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A Literature Review of Music in Computer Science

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Abstract: Music has been a big part of human life since ancient civilizations, and listening to music is fun and for the benefit of humans. Over time, computer science continues to develop, and music begins to be recorded digitally and belongs to the group of unstructured data whose data needs to be managed to become structured data. Much academic work has analyzed how music is digitized, and there is also mixed analysis of the negative effects of music, but most research agrees that digitization has many positive effects in the computer science-backed music world. This paper analyzes and reviews papers that discuss the application of computer science technology that plays a role in managing digital music data, which is better known in the form of sound or sound. Many papers analyze what people think about the use of technology in music education, and several have proposed different ideas that can be applied. The literature review discussed in this paper is divided into three parts: the rise of digital music, how computer science can be integrated into music education, and music creation through computer science. The literature review in this paper is carried out in 4 steps: paper collection, selective screening, classification, and summary analysis.

Keywords: Music in Computer Science, Computer Music, Music Pattern Recognition, Computational Music Thinking

1. Introduction

Computer science has developed rapidly in the last few centuries and has influenced people's lives so much that most of our daily activities are confirmed to be using computer science. Through computer science, many technical marvels have been created and enabled the emergence of extensive corporate management, social networking sites, and much more. Nowadays, the smartphones we use are some of the gadgets that use this computer science technology, and it is hard to imagine how to live without computer science technology. The development of research in the field of computer science is still being developed and explored, and in its development, it is combined with many things according to its uses and applications, including music. Music is an art form that has been a big part of human cultural activity since time immemorial, and over time, it is only natural that we should explore the possible applications of computer science to music.

Meanwhile, the term music is a sound that is arranged in such a way that it can be heard by humans, which contains rhythms, songs, tones, and sound harmonies that can be produced naturally, such as the sound of the wind blowing or produced with one or a combination of several musical instruments designed to produce a musical sound. In addition, music can also be accompanied by a human choir consisting of six types, of which there are three types of female voices, namely alto, Mezzo-Soprano, and Soprano, as well as three types of male voices, namely bass, baritone, and tenor.

In this paper, we conduct a literature review as a starting point for researching the knowledge of computer science which limits the use of unstructured data, namely data in the form of sound. What this paper does is that first, we did a Google Scholar search for papers of all time with the phrase "computer science music" and got 2,900,000 search results. However, when each search result link is opened and read, it turns out that not all search results represent the searched phrase. Then the exact search for papers all the time with the same phrase but limited to the search only on article titles and returns only 44 papers containing that search phrase. This shows that research on music data processing with computer science or the use of

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computer science for music is still interesting. Few have done it, and interesting to observe.

In addition, this literature review was created because very few literature reviews have been conducted on this particular topic. We believe that it is essential that a literature review on this topic is conducted to gather and condense the knowledge and information we have on this topic. Furthermore, through this paper, we want to convey this to people in an easy-to-understand format where we try to understand the problem based on previous research. Hopefully, we can develop interpretations of past papers and use this literature review to fuel future research on computer technology used for voice data.

In order to complete this literature review, it was done in four steps, as seen in Figure 1, where the activities were carried on starting from the paper collection, selective filtering, classification, and analysis summarization. The following section will explain in more detail the steps.

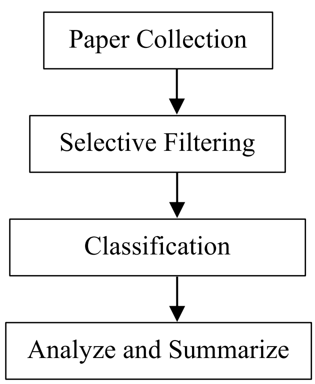

Figure 1. Literature Review Creation Steps

2. Literature review implementation

This section will explain the four steps of literature review activities carried out in this paper, as seen in figure 1, where there are four steps: paper collection, selective filtering, classification, and analysis and summary.

A. Paper collection

The first step in this paper is to collect many academic papers using Google Scholar, a free web search engine that can show us scientific literature of various formats and disciplines. To keep it a generic search, we use the search term "music in computer science" in google scholar. The search returned minimal results, with only 20 papers for publication published at any time from 1989 to 2020. To keep work current and relevant, we use a filter that will only show academic papers from 2015 to 2021. Figure 2 shows the result of searching on google scholar.

To address this, we use more specific search terms with different levels of focus. From the results of filtering and searching for papers using Google Scholar, we collect papers with titles that seem related to our main topic, some of which have special requirements if we want to access them. In this case, we find and limit the total to 120 papers. Next, the search terms used are digital music, music technology, music education technology, computer music, music generation, and music composition technology.

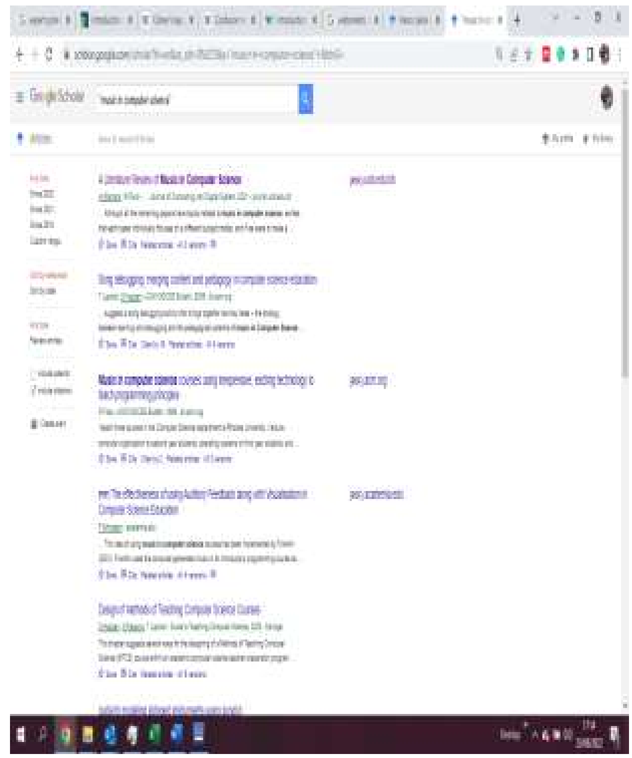

Figure 2. Searching results on google scholar

B. Selective filtering

After collecting papers, we do not use all of them in this second stage and limit them. We only want to use papers relevant to our research related to applying computer science technology to unstructured data in the form of sound, so we do selective filtering. This stage is done by skimming all academic papers obtained from the next stage, and if the topic is not related to music in computer science, then we discard it. So that after selective selection, there were 62 papers left.

C. Classifications

In this third stage, the classification stage is carried out in 2 sub-stages starting with subtopic classification, where the classification will be divided into three sub-topics, namely the rise of digital music, how computer science can be integrated into music education, and the creation of music through the use of computer science. The next stage is paper quality sub-classification which is divided into two sub-stages, namely subtopic classification and paper quality

1) Subtopic classification

Although all the remaining papers have topics related to music in computer science, we feel that each paper individually focuses on a different subject matter, and if we were to make a literature review of it, it would not be systematic and structured. Therefore, This is why we need a way to divide the filtered papers. In order to review the academic paper most effectively and cohesively, we have divided it into three parts, namely:

a. The rise of digital music

The newest form of music media is digital music, and in this section, we will explore and limit it to only papers discussing how digital music emerged and its impact on the music industry. In addition, we also explore some of the exciting uses of computer science in music.

b. How computer science can be integrated into musical education

Music education has become an integral part of keeping our musical culture alive. This section will be limited to papers on how computer science technology can assist music education.

c. Music creation through the use of computer science

In this section, we limit ourselves to papers that show how computer science technology can help people with or without musical composition experience become more creative in creating music.

