect science, math, technology and music. It includes instructions and suggestions for teachers to develop lesson plans to encourage creativity in learning and enable deeper learning (Katsouros et al., 2018).

The main purpose of the iMuSciCA project is to explore the phenomena and scientific rules of physics, geometry, mathematics and technology disciplines through musical activities, to examine them from different perspectives, and to develop curriculum topics that contribute to innovative interdisciplinary approaches. iMuSciCA Workbench is the main web platform where the user can perform STEAM related activities according to the iMuSciCA pedagogical framework. It provides tools categorized by different STEAM areas in music, science

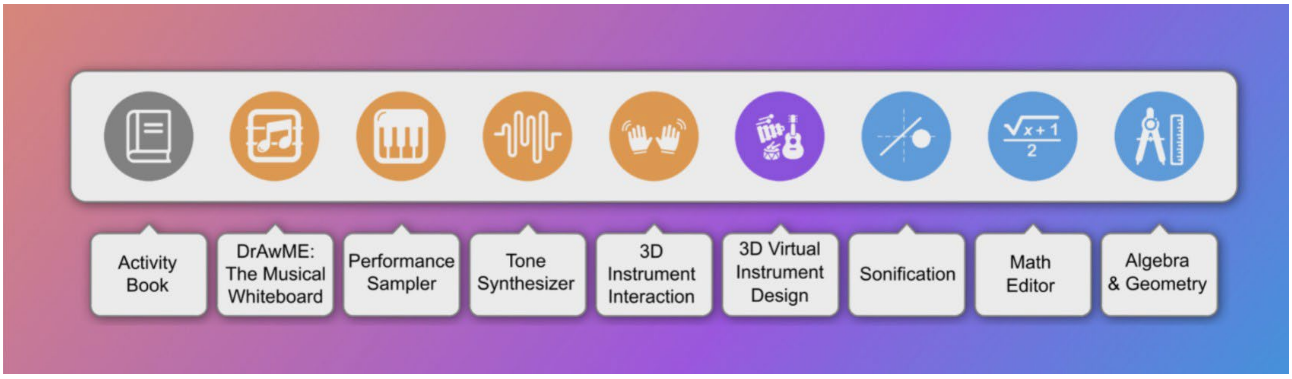


Figure 4. iMuSciCa workbench

and math, engineering and technology. These tools are Physical Model-based Sound Synthesis, Activity Enviroments, Music Tools, Visualization, Metronome, Sound Recorder and Clipboard. (Kritsis, 2019).

The iMuSciCA project directly addresses current needs in education and learning for new pedagogical methodologies and innovative educational technology tools, by providing students and teachers with opportunities for collaboration, co-creation, in order to support active, exploratory, individualized and engaging learning. As a STEAM-focused project, iMuSciCA has designed a suite of software tools and services to teach/learn STEAM, built on new enabling technologies integrated into a platform that will provide interactive music activities. iMuSciCA aims to support secondary school students in the mastery of core academic content in STEM subjects (Physics, Geometry, Mathematics and Technology) as well as supporting the development of creativity and deeper learning skills by participating in music activities (iMuSciCA, 2022 October 2). The Workbench of iMuSciCA website is given **Figure 4** (iMuSciCA Workbench, 2022 December 2).

At iMuSciCA, the 3D design and printing of musical instruments is accomplished through a web-based workbench that integrates advanced core enabling technologies, including body-tracking sensors for motion recognition, interactive pens and tablets, as well as sound creation and manipulation tools (Kaliakatsos-Papakostas et al., 2020). There are 8 tools in the iMuSciCA application. You can design 3D virtual instruments with The Musical Whiteboard. In this environment, the user can load pre-designed multichord, xylophone, guitar and membrane instruments. Thus, with The Musical Whiteboard, you can hear how the sound changes by adjusting various parameters such as length or chord tension of the sound produced from the instrument (Katsouros et al., 2018). The Performance Sampler, on the other hand, is designed for the user to load up to four recorded waveforms and create a composition from these recorded tracks (Kritsis et al., 2019).

