Full research paper

TECHNOLOGY-ENHANCED THINKING SCAFFOLDING IN MUSICAL EDUCATION

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ABSTRACT

In pedagogical language, "scaffolding" is frequently used to replace the expression "support in learning". In didactic terms, the practice in the classroom shows that various types of support, such as the teacher, colleagues, and technologies, contribute to more efficient learning. In terms of technologies, the present study aims to test the role of programming as a scaffolding agent in learning music theory by memorizing and understanding musical notation elements. In this sense, a sample of 87 students (*N* = 87) from an urban environment in Romania carried out programming activities using the Sonic Pi application in the Music and movement classes, implemented through an educational project with 24 lessons designed for integrated music-programming learning. The study results describe the acquisition of knowledge, in terms of recognition of musical notation elements, achieved under the influence of cognitive capacities scaffolded by digital technologies. Better post-test results and homogeneous variances between and within the three classes of the participant's sample confirm the possibility of achieving technology-enhanced thinking scaffolding in musical education. The results of the music-programming integrated learning framework could be translated into a more efficient use of teaching time and an increased flexibility of interactions.

KEYWORDS

Cognitive processes, music-programming learning, primary education, scaffolding, Sonic Pi

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Highlights

- *Primary school students (11 years old) can convert the game of generating sounds through programming into acquisitions of learning music theory.*
- *Digital technologies can scaffold the cognitive processes (memorization, understanding) involved in the achievement of musical education.*

INTRODUCTION

Music has always been a force that creates social cohesion and strongly influences human beings, especially young people. A study where children aged 11-14 were involved in which it was intended to "ascertain how regular involvement in music activities can cultivate mindfulness, integrating body, mind and spirit, subsequently facilitating holistic development that will enable children to overcome their challenging social circumstances" (Auerbach and Delport, 2018: 3) found that those activities carried out in a non-formal environment, optimize the educational process. Children were engaging in activities with pleasure.

Computers are considered to produce the same effect on young people, they are a subject of interest to them, especially because "interest in computers seems to begin at around age 4" (Webster, 2002: 233), only that these devices, which produce good mood among young people, are more modern means with a short history. This means that the experience of interactions with digital technologies, at this time, is not one that is inherited and passed down over generations. Today, computers have entered our lives, and we find them in various objects around us that we call "smart objects". This process has just begun, and in the future, "we will see more sophisticated virtual worlds; Second Life is today's Mosaic" (Wing, 2008: 3723). Thus, what we live, and experience today is already a digital habitat, and the future will increase the degree of integration of the real world into the virtual one. Computers are being used on an ever-increasing scale, and everything that a computer display is virtual, even the smallest information because in reality and in the processes they carry out, there are only 0 and 1, i.e., absence and presence of a signal, these being the basic units of information in the binary system. Learning, like any other activity that the individual or groups of people are engaged in, will be part of this new reality, which grows and develops quickly, like a child.

In the teaching-learning process, integrating music with computers can result in a relevant educational object for the digital age, allowing the student to explore or deepen sound parameters, all done with pleasure and enthusiasm. In such an integrated scenario, "the learning environment should be able to represent activity-oriented musical experiences, where students - properly sustained by scaffold elements - are involved in the process of music construction/deconstruction" (Ludovico and Mangione, 2015: 452). Thus, digital technologies are equated with supporting elements in formal education in this specific context of understanding musical works, digital musical reproduction, or the construction of completely new melodic fragments. Under the influence and reality of technological advancement, "there's always new information about the usage of music and people, especially parents, should be regarded as the ones in the front row to find out about the modern and original ways in which music is practiced and applied" (Simion, 2015: 489). A modern way to practice, learn, and apply music includes the use of the computer, and because the role of parents in enrolling children's education in an up-to-date education was also emphasized, the integration of music education with computer science education addresses all forms of education.