2) Paper quality classification

The second form of sub-classification carried out is to separate papers based on the type of paper quality, as shown in Table 1 below with 62 papers, specifically for journals that refer to the scimago rating journal at https://scimagojr.com. Figure 3 is a graph of paper qualification classification referring to the data in table 1, where there is 5 paper type such as B.S Thesis, 2 Ph.D. dissertations, 7 Journal Q1, 11 Journal Q2, 4 Journal Q3, 1 Journal no Q, and 32 conference proceeding, where each paper type has a total number of papers and refer to the number of paper in the references in this paper. Paper type Conference proceeding as the most references with 32 papers where journal no Q as the minor reference with only one paper.

TABLE I. PAPER QUALITY CLASSIFICATION

Paper type	References	Total
B. S. Thesis	[1], [14], [28], [29], [34]	5
Ph. D dissertation	[2], [43]	2
Journal Q1	[7], [12], [22], [25], [32], [51], [60]	7
Journal Q2	[3], [4], [5], [6], [8], [9], [11], [18], [19], [35], [52]	11
Journal Q3	[10], [13], [20], [24]	4
Journal no Q	[40]	1
Conference proceedings	[15], [16], [17], [21], [23], [26], [27], [30], [31], [33], [37], [38], [39], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [53], [54], [55], [56], [57], [58], [59], [61], [62]	32
Total		**62**

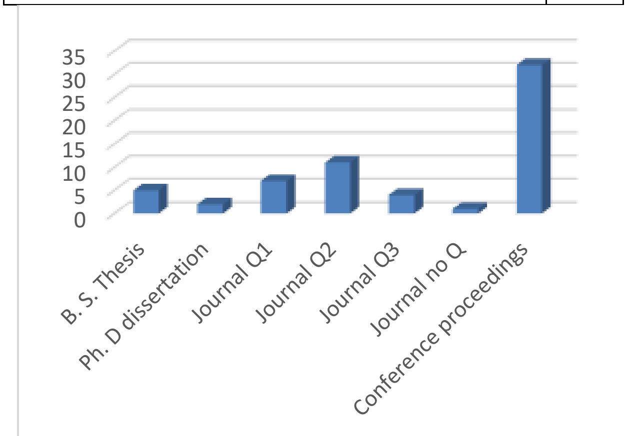

Figure 3. Paper Quality Classification Graphic

D. Analyze and summarize

In this last step, each of the papers was analyzed thoroughly and summarized, and key points from each academic paper were taken and used as material for this literature review. This step was explained in the third section as the next section, where the explanation will refer to the three sub-topic classification, such as the rise of digital music, how computer science can be integrated into music education, and music creation through the use of computer science.

3. LITERATURE REVIEW

As mentioned before, this section will explain in detail the three sub-topic classifications such as the rise of digital music, how computer science can be integrated into music education, and music creation through computer science.

1. The Rise of Digital Music

Music has become a big part of human life and has played a significant role in human life for a long time. Tracing its origins means understanding many things that can be extracted from the music itself. In line with the sound, the almighty created the ear as a tool humans can use to listen to this sound or music. The formation of the human ear when referring to the theory of evolution, the formation of the human ear was when mammals evolved, where they formed rib bones from the jaw spine, which would be used to receive sound waves in the air and, of course, these ribs would become part of the ear. With a better level of intelligence and sense of hearing, humans learn to do vocalizations to increase the beauty of the sound produced with sound and its combination with musical instruments, which can change the mood or please the mood when hearing certain types of music.

Over time, humans began to experiment with creating a harmonious sound. Traces of this can be found in our ancestors, where early hominids would form groups to sing and bond together. Finally, they began to make instruments that can produce sounds, and so these sounds, called musical instruments, are combined with the human voice to produce sound sounds which are called music and, in essence, can bring human emotions and feelings when listening to music certain. In his paper, M. Williams reviews research conducted by other researchers and concludes that after humans evolved to utilize language, music was created to take advantage of the greater efficiency of language as a bonding mechanism [1].

According to H. Sun, the most popular way of recording music before the digital era was to use a technique called analog recording. This allows music to be played back at a later time. The shift from analog to digital is believed to have started with the creation of the compact disc, or CDs for short, in 1982. When Peer-To-Peer, P2P for short, a file-sharing service, was introduced, the music industry began to thrive forever changing. Responses to these changes are varied and complex. Some major labels try to defend themselves by reaffirming more vigorous copyright enforcement, while independent labels embrace new opportunities. As the digital transition occurred, Apple, a technology company, made the first significant advances. They developed the iPod as a media player and iTunes, a media management application. It created a platform for people to enjoy digital music, and soon after, several other companies created similar platforms. However, the nature of their system left some to be desired [2].

Aguiar and J. Waldfogel describe their findings on how unpredictable music quality uses digital sales in the United States, Canada, and 15 other European countries by time and vintage. They concluded that the digitization of music had brought many positive side effects. They point out that the overall quality of music has improved worldwide after the change. Their research note notes that products with modest release prospects will occupy the top positions despite the concentration of growth in sales and product numbers[3].

Aguiar and Martens found significant changes in how people consume music based on data obtained from the IFPI, known as the International Federation of the Phonographic Industry. From 1999 to 2014, recorded music sales declined while digital music sales increased exponentially. With the advent and development of digital music, there is a fear of music piracy, and it is feared that most people will choose to pirate music instead of buying licensed music. Therefore, it reduces music revenue and, in turn, eliminates the incentive to create innovative music. An analysis of 16,500 clickstream activities of internet users in 2011 showed no evidence of unauthorized music downloads on digital music purchases.

On the contrary, it was found that there is a positive relationship between them. From their statistics, it can be understood that digital music purchases would drop by 2% if pirated music websites did not exist. It also shows that different countries are affected by pirated music differently. In addition, they need to consider that the music industry continues and will continue to grow [4].

Several people assume that the digitization of music would cause the music industry to lose intermediation between music producers and consumers. However, P. Galuszka argues against this, as the music industry is exceedingly complex, and intermediation provides several benefits to both producers and consumers. Music aggregators such as iTunes or Spotify allow major record company, independent labels, and artists to put their products on digital music stores for consumption [5].

Several hypotheses test the interaction order by Brewer and Goldsmith by J.F. Popham and C. Volpe, where correlated with action in terms of piracy in terms of digital music. This provides an argument that the hypothesis obtained in the study is that the internet is used to commit cybercrimes. Especially in terms of piracy in digital music without the owner's permission, either on YouTube or in the form of music videos. For this paper, five theories and five forms of measurements were used:

- The encounter

  The first proposed idea is the ‘encounter.’ It is the process people use to gain non-conformist knowledge on the Internet. Popham and Volpe use an adapted version of the Computer Self Efficacy Scale to test this.

- Shielding

  The Internet is a shield for the perpetrators, hiding people's negative behaviors. The scale of the measure was derived from a questionnaire by Lwin and Williams.

- Imitation

  The Internet enables the formation of custom networks for digital gatherings focused on counter-hegemonic exchange.