In the 3D Virtual Instrument Design tool, when users open the application, they see a standard-tuned acoustic guitar, but they have the opportunity to change parameters such as the structure of the material of the string, its thickness and tension. In this way, they experience how the sound obtained from the guitar changes under which factors (Andreotti & Frans, 2019). 3D musical instruments are a workbench where you can simulate and analyze sound developed according to acoustic principles derived from physics and mathematics. You can also accurately experience harmonic ratios as a result of the physical properties of sounds (Stergiopoulos, 2021 May).

UPISketch

UPISketch is a software designed by Iannis Xenakis in collaboration with the European University of Cyprus to create drawing-based sound compositions. With the invention of UPIC by Xenakis in 1977, it was the first time that musical ideas drawn by a computer were realized as sonic. The idea of explaining the development of sound parameters using today's technology and creating a musical form in line with graphical curves led to the birth of UPISketch software. (Bourotte and Kanach, 2019). UPISketch is designed to be open access, simple and intuitive, enabling the realization of cross-platform audio applications. Thanks to this program, the user can design sound movements by defining melodic lines without the need for solfeggio knowledge, as in a musical score. Thus, it can be easily used by children as a pedagogical tool (UPISketch, 2022 December 2). In addition, the application integrates mathematics and music under the same roof, allowing users to produce mathematically supported musical elements. Thus, the UPISketch program represents an important STEAM example that can create connections between music, technology and mathematics for children. The sample usage of UPISketch application is given **Figure 5** (UPISketch, 2022 December 2).