In a formal education setting where the students have experienced sound generation with a computer, the research aimed to test the role of computer programming as a scaffolding agent in learning music theory by memorizing and understanding musical notation elements during their practical use. In this sense, whether certain results of interaction with knowledge from the musical domain can be attributed to computer programming is of interest. Thus, the first made-up research question is:

Q1: To what extent can digital technologies provide scaffolding support in the cognitive processes involved in the realization of music education?

In terms of digital technologies, *Sonic Pi*, the application used in this study, can determine meaningful learning experiences, given the fact that it makes the connection between two different domains, music and programming, with the possibility of mutual support in the student's actions to improve knowledge in one of the domains. It has been stated that *Sonic Pi* was created to support the programming-oriented curriculum in the United Kingdom (Aaron, 2016). Still, it is to be analyzed if such an activity, presented as a musical creation game, is suitable for some students in primary education aged 10-11 years. Then the second research question is:

Q2: What is the evidence that elementary school students can convert the play of electronic sound generation with the *Sonic Pi* software into acquisitions of music theory learning?

Regarding the structure of the paper, at the beginning, a brief review of the evolution of the term "scaffolding" is made, followed by a section assigned for framing the research problem, conceptualizing the use of digital technologies as mind tools for scaffolding thinking. The next section presents the research purpose. The section dedicated to the research includes the study's hypothesis, participants, research design, and explanations for the educational project designed for integrated music programming learning. The section dedicated to the results presents, in a pre-test and post-test comparative analysis, the results of the students obtained after completing 24 lessons that integrated music with programming in the didactic process. Finally, the discussion section compares the results of the study with those recorded in the theoretical foundation, and in the end, the conclusions are presented in the last section.

THEORETICAL FRAMEWORK

The use of social skills requires cooperation and collaboration, which involves the implicit existence of support in the activity carried out. When this activity is one of learning, in pedagogical language, a synonym frequently used to replace the expression of support in learning is the term "scaffolding". The conceptualization of the term scaffolding in pedagogy was carried out by Wood, Bruner, and Ross in 1976 (Kim and Hannafin, 2011) and fits perfectly a sociocultural perspective in which the role of the teacher is emphasized to provide support in learning in accordance with the socio-constructivist type of instruction. At its origin, "the concept of scaffolding refers to temporary and adaptive support, originally in dyadic adult–child interaction" (Smit et al., 2013: 817), but support can also come from other sources, such as a more capable peer. When using the term "scaffolding", we are talking about external support, which can also be of another type. Therefore, "probably the most common way of describing the provision of assistance to learners has been related to the use of the building metaphor, scaffolding" (Yelland and Masters, 2007: 363). Nevertheless, today, human beings benefit from assistants that did not exist a short time ago, and they were created precisely for this purpose, to provide the necessary support at the right time. An example in this sense is virtual assistants, such as Siri or Cortana, who are ready to offer support on certain operating systems at any time. Robotic Process Automation (RPA) is a field on the rise; in fact, we find ourselves at the moment when robots compete with human actions, replace human beings in the field of work, and perform tasks much better. In this sense, digital technologies can provide support as substitutes for human intervention. In such a context, "computers can provide effective *scaffolding* for young children" (Webster, 2002: 233), and perhaps for these reasons, it was stated that: "renewed interest in scaffolding has been evident in education research" (Kim and Hannafin, 2011: 403).

The initial concept indicated the most capable adults or peers as potential sources of support in learning. Still, the concept was expanded and expanded in scope, so the specialized literature mentions even more possibilities of mediating learning under the term "scaffolding". As a result of extensive documentation, through the analysis of a series of studies in this field and the organization of international conferences with the unique theme of scaffolding, it is stated that "in general, multiple agents provide scaffolding in the classroom including the teacher, other students, paper-based artifacts, classroom decorations, technology, and far more" (Davis and Miyake, 2004: 267). These aspects are confirmed by the practice in the classroom, where various types of support such as the teacher, peers, or technologies compete and that make learning more efficient, which is why scaffolding must be seen as a system, as found in the vision of Reiser (2004; as cited in Kim and Hannafin, 2011).