- Affect

  ‘effect’ concerns the person’s assessment of their behavior. A singular measure of effect was used based on the procedures used by Panas & Ninni.

- Moral disengagement

  The people feel that what they are doing is not too morally wrong. A cumulative and singular measure was used based on the methods from Bandura et al.

In their paper, J. Waldfogel proposes the golden age of music as an elaboration on how digitalization where most people assume that digitization to the industry would cause a significant reduction in their revenue, which is especially true for the music industry. They concluded that the discontinuous nature of the Internet might cause people to do digital music piracy [6]. However, it was observed that the main effect of digitization was reducing the creation of new works for the market. Nevertheless, it would also seem that digitization has made music more widely accessible to people.

Digitization has led to piracy, which in turn causes decreased revenue, and threats to reduce revenue result in reduced costs. It is unclear whether copyright is doing its function and needs further assessment. It is good to enforce rules against piracy, but it should not hinder creative output [7]. R. Fleischer and P. Snickars took software studies and digital humanities approach towards streaming media, where in 2017, Spotify was using almost 100 million users. In their time spent on the research project, they discovered that it was difficult for them to grasp the definition and the nature of Spotify. This is why they tried localizing and historicizing Spotify as a company.

They attempted to localize Spotify as a company and found it difficult as there were a lot of grey areas. In 2012, Snickars discussed with Sophia Bendz, who was Spotify's Head of Marketing. She was asked what type of company is Spotify classified as, and she replied that it was a tech company. However, after some analysis, Fleischer and Snickars stated that Spotify had become more of a media company. Aside from localizing Spotify, they also took a crack at historicizing Spotify. They felt that this was important because Spotify is constantly changing, so their research and findings should be based on historical information. Due to its immense number of users and growing valuation, Spotify is often considered a prosperous company. However, the researchers explored multiple other perspectives on how to view Spotify's history and noticed that it was filled with unachieved visions and predictions [8].

Dai and Yu analyzed contestability in digital music players and hypothesize that the power of the firm's market is held at bay due to threats from new entrants. Others argue against this point because they think a contestable market is rare. At the beginning of the digitization of music, the market for portable music players was dominated by Apple. Apple developed the iPod, a portable personal media player released in 2001. Since 2004, the iPod has been the dominant digital music player, with its sales being 90% of the market in the US. Quality-adjusted price index estimates as part of a study conducted by Dai and Yu, who used data between 2002 and 2010 in which they found that there was a decline of about 20% annually for the market price index. They consider this a supporting idea that proves their hypothesis correct [9].

Consumers of digital music usually keep their library of songs on their hard disks. One issue they may encounter is the duplication of music files. This is not optimal as they take unnecessary space in the hard disk. Existing applications detect duplicate music files but still leave something to be desired. H. I. Hamzah, T. J. Low, and A. A. Mutalib decide to tackle this problem. They propose the Cognitive and Constructive Learning (CCL) approach. They came up with the Digital Music Archiving Model (DMAM). To test the effectiveness of their model, they compare it to existing applications that detect duplicate music files. The analysis shows that the DMAM is better than the other applications [10].

The article by A. H. D. Crooke contextualizes music technology in Hip Hop. They start their paper by explaining the historical significance of music technology to the Hip Hop tradition of beat making. As time went on, the beat-making culture started to expand and diversify. This diversity extends to the equipment used. The article gives a typology of these beat-making equipment. It shows the varying music technology and states how they should be considered as instruments on their own. It also explains how these technologies are integrated into music therapy.

Crooke expressed his research opinion in the hope of changing the way people view music technology in music therapy. On the one hand, music therapy can affect the development of the human psyche; besides that, there is a negative side where certain music can also damage the human psyche and morals with descriptions of invitations to violate the law and crime. What is more, Hip Hop music is also strongly associated with social justice acts because they are a product of minority cultures [11].

Throughout the continuous development of the digitization of music, one of the most notable applications regarding music is Shazam. Shazam is an application that can help people identify music that's currently being played. A. L. Wang attempts to break down how Shazam functions. Shazam uses the microphone to take in a query containing the small and short ambient audio sample. The minor is as short as two seconds. Then, it searches through its extensive database containing around 40 million songs. There may be distortions in the query audio, and they may be filtered out. The algorithm Shazam utilizes is comparatively better than previously available algorithms. Firstly, it computes faster, processing time as fast as a millisecond. It is also more tolerant of distortion to the query audio by about 20 to 30 db SNR. When comparing the efficiency, It was found that Shazam is approximately 1e + 9 times more efficient [12].

Recording companies and music promoters use data from sales reports to make strategic decisions. In their paper, E. Kristiani et al. discuss data warehouse design techniques. To simulate accurate data, they use chinook, a data sample available to the masses. During the design process, they use Object Relational Mapping. The creation of the data warehouse design is to help relevant stakeholders in making essential decisions [13]. M. I. Fadhil, R. Magdalena, and I. N. Ramatryana wanted to make a database containing the reff and verses of songs. However, manually separating these reff and verses would be very work-intensive and time-consuming. To help overcome this, the research on ways to automatically do these separations. They achieved a way to do this by using correlation calculations between frames.

The system receives an mp3 song as an input and converts it into small frames in the framing process. Each of the frames is transformed using the Harmonic Fast Fourier Transform method. The result determines the correlation pattern of the frames. Then, it can determine the location of the reff and verse. Lastly, the reff and verse are taken from the song depending on the previously determined location. The researchers conducted this process on 25 songs and analyzed the result. The study produces more than 50% accuracy in determining the location of the reff and verse. The best computation time produced in this final project is 86 seconds with a 1000ms frame to cut a single song mp3 file [14].

Ubimus, introduced in 1999 by Weiser, is a research focus that combines Ubiquitous (Ubicomp) computing and music, which literally means Ubicomp calculates anywhere, anytime, anything, and every day, including the definition of Invisible computing, Silent technology, or Pervasive computing. This Ubicomp examines the use of software and hardware in implementing its benefits in the music field, which uses special software to produce digital music following the selection of unique hardware that can produce variations of the musical art itself [36].

2. How Computer Science Can be Integrated into Musical Education

ARPiano, an abbreviation of Augmented Reality Piano, is an augmented reality keyboard designed for fun and efficient music learning. F. Trujano et al. discussed that music sheets might be difficult and off-putting for beginners because they need to understand the musical theory before being able to read them. Using augmented reality (AR), a different method could be used by using a system where the user plays the note to correspond with the bars that appear. ARPiano can locate a physical keyboard and overlay digital objects on individual keys and around the keyboards. Furthermore, it has other features, such as analyzing mistakes made during the performance or playing the song at different speeds [15].

In their paper, S. Cannas took an interesting approach as they analyzed how pedagogical methods can be used in learning music and geometry. Several musical graphs exist, such as the Tonnetz, a note-based graph, and the chicken-wire torus, a chord-based graph. There are also circular geometric models such as the circle of fifths and the tone-clock. These graphs are sometimes used in musical theory to help visualize and convey the relations between musical objects.

Festival of Science (2017) was held at the Vaisseau of Strasbourg. There, they set up an IT-mathemusical laboratory specially designed for children. Cannas used two main methods for musical education: a software named HexaChord and a wooden model of the Tonnetz and chicken-wire torus. HexaChord was utilized due to its ability to visualize the progression of a song in a geometric model. Connecting the software to a piano keyboard to record a musical arrangement was also possible. The children were interested in the wooden model more than the software. One reason is that the children recognize the model to be entertaining. In comparison, the piano keyboard and HexaChord were viewed as foreign items they did not understand. The results also showed that the mathematical skills required to make chords were less complicated than the musical skills required.