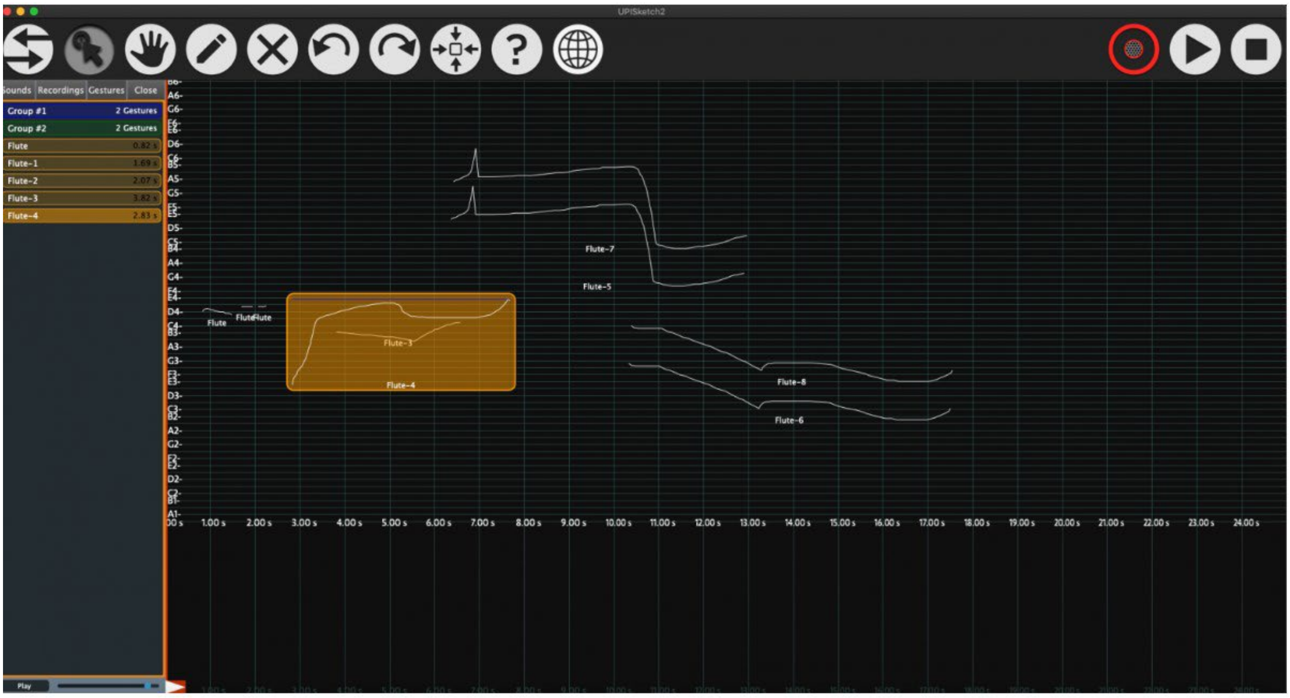


Figure 5. An example of UPISketch application

DISCUSSION AND CONCLUSION

In line with the researches carried out about these applications, the importance of the music discipline within the STEAM approach is clear. Studies have proved that digital learning environments developed with this understanding provide positive contributions to students. Wanzer et al. (2020) conducted a meta-analysis of 13 studies published between 2012-2018 to examine whether the EarSketch learning environment and curriculum support students' motivation in informatics in their future careers. Experts stated that EarSketch is a computer education program and curriculum that can help students continue to pursue informatics in the future and support the STEM approach (Wanzer et al., 2020).

Harris and Carroll (2020, July) stated in their study that web-based music applications used in music education have positive contributions to classroom teachers' music teaching and self-efficacy beliefs.

With 38 primary school teachers working in Indonesia, Julia et al. (2020) carried out music design applications with the Scratch program in order to improve the technology-based music education skills of the teachers. At the end of the research, it was concluded that the teachers could easily implement the relevant program and thus enrich their music teaching environment by improving their technological skills.

In a postgraduate study conducted in Turkey, the effects of Scratch programming and Makey Makey electronic card on the development of primary school students in reading and writing notes in music lessons were investigated. In this 12-week study, it was observed that students' reading and writing skills improved at all grade levels (Özkandemir, 2019).

Based on the findings obtained in this research, we can conclude that STEAM-based digital music education applications are designed within universities or developed within the scope of a project. Although the relevant programs are designed for all ages, they are mostly aimed at primary and secondary school students. In addition, these programs are often carried out within the framework of mathematics, technology and music disciplines. STEAM-based digital music education programs are designed to develop students' creativity and have features that students can easily access and implement.

The results obtained in this study show that these programs are at the forefront of producing music through coding and that they are actively used in international music education. Based on our experience, it is important to have different language options so that STEAM-based digital music education applications can be used more actively around the world. In particular, we think that these applications will be useful in developing computational thinking skills in children. In addition, we believe that music teachers will realize effective learning by enriching the course content by learning these applications.

REFERENCES

Andreotti, E. and Frans, R. (2019). The connection between physics, engineering and music as an example of STEAM education. *Physics Education*, 54(4). https://doi.org/10.1088/1361-6552/ab246a

Bourotte, R. and Kanach, S. (2019). UPISketch: The UPIC idea and its current applications for initiating new audiences to music. *Organised Sound, Bringing New Music to New Audiences*, 23(3), 252-260. https://doi.org/10.1017/S1355771819000323

Brown, R. and Ruthmann, A. (2020). *Scratch music projects.* New York: Oxford University Press.

Çepni, S. (2018a). *Araştırma ve proje çalışmalarına giriş.* Celepler Matbaacılık Yayın ve Dağıtım.

Çepni, S. (2018b). (Ed.). *Kuramdan uygulamaya STEM eğitimi.* Pegem Akademi.

Chrome Music Lab. (2022, October 2). *About chrome music lab.* https://musiclab.chromeexperiments.com/About.

Clauhs, M. (2021). Songwriting with iconic notation in a music technology classroom. *Music Education Journal*, 107(3), 22-30. https://doi.org/10.1177/0027432121992410

Code Club. (2022, December 7). *About code club.* Available at: https://codeclub.org/en/about.