The integration and the natural place of digital technologies in such a system is confirmed by a study carried out over two years, where the participants were students around the age of 8 in primary education and which targeted digital technologies as specific and extended form of providing support in learning, concluding that their "work has also indicated that the computer and the type of tasks used create a context which is a type of scaffold, that may be complemented with suitable cognitive and affective strategies" (Yelland and Masters, 2007: 380). Considering the complementary role of cognitive strategies in an obvious relationship between pedagogy and psychology, "Rogoff (1990) defined scaffolding as a meta-activity that assists learners in separating given tasks into pieces, and this definition can explain supporting learners in *decomposition*, which is among the sub-components of" computational thinking (Kukul and Çakır, 2020: 38).
The use of the term Computational Thinking (CT) is attributed to Seymour Papert (1980; as cited in Agostini, 2020), who first used it in 1980, and was brought back to public attention in 2006 by Jeannette Wing (2006; as cited in Kukul and Çakır, 2020). Meanwhile, computational thinking has become part of the curriculum of several countries around the globe, such as Cyprus (European Education and Culture Executive Agency, Eurydice, 2019) and New Zealand (Petrie, 2021). Computational thinking allows the formulation of problems and viable solutions in both human and computer minds (Selby, 2011). So, computational thinking is the use of cognitive skills to face a problem with the help of the computer, a problem that can be solved in this tandem, human-computer. In the context where, through scaffolding, students are oriented towards identifying the problem along with the progressive structuring of tasks to solve it, as Reiser claims (2004; as cited in Kim and Hannafin, 2011), scaffolding has similar characteristics to computational thinking, in the sense that it accompanies the student on the path from problem identification to its solution. In this context, solving the problem means obtaining the information sought through a thought process supported by scaffolding by digital technologies. Hence, the information determines the human being to think, a process in which computer equipment also participates, by the fact that it causes, in turn, the human being to think and process the information: structured, logical, and algorithmic. Information from various sources can be processed, and this is a complex process that we call learning. This complex process involves, inclusively, auditory processing, and when sound characteristics and patterns of sound groups are processed, learning is included in the realization of music education.
Based on Rogoff's statement (1990; as cited in Kukul and Çakır, 2020), which perceives common points between the role of scaffolding and that of computational thinking, that of being a support for those who learn in *decomposition* and under the evidence of the fact that music is decomposed into elements of form (stanzas/ refrains), musical phrases, measures, musical notes, sound qualities, we understand that digital technologies can have the ability to provide scaffolding support in the cognitive processes involved in making music education. Thus, connections are present between pedagogy, psychology, and music, as Webster (2022) also highlights when he states that using apps to scaffold music composition and improvisation is of a great deal for learning. In this regard, in an analysis of the specialized literature it was concluded that "handheld technology presents an opportunity to scaffold students' musical learning, enhance self-expression, and explore timbral relationships" (Carlisle, 2014: 12). Also, in an empirical investigation that aimed to analyze how computational thinking supports learning objectives set for content areas specific to music and computer programming and in which the *Sonic Pi* application was used during the undertaken activities with 22 students of ages 11 to 12, "appropriate learning outcomes were created to be in line with the main lesson activities and curricula links in the Music Curriculum and DTC in NZ" (Petrie, 2021: 5), DTC being the acronym for Digital Technologies Content, and NZ for New Zealand.
The examples presented promote the idea that "to scaffold students' scientific inquiry, teachers use technologies to access real-world examples to vividly illustrate the nature of science as complex, social, and challenging" (Kim and Hannafin, 2011: 409). In a real-world setting, at the time of 2022, both the student and the teaching staff return post-pandemic to their usual activity. However, following the pandemic experience, which imposed social distancing, the reconsideration or strengthening of social skills requires cooperation and collaboration, which presumes the implicit existence of support in the activity carried out. The introduction of the basics of programming languages in the study of music seems to be a favourable context for cooperation and encouraging the necessary skills for the cultural and artistic expression of students, which we want to use as a strategy to activate the potential of students at the level of the 4th grade. For such a context, "we believe that play for a child or an adult, as well as specifically for a computer science student, includes two key factors. The first is exploring something relevant and interesting to the individual, and the second is doing this in a social environment" (Anderson and Gegg-Harrison, 2013: 499).
With regard to the social environment of the primary classes, a study from Sweden that integrates the teaching of programming with mathematics notes, "the fact that programming trains students' communication skills is another aspect mentioned by the interviewed teachers. They argue that students work often in groups with programming, collaborating on solving tasks" (Stigberg and Stigberg, 2019: 491). By the fact that music is a phenomenon of general interest, which can be explored through computer programming in the social environment, starting from the primary education classes, precisely because it offers the opportunity to explore something interesting and relevant for the learner, where learning to program can be enjoyable and approached with enthusiasm, a comfort zone suitable for the student can be seen for the transition towards proximity development. On a social level, this is a proper context for communication and collaboration, and even more than that, programming can be used for pedagogical purposes and for the development of various non-digital skills from various curricular areas. For example, between the curricular areas *Arts* and *Technologies - Computer Science*, in general, but more precisely between music and programming, similar forms