A second activity was conducted at another Festival of Science (2017) held in Cagliari, Italy. The results showed that most were impressed and astounded by the integration of computers in music learning and how mathematics can be used as a learning tool [16]. What is different is that this time, most participants are those with musical backgrounds, allowing them to understand HexaChord more easily.

In learning a musical instrument, it is usually of great significance that the external instrument becomes one with the musician's consciousness. M. Myllykoski et al. think that obtaining such skill requires patience and perseverance. As an alternative, they developed SmartHand, which is a wearable device for musical education. The idea was to reduce the need for external instruments and use something we already know about our sensory-motor skills. The developed prototype was a wearable glove with touch sensors. One hand wears the glove and acts as an instrument while the other plays it. The glove's note mapping uses the western tonal system but may be switched with other systems.

They used several different approaches to studying the parameters needed for their project. They use collaborative design to conceptualize and design the project. As for sketching the interaction, bodystorming was used. Use scenarios were utilized to explain the particulars of the experiment further. Interviews were also conducted to gain the project requirements and user experience [17].

P. R. Webster suggested that the use of computing technology in music should be more than just using hardware but also includes software that is combined to create and arrange music so that humans are familiar with it and assisted by computing technology in designing and making music. They outline that there is a newfound respect for computer-assisted teaching. Interest in constructionism as an idea underlying learning created more contemporary research on music technology. Such an approach focuses on creativity and motivation to learn using activities [18].

G. Waddel and A. Williamon conducted research focused on using digital technologies by a student in individual settings. An exploratory survey was made to provide insight and knowledge on this topic. It had a total of 338 respondents, all of whom were musicians. The survey was shared online and contained several sections, and the first one is regarding the characteristics of the respondents. The second section is about their use of technology in their daily life. The third section asks about technology in their learning process. The fourth and final section asks them how they view future technologies.

From the survey result, it was found that while musicians have several issues with technology, they generally have a positive attitude towards it. They actively use technology such as smartphones, laptops, and desktops for video and audio recording and playback. The majority also prefer to use applications for music tools such as tuners, metronomes, and video or audio recording instead of the actual equipment. It also shows that, generally, musicians are optimistic about hypothetical future technologies [19].

A study conducted by S. Nart aims to explore the software that may be used by music teachers and how effective they are in educating the students. By the time of writing, there is much software that fits inside the category of musical education. There are many possible ways the teacher may use this software to spread musical knowledge, compose, and perform music. However, it is of utmost importance for the teacher to understand the software's features well.

In their study, Nart highlights five types of musical software. Tutorial software is a less interactive medium that displays detailed explanations of music drills and practices software, allowing students to practice at whatever level they want. Game software educates students through interactive computer games that may have an evaluating system. Notation Software lets the students arrange or edit music—sequencing and recording software records the music and allows editing via sequencer section.

The main goal of software implementation in musical education is to positively impact both the educator and students. The expanded teaching methods support group activities and allow an increase in scientific thinking skills. It also provides encouragement and motivation to those learning music [20].

Similarly, a study by R. Uptis, P. C. Abrami, and K. Bose seeks to understand how music teachers consider the significance of self-regulation and how they implement digital tools in their teaching process. Evidence from other research shows that digital tools can help students learn music, significantly correlating to supporting their self-regulation, given that they are guided along the way by a teacher or mentor. The writers of the paper wish to know if this is the case with independent music teachers.

To answer the question, they created a survey to gather information. In short, the survey consisted of questions regarding the demographic of the participants, which were all teachers—their opinions and views on digital tools, studio practices, digital tools usage, and development activities. The survey was conducted in Canada and distributed across the dataset of The Royal Conservatory along with music schools and conservatories. They also invited the teachers to reply to a prompt. In total, they amassed 1,468 submissions and 443 responses for the prompt. The results show that the teachers think it is imperative to have self-regulating activities as they have numerous benefits for both teachers and the students. When asked to describe their comfort level with technology, the average rating was 4.85 out of 7. Metronomes and audio recorders were among the most commonly used tool. Overall, the teachers were divided on their opinion if technology helps their students or not. It is believed that many teachers refuse to use technology in their teaching because they do not need it to teach their students music successfully. The comfort level with technology did not seem to matter as they do not see it as a requirement in their teaching process [21].

W.I. Bauer and R.J. Dammers observe how collegiate music teacher education programs help preservice teachers use technology in teaching the K-12 music curriculum. Using 250 NASM schools where half of them were randomly selected, and from each of them, the head of music education was asked to complete an online survey. A total of 89 respondents participated. After reviewing the result, approximately 80% of the respondents said there is a music technology class for the student. 77% said those classes included integrated information about pedagogical uses of technology. Bauer and Dammers feel that a single class is not enough. Technology, musical content, and pedagogy should be integrated into music learning [22].

Studio One is software used as a digital audio workstation. In a paper by R. Putra, he proposed Studio One as an alternative to traditional music education for students of Sendratari PGRI Palembang. Initially, he explains the importance of musical education, especially regarding traditional music. The reasoning for this is that it is essential we do not lose our tradition. He emphasizes that the medium for education plays an important role. Innovations in technology have allowed students to learn music through a digital medium. This brings us to the main point of the paper. It used software such as Studio One as an alternative way of teaching music. Studio One is a product created by the company Presonus that connects MIDI controller and sequencer audio digital for Windows. It has comprehensive features that allow for productive audio and music creation. An experiment was conducted where it used the following equipment Laptop/CPU with Studio One installed, mouse, MIDI-

Controller, and speaker. Participants were then taught to create musical melodies using the Studio One software. From the gathered results, it can be concluded that Studio One can be an effective tool in aiding students in learning traditional music [23].

Another paper by F. D. Pramanta, A. Rohman, and M. R. Kurniawan tries to promote traditional music education using modern technology. They explained the difficulties in traditional music education, including getting access to the instruments, which may cost significant amounts of money. Their proposed solution was to use Realsense-based technology to simulate real instruments. It can be used to visualize traditional instruments such as the Javanese gamelan. The application's output will be displayed on a mobile device for the students to see. They hope that using this method, students at primary school and *middle school* levels can gain a better understanding of traditional instruments [24].

Hhuang et al. explored how elementary school students unfamiliar with music theory experience automated music composition tools. This research creates software that students use to compose and arrange their music, an automatic music composition software in music education. The melodies and rhythm will be up to the students, but the software automatically generates more abstract stuff such as chord configuration and arrangement. In order to test the software, students from the non-experimental school in their sixth year are gathered to use it. They were observed in the level of reaction, learning effectiveness, and the correlation between them. The conclusion is that students using the ACME software gained improvements in terms of reaction level and learning level [25].

While most propose technology to be incorporated into the teaching process, T. Siburian, R. Dewi, and Widodo propose to use technology to help recommend course places. First, they explained that music has widespread interest for many people and how many varying types it has. Due to this, people interested in learning music may struggle to decide where to start. An excellent place to study music is in a course place, but even then, there are many types of courses for different kinds of music. Their proposed method uses a recommendation system based on the Multi-Factor Evaluation Process (MFEP). MFEP takes in many criteria that will be used for decision-making. It then uses a weighting system calculation to give a score to each criterion. The scores allow a qualitative comparison of the different factors [26].