EarSketch. (2022, October 2). *EarSketch.* https://earsketch.gatech.edu/landing/#/

Engelman, S., Magerko, B., McKin, T., Miller, M., Edwards, D. and Freeman, J. (2017). Creativity in Authentic STEAM education with EarSketch. *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education,* 183-188. https://doi.org/10.1145/3017680.3017763

Fukuyama, M. (2018). Society 5.0: Aiming for a new human-centered society. *Japan Spotlight*, 27, 47-50. https://www.jef.or.jp/journal/pdf/220th_Special_Article_02.pdf

Garg, D. (2013). *Visualyzic: A live-input visualizer.* (Master of Science). B.Tech., Guru Gobind Singh Indraprastha University.

Gouzouasis, P. and Bakan, D. (2011). The future of music making and music education in a transformative digital world. *Unesco Observatory, Faculty of Architecture, Building and Planning, The University of Melbourne refereed e-journal*, 2(2), 1-22. https://www.unescoejournal.com/wp-content/uploads/2020/03/2-2-12-GOUZOUASIS.pdf

Green, B. N., Johnson, C. D. and Adams, A. (2006). Writing narrative literature reviews for peer-reviewed journals: secrets of the trade. *J. Sports Chiropr Rehabil*, 5(3), 101-117. https://doi.org/10.1016/S0899-3467(07)60142-6

Griffin Jr., A. (2021). *Elementary rhythm pedagogy analysis.* Master of Music Education. Lindenwood University.

Groove Pizza. (2022, October 2). *Musedlab nyu music experience design.* https://musedlab.org/groovepizza/.

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Kellam, N. N. and Walther, J. (2015). Collaborative creativity in STEAM: Narratives of art education students' experiences in transdisciplinary spaces. *International Journal of Education & the Arts*, 16(15). http://www.ijea.org/v16n15/.

Harris, J. and Carroll, C. (2020, July). *Using web-based music composition applications to enhance non-specialist primary teachers' self-efficacy in making and teaching music.* 12th International Conference on Education and New Learning Technologies, Online Conference. https://doi.org/10.21125/edulearn.2020.2087

Hasanova, N. K. (2021). Possibilities of music education and upbringing in the formation of personal maturity. *ISJ Theoretical & Applied Science*, 8(100), 420-422. https://doi.org/10.15863/TAS

Hawkins, I., Ratan, R., Blair, D. and Fordham, J. (2019). The effects of gender role stereotypes in digital learning games on motivation for STEM achievement. *Journal of Science Education and Technology*, 28, 628-637. https://doi.org/10.1007/s10956-019-09792-w

Hernandez, E. (2021). *An investigation of the impact of the covid-19 pandemic on the use of computer-aided instruction in middle school choral programs.* The Degree of Master of Arts. Texas Woman's University.

Holland, S., Wilkie-McKenna, K., McPherson, A. and Wanderley, M. M. (Ed.). (2019). The Groove pizza. New Direction in Music and Human-Computer Interaction, 71-94. https://doi.org/10.1007/978-3-319-92069-6_5

Huang, H. (2020). Music in STEAM: Beyond notes. *The STEAM Journal*, 4(2), 1-11. https://doi.org/10.5642/steam.20200402

iMuSciCA Workbench. (2022, December 2). *iMuSciCA workbench.* https://workbench.imuscica.eu/

iMuSciCA. (2022, October 2). *About iMuSciCa.* http://www.imuscica.eu/imuscica-project/

Jeon, S. and Lee, Y. (2014). Art based STEAM education program using EPL. *Journal of the Korea Society of Computer and Information*, 19(4), 149-158. https://doi.org/10.9708/jksci.2014.19.4.149

Julia, J., Iswara, P. D., Gunara, S., Yildiz, Y. M. and Agustian, E. (2020). Developing elementary school teacher competence in making music learning media using scratch application: Action research. *Elementary School Forum (Mimbar Sekolah Dasar)*, 7(3), 362-385. https://doi.org/10.17509/mimbar-sd.v7i3.29100

Kaliakatsos-Papakostas, M., Kritsis, K. and Katsouros, V. (2020). Music in education through technology. *Educational Technology.* ERCIM News is published by ERCIM EEIG.