Computer technology with special software and hardware used to teach music to students with visual impairment was implemented in a rehabilitation center in Leningrad, Russia. In its application, braille letters are used to make it easier for students who have vision problems, and besides that, they are equipped with a 19-inch touch screen MIDI keyboard, two active speakers, and a microphone are used to make it easier to see and communicate with the system[37][38]. In addition, the system is equipped with speech applications such as JAWS and NVDA for voice access to the system, including games to increase student interest in learning [39].

A project called L2Ork was developed at Virginia Tech University, the USA, in 2009 with the aim of integrating arts and science into primary and secondary school education in the USA, where there are ten female and male students aged 11 to 13 years. This project aims to make students proficient in creating and designing complex digital music arts while learning computer programming[40].

To study algorithm coding with a programming language as a new model for music education. Nuterpea is a programming language used for teaching the art of music (www.nuterpea.org) so that students focus on the music rather than programming languages developed at the state university of the western state of Colorado, USA, where students who do not have a computer or music background are invited. The curriculum is designed to include computer science in learning music theory around the music genre that is easily programmed with the programming language and follows topics that contain music theory and structure, and besides that, programming language syntax is given in this case [41].

EarSketch is free web-based learning accessible at http://earsketch.gatech.edu, developed at the Georgia Institute of Technology, US music school. This aims to provide an understanding of computer science through art learning music for students in the university without any previous knowledge of music or computer science[42]. The application of Earsketch is carried out using the Python or JavaScript programming language, which focuses on hip hop and dubstep music to learn the basics of programming languages such as variables, loops, options, functions, strings, recursion, and others [43][44].

Another study developed at the Lawrence University of Technology in the USA demonstrates an idea of teaching mathematics and computer science to elementary and middle school students by integrating programming languages, dance, music, and the arts known as the MathDance & Music project. Teaching was piloted to study it using the scratch app version 2.0, which showed that students could quickly learn math and computer science while simultaneously learning music and art. The MathDance & Music application is the same as any other programming language with variables, repetition, selection, functions, and others, where students learn to code with this application in composing music. [45].

A study by the University of Applied Sciences and Arts Northwestern Switzerland linked teaching computer science and music science using five Computational Musical Thinking (CMT) patterns such as interpreters, interactions, opportunities, hierarchies, and rewriting rules in a game design and simulation. The application of CMT greatly helps students understand computer science and music simultaneously. It is proven in its application that students become more enthusiastic about studying computer science and music at the same time even though they do not have the basics of either computer science or music [46].

A study examined the correlation between female gender in the relationship between music and computer science education in Brazil. This study focused on female senior high school students interested in continuing their education at university. These female students were taught the basics of programming and the art of music, including playing musical instruments simultaneously. In addition, this project was carried out using games with the aim of attracting female students to be more interested in studying simultaneously, namely music science and computer science. This research shows that female students are successfully learning the arts of music and computer science simultaneously, and the application of games makes it more exciting and easier to follow the subject matter presented[47].

A study of multiculturalism in the US was undertaken to identify computer science teaching, its effects on black music, and its application for new computer science and non-computer science sophomore students. This study aims to increase diversity in computer science, where the 2015 data shows that only 8.6% of black / African Americans, 19.6% Asian, and 6.8 Hispanic / Latino have jobs in their respective fields in computer science. Therefore teaching the basics of computer science combined with the application of black music such as Hip-hop and R&B increases interest in learning, especially for black or African American students in the field of computer science[48].

A study conducted at the College of Charleston, USA, where data used between 2010 and 2014 showed brilliant results when course delivery in programming basics was linked to music theory and practice for first-year students from multiple disciplines. The subjects provided include computers, the art of music, music appreciation, and the basics of music, as well as the subject matter such as introduction to computer music, music programming, computer music performances, and others[49].

A study developed an open-source tool called BlockyTalky that can run on low-cost processors such as the raspberry pi interactive computer music device for teens between the ages of 11 and 13 to program music behavior and user interaction matter. In this case, proving that computer music supports computer science learning as part of integrating computer music into the computer science curriculum[50].

BlockTalky is available in a web-based form with real-time sensors, message reception, and sending, which in its development using the Google Blockly toolkit together with Javascript and the programming languages Elixir and BlockyTalky have been successfully applied to music theory learning and practice in playing musical instruments and have proven very easy. implemented even though they do not have knowledge of music or computer science[51][52]

A study in Italy was proposed using the LEGO brick game approach in the context of learning algorithmic programming concepts and applying Google Blockly visual programming in learning music through programming concepts [53].

This methodology combines the lego brick game as a means for elementary school students to learn basic music notation, and in practice, these students are required to play the lego brick, which is equipped with basic music notation on each brick and played physically as well as on the second block. Step. Students work in teams to create music coding software by laying virtual LEGO bricks [54].

Google Blockly is a visual programming language implemented in many other fields, such as its application to create applications so that girls like to learn programming languages . Its application is named Wyliodrin [56]. The application was successfully implemented for research on 24 young girls in Germany [55]. Besides that, it was applied to children's primary school in Bucharest, Romania, to understand computer hardware theory studied by the Internet of Things (IoT). In addition, research in Japan was carried out by making prototypes for the SPIN process to increase software reliability in reducing bugs and errors [57]. In addition, there are many more applications, but not all of them intersect with applications in music learning.

3. *Music Creation Through the Use of Computer Science*

As computer science is continuously being implemented in music, the next logical step is the automated generation of music. However, achieving a realistic generation is not an easy challenge. Prior works on music generation focused mainly on symbolic representations such as scores, MIDI[1] sequence, etc. Due to this, several aspects of music are removed, impacting the music quality. One example of such an aspect is the approximate timing of the notes played by a musician.

A proposed solution for generating music is to model the music in the raw audio domain. Models that are capable of doing this are the autoregressive models. To be exact, autoregressive discrete autoencoders are used to capture local signal structure in waveforms which are then used to generate piano music. They experimented with autoregressive models to create the long-range structure for the audio signals. They modeled this structure on approximately 400,000 timesteps, which allows them to create stylistically consistent music. The result shows a successful generation with stylistic bits [27].

In their paper, R. Manzelli et al. discuss the approach to combining symbolic and raw audio models. They explain that symbolic models can be used for note generation, and raw audio models can generate the expressiveness and nuance of performed music.

They used two different types of deep learning models to generate music. The first of which utilizes raw audio models. Initially, a raw audio generation used LSTMs. Then WaveNet was developed by DeepMind. It was capable of interacting with raw audio. The other deep learning models used are the symbolic models. A commonly used one is MIDI. However, many other exists Chord2Vec, piano roll representation, Blues Melody Generation, and many more. A work-in-progress model was developed to achieve this by working with WaveNet architecture and the LTSM network. In the future, they plan on combining them into a coupled architecture, omitting the requirements for synthesizing the files before usage [28].

J. Cruz compared deep learning algorithms and Markov models on their effectiveness in music generation. Early in the deep learning model development, a decision was made to use a Recurrent Neural Network (RNN) model as the basis. The final architecture used is a Biaxial Recurrent Neural Network with several modifications. The model was separated into four and trained on music collections by four piano composers. Each of the models was instructed to generate 100 songs. The resulting songs were distinct and pleasant to listen to, but they show apparent evidence of being computer-generated as there are repetitive patterns and abrupt silence. As for the Markov model, a Hidden Markov Model (HMM) was used. It undergoes the same procedures as the deep learning model for generating music. To compare the results, the models were passed to a classifier that attempts to classify the music based on the composer they were trained on. Results show that the songs made by the deep learning model were more accurately classified than the Markov model [29].

L. Yang et al. have created a model called MidiNet, which is capable of music generation using a Convolutional Neural Network (CNN) model. The model uses random noises as input and generates the music in musical bars. The distribution of melodies was possible due to the model being a Generative Adversarial Network (GAN). Previous knowledge can be utilized to achieve music that follows a chord sequence. 1,022 MIDI tabs of pop music were acquired from TheoryTab and used as the training set. To reduce the complexity of the data, they filter out some chords and group the remaining tabs. Their model uses the TensorFlow library to help complete its training and tasks.

MidiNet was compared with three MelodtRNN models by eight bars of melody generated by each model. Analyzing them were 21 participants, 10 of whom have musical backgrounds of varying degrees. The questionnaire was conducted online. They were asked to be in a quiet room and were given random melodies generated by the models. Even though all of the melodies were generated by a machine, the participants were told that some of the music may be or may not be accurate. Several different questions were asked, and by the end of the experiment, it was found that MidiNet could generate exciting melodies and be on par with MelodyRNN in being realistic and pleasant to hear. L. Yang et al. found the results of the experiment to be quite satisfying. They feel that their model can be a great alternative to RNNs. They plan to expand MidiNet to generate music with multiple tracks, velocity, and pauses. Moreover, they also hope the model could implement music theory and receive input from music information retrieval models [30].

J. Granger et al. present Lumanote as an interactive music composition tool for beginner or intermediate composers. After analyzing existing tools for musical composition, they have decided on four main requirements:

- Build an efficient composition software
- The software can be used with or without a musical instrument
- Show appropriate chords and notes to users with little music composition experience
- Guide uses to create songs without being forceful

The resulting product can be accessed on the website www.lumanote.net. It scans for any MIDI-type devices connected to the hardware. Then the user will be introduced to the main interface and may begin composing. To see the effectiveness of Lumanote, an evaluation was conducted on 20 people. They were asked to create a simple piece of music with and without Lumanote. Results showed that all participants improved their composition's quality and musicality after using Lumanote, regardless of their musical experiences [31].

A new way of conducting computational calculation is through the use of biocomputers. Bio computers are computers that use electronic components from biological materials. With the development of biocomputers also comes the development of bio-memristors, jointing passive components that serves as a resistor with memory. E. R. Miranda, E. Braund, and S. Ventakesh are interested in using the bio memristor to build a music generation system. Their music generation system uses a voltage through the bio-memristor to represent music input. The music output is the current obtained from the system's memristive behavior [32]. The particular bio-computer they use is the PhyBox.

Choi, Fazekas, and Sandler used the Repetitive Neural Network model to introduce automatic jazz chord progressions using and implementing character and word-based rock drum tracks using LSTM units. Two LSTM layers were used. They both had 512 hidden units in them.

The Keras framework was also used. For the training data, musical pieces were taken from The Realbooks and The Fakebooks. The character-based RNN failed to create structure when composing drum tracks, so they proceeded with word-based RNN, which was able to perform well on both tasks. This proves that LSTM may be used as a tool in assisting music composition [33].

This software helps composers to use computers effectively even if they have no prior knowledge as software engineers. In their paper, R. B. Dannenberg explores the idea of Languages for Computer Music as a language distinct from ordinary programming languages. They point out some of the differences between common programming languages and computer music languages which include:

- Programming languages focus on getting quick answers while computer music generates 'answers' within a set time.
- It is essential To enable the processing of large capacity audio files, where the audio is counted incrementally and constantly to pass the recorded audio samples through the use of generators and operators.
- The application of musical arrangements requires accurate and dynamic calculations in which the preparation requires the use of human language, which is more expressive in conveying the meaning of the music than the human voice produced.

They also show examples of existing computer music languages: Music N, Max/MSP and Pd, SuperCollider, and many more Even after many years of development, computer music languages are still constantly being developed because of the extensive range of users with a large range of needs [34].

M. N. Caceres et al. proposed a different idea for automated music generation in their paper. A system would generate musical melodies while being supervised and guided by a user using a mechanical device. It captures the user's movements with the mechanical device and translates them into melodies. The machine can improve by learning from previous compositions using the Case-Base Reasoning architecture. Furthermore, the machine can change the user's movement to create more fabulous musical melodies.

A mechanical device was incorporated because it is one of their goals to encourage human-machine collaboration. Users are asked to create a profile and select several parameters when using it. The system may search from their internal memory or the Internet for previous solutions based on these parameters. These solutions and the user's movement will be training sets for note probability calculation. Based on how good is the result, it may be stored in the memory for later melody generations.

There were three experiments conducted during this research. The first one is to check the learning architecture. The second checks the features of the system. The last one conducts a usability and listening test. Feedback from users indicated that the melodies generated by the system are good and follow a single style. In the future, they would like the system to take in emotions as another input for the music generation. They would also like to introduce a way to include musical styles, not depending on tagged MIDI files. Moreover, they would like to improve the user's interaction by incorporating other devices like the mouse or joystick [35].

In Brazil, early year students for computer science and engineering study programs are directed to make music as a musical instrument for students who are interested in researching the field of games which for them is part of a final project and where theory and practice about music are also delivered to the student[58]. They use the Java programming language as part of the object-oriented programming concept and the Greenfoot Introductory Learning Environment concept [59].

A study conducted at The Australian National University (ANU) reports on the activity of LENS: ANU Laptop ENSemble, which combines musicians and brings musicians and computer scientists into an ensemble laptop where a musician or a computer scientist can hold a concert with his laptop ensemble as a musical instrument[60].

Another study was conducted at the College of Charleston, USA, to develop a free and open-source software called JythonMusic (http://jythonmusic.org), which was developed using the Python programming language with the Jython library, which can be run with the Java Virtual Machine (JVM) to create interactive music that helps composers with manipulation. Music, pictures, and graphical interface include MIDI support and an OSC library[53]. There have been several projects developed starting in 2010 called Laptop Orchestra. In 2011 a project called Monterey Mirror, and in 2014 a project called Time Jitters. Also, in 2015 a project called Diving into infinity and the Migrant Project, and in 2016, a project called SoundMorpheus. [54].

Research conducted in the department of computer science at the College of Charleston, USA, developed Specter, which performs music information retrieval (MIR) by combining sound spatialization for musical arrangements and live music orchestras using Kinect sensors and interfaces such as hand tracking, smartphone-based OSC library controllers, and voice. In three dimensions. This system was developed with the open-source JythonMusic (http://jythonmusic.org) as software for music processing, graphics, animation, and audio or sound manipulation [61][62].

4. AUTHORS' OPINION

Conducting this literature review has been an enlightening experience for us as it has taught us how music and computer science can be integrated. It has given us a new appreciation for how far the music industry has evolved and how influential technology is in our lives. We agree with the notion that digitization has brought a positive impact on the music industry and how we consume it. Regarding using musical education integrated with computer science, we believe it is helpful to some extent. We believe that technological advancements should be embraced to improve the teaching process. However, we do not believe it is adequate only to use digital simulations during the whole teaching process. Practical use of it is a necessary step in learning.