Katsouros, V., Fotinea, E., Frans, R., Andreotti, E., Stergiopoulos, P., Chaniotakis, M., Fischer, T., Piechaud, R., Karpati, Z., Laborde, P., Martin-Albo, D., Simistira, F. and Liwicki, M. (2018). iMuSciCA: Interactive music science collaborative activities for STEAM learning. *Designing for the User Experience in Learning Systems. Human–Computer Interaction Series*. Springer, Cham. https://doi.org/10.1007/978-3-319-94794-5_7

Kocaman Karaoğlu, A., Bal Çetinkaya, K. and Çimşir, E. (2020). Toplum 5.0 sürecinde Türkiye'de eğitimde dijital dönüşüm. *Üniversite Araştırmaları Dergisi*, 3(3), 147-158. https://dergipark.org.tr/tr/pub/uad/issue/57871/815428

Kosasih, E. (2021). Counterpoint: Music and art education. *MA Projects*, 144. https://digitalcommons.sia.edu/stu_proj/114

Kritsis, K., Bouillon, M., Albo, D. M., Acosta, C., Piechaud, R. and Katsouros, V. (2019). *iMuSciCA: A web platform for science education through*. Web Audio Conference WAC. Trondheim, Norway.

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *Art Education*, 69(6), 44-49. https://doi.org/10.1080/00043125.2016.1224873

Lin, M. H., Chen, H. C. and Liu, K. S. (2017). A study of the effects of digital learning on learning motivation and learning outcome. *EURASIA Journal of Mathematics Science and Technology Education*, 13(7), 3553-3564. https://doi.org/10.12973/eurasia.2017.00744a

Magerko, B., Freeman, J., Mcklin, T., Reilly, M., Livingston, E., Mccoid, S. and Crews Brown, A. (2016). EarSketch: A STEAM-based approach for underrepresented populations in high school computer science education. *ACM Transaction on Computing Education*, 16(4), 14-25. https://doi.org/10.1145/2886418

Mahadevan, A., Freeman, J., Magerko, B. and Martinez, J. C. (2015). EarSketch: Teaching computational music remixing in an online Web Audio based learning environment. In Proceedings of the Web Audio Conference (WAC), Paris, France.

Maloney, J., Recnick, M., Rusk, N. and Silverman, B. (2010). The scratch programming language and environment. *ACM Transaction on Computing Educaiton*, 10(4), 1-16. https://doi.org/10.1145/1868358.1868363

MathSciencesMusic (2022, October 2). *Math, sciences and music website.* https://mathsciencemusic.org/

McDonald C. V. (2016). STEM education: A review of the contribution of the disciplines of science, technology, engineering and mathematics. *Science Education International*, 27(4), 530–569. https://www.icaseonline.net/sei/december2016/p4.pdf

McKlin, T., Magerko, B., Lee, T., Wanzer, D., Edwards, D. and Freeman, J. (2018, February). *Authenticity and personal creativity: How EarSketch affect student persistence.* Proceedings of the 49th ACM Technical Symposium on Computer Science Education, 987–992. https://doi.org/10.1145/3159450.3159523

Mishra, K. G. (2021). Understanding music as a mathematical activity through chrome music lab. *Indian Journal of Educational Technology*, 3(2), 166-181.

Morton, B. G., Gregorio, J., Rosen, D. S., Vallett, R. and Kim, Y. (2017, June). *STEAM education through music technology.* ASEE Annual Conference & Exposition.

Nart, S. (2016). Music software in the technology integrated music education. *Turkish Online Journal of Educational Technology, TOJET*, 15(2), 78-84. https://eric.ed.gov/?id=EJ1096456

Özkandemir, O. (2019). *İlkokul müzik derslerinde robotik ve kodlama programlarının kullanılmasına yönelik örnek bir çalışma.* (Yayınlanmış Yüksek Lisans Tezi). Marmara Üniversitesi. Eğitim Bilimleri Enstitüsü.

Payne, W. and Ruthmann, A. (2019). Music making in scratch: High floors, low ceilings, and narrow walls? *The Journal of Interactive Technology & Pedagogy.*

Phanichraksaphong, V. and Tsai, W. H. (2021). Automatic evaluation of piano performances for STEAM education. *Applied Sciences*, 11(24), 2-22. https://doi.org/10.3390/app112411783

Resnick, M., Maloney, J., Monroy-Hernandez, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B. and Kafai, Y. (2009). Scratch: Programming for all. *Communication of the ACM*, 52(11), 60-67. https://doi.org/10.1145/1592761.1592779

Sarıçam, U. (2019). *Dijital oyun tabanlı STEM uygulamalarının öğrencilerin STEM alanlarına ilgileri ve bilimsel yaratıcılığı üzerine etkisi: minecraft örneği.* Yüksek Lisans Tezi. Marmara Üniversitesi.

Scratch. (2022, December 2). *Scratch website.* Available at: https://scratch.mit.edu/projects/773423305/editor.

Snyder, H. (2019). Literature Review as a Research Methodology: An Overview and Guidelines. *Journal of Business Research*, 104, 333-339. https://doi.org/10.1016/j.jbusres.2019.07.039

Sousa, M. J. and Rocha, A. (2019). Digital learning: Developing skills for digital transformation of organizations. *Future Generation Computer Systems*, 91, 327-334. https://doi.org/10.1016/j.future.2018.08.048

Starkey L. (2012) *Teaching and learning in the digital age*. Taylor and Francis. https://doi.org/10.4324/9780203117422

Stergiopoulos, P. (2021, May). Music and STEM. Multiple sides of the same coin. International Conference | STE(A)M educators & education, p.202-220. ISBN: 978-618-5497-24-8

Tynker Review. (2022, December 7). *Tynker review: Teaching coding for students & teachers.* Available at: https://schools.zenva.com/tynker-review/

Ünlü, M. (2019). Dijital Çağda E-Öğrenme Ortamlarının Kalitesini Artırmaya Yönelik Gerçekleştirilen Uluslararası Çalışmalar. *Ufuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 8(16), 165-182. https://dergipark.org.tr/tr/pub/ufuksbedergi/issue/58933/849543

UPISketch. (2022, December 2). *Interfaces. Activities, composition tools.* http://www.interfacesnetwork.eu/post.php?pid=230-upisketch

Uyanık, S. (2021). *Ortaokul öğrencilerine sosyobilimsel konu temelli çevrimiçi STEM eğitimine yönelik örnek bir tasarım geliştirilmesi ve değerlendirilmesi.* Yüksek Lisans Tezi. Marmara Üniversitesi.

Valko, N. V., Kushnir, N. O. and Osadchyi, V. V. (2020). Cloud technologies for STEM education. *Proceedings of the 7th Workshop on Cloud Technologies in Education*, (CTE 2019), 435-447. https://doi.org/10.55056/cte.384

Wanzer, D. L., McKlin, T., Freeman, J., Magerko, B. and Lee, T. (2020) Promoting intentions to persist in computing: an examination of six years of the EarSketch program. *Computer Science Education*, 30(4), 394-419. https://doi.org/10.1080/08993408.2020.1714313

Zhou, Y. (2020). Research on music education model by using computer music technology in colleges. *Journal of Physics: Conference Series Vol 1624*. https://doi.org/10.1088/1742-6596/1624/2/022053