We hope that by creating this literature review, we can provide a comprehensible summary of music in computer science. It hopefully would be helpful for people seeking to learn more about the topic. Allowing them to identify prior research to prevent repetition, complete the need for additional research or even reveal gaps that may exist in past research.

5. CONCLUSION

During this literature review, we learned about how the music industry experienced a change through digitization. Then arises the concern of piracy and revenue loss. The collected reviews have mixed results regarding this, some state that digitization shows no proof of a decrease in sales, while some say otherwise. However, most research found that the digitization of music has led to several positive things, such as music variety and quality improvements. As technology continues to advance, breakthroughs are found in the music industry. We collected papers that touched on some of these advancements.

Most software allows the user to learn about music theory or how to play specific instruments. Integrating it into musical education is one of the more common uses of computer science in music. Several papers propose a wide range of techniques to enhance the learning experience. Several types of research were focused on learning the technology used by music teachers and their views on it. Outside of that, research was also concentrated on creating a recommendation system for course places.

Another common use of computer science in music is to help create music. There are a large number of proposals for this, including, but not limited to, automatic music generation, interactive music composition workshops, or computer music languages. The most used apparatus is computer software or sophisticated devices to achieve this. This literature review gives more details on how these tools are technically achieved.

Overall, music is something that is constantly changing and evolving. There are many directions that it can go, and we believe that it is possible for there to be further advancements in the music industry.

REFERENCES

[1] M. Williams, "On the Origin of Music," B.S. Thesis, Westminster University, London, 2018

[2] H. Sun, "Digital disruption in the recording", Ph.D. dissertation, University of Edinburgh, Edinburgh, Scottland, 2016.

[3] L. Aguiar and J. Waldfogel, "Even the losers get lucky sometimes: New products and the evolution of music quality since Napster" *Information Economics and Policy*, vol. 34, pp. 1–15, 2016.

[4] L. Aguiar, and B. Martens, "Digital music consumption on the Internet: Evidence from clickstream data" *Information Economics and Policy*, vol 34, pp 27-43, 2016.

[5] P. Galuszka, "Music Aggregators and Intermediation of the Digital Music Market" *International Journal of Communication*, vol. 9, pp 254-273, 2015.

[6] J. F. Popham, and C. Volpe, "Predicting moral disengagement from the hatms associated with digital music piracy: an exploratory, integrative test of digital drift and the criminal interaction order" *International Journal of Cyber Criminology*, vol 12, issue 1, 2018.

[7] J. Waldfogel, "How digitization has created a golden age of music, movies, books, and television", *Journal of Economic Perspectives*, vol 31, no 3, pp 195-214, 2017.

[8] R. Fleischer, and P. Snickars, "Discovering Spotify – A Thematic Introduction" *Culture Unbound*, vol. 9, pp 130-145, 2017.

[9] W. Dai, K. Yu, "Contestability in the digital music player market", Journal of Industry, *Competition and Trade*, vol 19, pp 293-311, 2019

[10] H. I. Hamzah, T. J. Low, and A. A. Mutalib, "Preventing duplication of digital music file using a new cognitive and constructive learning approach", *International Journal of Interactive Digital Media*, vol. 4, pp 7-14, 2016.

[11] A. H. D. Crooke, "Music technology and the hip hop beat making tradition: a history and topology of equipment for music therapy", *Voices: A World Forum for Music*, vol. 18, issue 2, 2018.

[12] A. Wang, "High performance and robust audio search", *The Journal of the Acoustical Society of America*, vol 140, no 4, pp 3378, 2016.

[13] E. Kristiani, E. Rahardja, F. Pasamboan, I. Raymond, and R. T. Ginting, "Perancangan dan simulasi data warehouse untuk pendukungan keputusan promosi musik", *Jurnal Teknik dan Ilmu Komputer*, vol 25, no 23, 2017.

[14] M. I. Fadhil, R. Magdalena, and I. N. Ramatryana, "Pemisahan reff dan verse secara otomatis pada musik mp3 menggunakan korelasi antar frame berbasis ciri harmonik fast fourier transform", B. S. Thesis, Teknik Elektro, Universitas Telkom, Jakarta, 2019

[15] F. Trujano, M. Khan, and P. Maes, "ARPiano efficient music learning using augmented reality" in *International Conference on Innovative Technologies and Learning*, Portoroz, Slovenia, 2018.

[16] S. Cannas. "Learning geometry and music through computer-aided music analysis and composition: a pedagogical approach" in *Journées d'Informatique Musicale* (JIM 2018), Amiens, France. 2018.

[17] M. Myllykoski, K. Tuuri, E. Viirret, and J. Louhivuori, "Prototyping hand-based wearable music education technology" in *Int. Conf. on New Interfaces for Musical Expression*, LA, USA, 2015.

[18] P. R. Webster, "Computer-based technology and music teaching and learning," *Critical Essays in Music Education*, vol 22, pp. 321–344, 2017.

[19] G. Waddell, and A. Williamon, “Technology use and attitudes in music learning”, *Technology Enhanced Music Learning and Performance*, vol 11, no 9, pp 80-95, 2019.

[20] S. Nart, “Music software in the technology integrated music education”, *The Turkish Online Journal of Educational Technology*, vol. 15, issue 2, 2016.

[21] R. Upitis, P. C. Abrami, and K. Boese, “The Use of Digital Tools by Independent Music Teachers” in *Int. Association for Development of the Information Society (IADIS)*, Algarve, Portugal, 2016.

[22] W. I. Bauer, and R. J. Dammers, “Technology in music teacher education: a national survey”, *Research Studies in Music Education*, vol. 18, no 1, pp 2-15, 2016.

[23] R. Putra, “Media software musik studio one sebagai alternatif pembelajaran seni musik tradisional pada mahasiswa sendratarik PGRI Palembang”, in *Seminar Nasional Pendidikan Program Pascasarjana Universitas PGRI Palembang*, Palembang, 2019.

[24] F. D. Pramanta, A. Rohman, and M. R. Kurniawan, “Aplikasi pembelajaran alat musik daerah gamelan Jawa berbasis teknologi realsense”, *Seminar Nasional Teknologi Informasi dan Aplikasinya*, vol 9, 2017.

[25] C. F. Hhuang, W. P. Nien, and Y. S. Yeh, “Learning effectiveness of applying automated music composition software in the high grades of elementary school”, *Computer & Education*, vol 83, pp 74-89, 2015

[26] T. Siburian, R. Dewi, and Widodo, “Sistem pendukung keputusan dalam merekomendasikan tempat les musik dipematangsiantar menggunakan metode multifactor evaluation process (MFEP)” in *Konferensi Nasional Teknologi Informasi dan Komputer,* Pematangsiantar, Oct 2018, vol 2, no 1.

[27] S. Dieleman, A. V. Oord, and K. Simonyan, “The challenge of realistic music generation: modeling raw audio at scale” in *Neural Information Processing Systems 2018*, London, United Kingdom, 2018.

[28] R. Manzelli, V. Thakkar, A. Siahkamari, and B. Kulis, “An End to End Model for Automatic Music Generation: Combining Deep Raw and Symbolic Audio Networks”, Dept. of Electrical and Computer Engineering, Boston University, Boston, 2018.

[29] J. Cruz, “Deep learning vs Markov model in music generation”, B.S. thesis, Pace Univ, New York City, New York, 2019.

[30] L. Yang, S. Chou, and Y. Yang, “MidiNet: a convolutional generative adversarial network for symbolic-domain music generation” in *International Society of Music Information Retrieval*, Canada, 2017.

[31] J. Granger et al. “Lumanote: a real-time interactive music composition assistant” in *Sketch Recognition Lab*, Texas, 2018.

[32] E. R. Miranda, E. Braund, and S. Ventakesh, “Composing with bioimemristors”, *Computer Music Journal* vol 42, issue 3, pp 28-46, 2018.

[33] K. Choi, G. Fazekas, and M. Sandler, “Text-based LSTM networks for automatic music composition” in *1st Conference on Computer Simulation of Musical Creativity*, Huddersfield, England, April 2016

[34] R. B. Dannenberg, “Languages for computer music,” B.S. Thesis, Sch. of Computer Science, Carnegie Mellon University, Pittsburgh, Pennsylvania, 2018

[35] M. N. Cacares, W. Hashimoto, S. R. Gonzales, B. P. Lancho, and J. M. Corchado, “Sensoring a generative system to create user-controlled melodies”, *Sensors*, vol 18, issue 10, 2018.

[36] F.L. Schiavoni, and L. Costalonga, “ Ubiquitous music: A computer science approach,” Journal of Cases on Information Technology (JCIT), 2015, vol. 17, no. 4, pp. 20-28.

[37] I.B. Gorbunova, and A.M. Voronov, “Music computer technologies in computer science and music studies at schools for children with deep visual impairment,” In Int'l Conference Proceedings, 2018, pp. 15-18.

[38] I. Gorbunova, and A. Govorova, “Music computer technologies in informatics and music studies at schools for children with deep visual impairments: from the experience,” In International Conference on Informatics in Schools: Situation, Evolution, and Perspectives, 2108, pp. 381-389.

[39] I.B. Gorbunova, and A.A. Govorova, “Music Computer Technologies as a Means of Teaching the Musical Art for Visually-Impaired People,” In 16th International Conference on Literature, Languages, Humanities & Social Sciences (LLHSS-18). Budapest, Hungary. Infl Conference Proceedings, 2018, pp. 15-19.

[40] L. Moyer, M. Klopfer, and J.V. Ernst, “Bridging the arts and computer science: Engaging at-risk students through the integration of music,” Technology and Engineering Teacher, 2018, vol. 77, no. 6, pp. 8-12.

[41] J. Peterson, and G. Haynes, “Integrating Computer Science into Music Education,” In Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education, 2017, pp. 459-464.

[42] J. Freeman, B. Magerko, and R. Verdin, “EarSketch: A web-based environment for teaching introductory computer science through music remixing,” In Proceedings of the 46th ACM Technical Symposium on Computer Science Education, 2015, pp. 1-5.

[43] K. Wright, “Learning to Code Music: Development of a Supplemental Unit for High School Computer Science,” thesis, 2017.

[44] J. Freeman, B. Magerko, and D. Edwards, and L. Ikkache, “EarSketch, a Web-application to Teach Computer Science through Music,” In Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education, 2017, pp. 640-640.

[45] M. Shamir, M. Kocherovsky, and C. Chung, “A paradigm for teaching math and computer science concepts in k-12 learning environment by integrating coding, animation, dance, music, and art,” In 2019 IEEE Integrated STEM Education Conference (ISEC), 2019, pp. 62-68.

[46] A. Repenning, J. Zurmühle, A. Lamprou, and D. Hug, “Computational Music Thinking Patterns: Connecting Music Education with Computer Science Education through the Design of Interactive Notations,” In CSEDU, 2020, pp. 641-652.

[47] C.N. Silla, A.L. Przybysz, A. Rivolli, T. Gimenez, C. Barroso, and J. Machado, “Girls, music and computer science,” In 2018 IEEE Frontiers in Education Conference (FIE), 2018, pp. 1-6.

[48] S. Oge, D. James, and C Jung, “An exploration of the intersection between Black music and teaching computer science for iConference 2017,” iConference 2017 Proceedings, 2017.

[49] B. Manaris, and B. Stevens, "Connecting Music and Computer Science: An Interdisciplinary Learning Community for First-Year University Students," co-authored with Bill Manaris, in Performing Arts As High-Impact Practice, ed. Michelle Hayford and Susan Kattwinkel (Cham, Switzerland: Palgrave Macmillan), 2018, pp.68–82.

[50] R.B. Shapiro, A. Kelly, M. Ahrens, and R. Fiebrink, “BlockyTalky: A physical and distributed computer music toolkit for kids,” NIME, 2016.

[51] R.B. Shapiro, A. Kelly, M. Ahrens, B. Johnson, H. Politi, and R. Fiebrink, “Tangible distributed computer music for youth,” Computer Music Journal, 2017, vol. 41, no. 2, pp. 52-68.

[52] A. Kelly, L. Finch, M. Bolles, and R.B. Shapiro, “BlockyTalky: New programmable tools to enable students’ learning networks,” International Journal of Child-Computer Interaction, 2018, vol. 18, pp. 8-18.

[53] A. Baratè, A. Formica, L.A. Ludovico, and D. Malchiodi, “Fostering computational thinking in secondary school through music-an educational experience based on google blockly,” In International Conference on Computer Supported Education, 2017, vol. 2, pp. 117-124). SCITEPRESS.

[54] A. Baratè, L.A. Ludovico, and D. Malchiodi, "Fostering computational thinking in primary school through a LEGO®-based music notation," Procedia computer science, vol. 112, pp. 1334-1344.

[55] M. Seraj, E.S. Katterfeldt, K. Bub, S. Autexier, and R. Drechsler, "Scratch and Google Blockly: How Girls' Programming Skills and Attitudes are Influenced.," In Proceedings of the 19th Koli Calling International Conference on Computing Education Research, 2019, pp. 1-10.

[56] I. Culic, A. Radovici, and L.M. Vasilescu, "Auto-generating Google Blockly visual programming elements for peripheral hardware," In 2015 14th RoEduNet International Conference-Networking in Education and Research (RoEduNet NER), 2015, pp. 94-98.

[57] S. Yamashita, M. Tsunoda, and T. Yokogawa, " Visual Programming Language for Model Checkers Based on Google Blockly," In International Conference on Product-Focused Software Process Improvement, 2017, pp. 597-601.

[58] C.N. Silla, A.L. Przybysz, and W.V. Leal, "Music education meets computer science and engineering education," In 2016 IEEE Frontiers in Education Conference (FIE), 2016, pp. 1-7.

[59] B. Swift, C. Martin, and A. Hunter, "Two perspectives on rebooting computer music education: Composition and computer science," In Proceedings of the Australasian Computer Music Conference. Australasian Computer Music Association, 2019.

[60] B. Manaris, B. Stevens, and A.R. Brown, "JythonMusic: An Environment for Teaching Algorithmic Music Composition, Dynamic Coding, and Musical Performativity", Journal of Music, Technology & Education, 2016, vol. 9, no. 1, pp. 55-78.

[61] B. Manaris, P. Brougham-Cook, D. Hughes, and A.R. Brown, "JythonMusic: An Environment for Developing Interactive Music Systems", Proceedings of the 18th International Conference on New Interfaces for Musical Expression (NIME 2018), Blacksburg, VA, Jun. 2018.

[62] B. Manaris, and S. Stoudenmier, "Specter: Combining Music Information Retrieval with Sound Spatialization", Proceedings of the 16th International Conference on Music Information Retrieval (ISMIR 2015), Malaga, Spain, Oct. 2015.

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