of thinking were observed, "both use concepts around sequence (the order in which notes appear in time; and the order of statements in a computer program) and repetition (in music this includes repeats, as well as forms such as rondo or the structure of popular songs; in computing loops and recursion provide this)" (Bell and Bell, 2018: 152). Thus, digital technologies strengthen the relationship between pedagogy and psychology in the case of developing musical skills.

Because "interactive and experience-based practical exercises present a way to teach theory in art education" (Váradi, 2018: 67), reproducing a sequence of musical notes from a cultural heritage work, implemented in a sequence of computer instructions, is a way of learning music theory by composing digital music. The fact that "technology can socialize learning, encouraging positive behaviors such as asking questions, giving explanations, and discussing disagreements" (Roschelle et al., 2010: 416) emphasizes how pedagogical and didactic aspects reconcile with technology. To make this contribution explicit, it is stated that "technology-enhanced scaffolding can situate problem identification and engagement by providing vivid descriptions, visualizations, and related questions and resources to students' experiences" (Kim and Hannafin, 2011: 409).

The process of realizing music education shows that there is a need for explanations, experiences in working with sound qualities, and answers to questions related to sound phenomenology since, in a study carried out with 286 primary school students, it was shown through the processed data and analyzed quantitatively as well as qualitatively, that the opinions formed on the way sound is transmitted wrong and this could be because, in the case of sound, information cannot be processed visually (Sözen and Bolat, 2011). This is where technologies can interfere with providing explanations, those technologies that have an oscillogram and thus allow the graphic representation of sound vibrations, as well as computer programming as a technique to generate sounds electronically, exploring, in this way, the presence of all relevant parameters in the formation of sounds. The teacher's feedback can sometimes be delayed or absent in the classroom where the teaching-learning process is traditionally approached. Yet, digital technologies can provide immediate feedback, contributing to an effective learning environment. This is addressed in a study that sought to explain scaffolding group feedback using the Eduinnova software made at Pontificia Universidad Católica de Chile (Roschelle et al., 2010). This is an example of the fact that technologies, through the solutions they offer, can have the ability to provide scaffolding support to make learning accessible, of interest in the present case being those actions characterized by problems in learning or understanding music.

FRAMING THE RESEARCH PROBLEM

In the sense of this characteristic of scaffolding, of providing temporary support, technologies can accompany the student on the route described by the dimension of cognitive processes, with six transit zones: memorization, understanding, application, analysis, evaluation, and creation, according to Bloom's revised taxonomy (Krathwohl, 2002), but, in each of these cognitive effort types, the amount of support provided may be different. On the six types of cognitive effort in which thinking skills are ranked from the lowest level (memorization) to the highest level (creating), digital technologies can support learning objectives from the bottom of the hierarchy so that later the support is withdrawn, for this purpose, but used, gradually, for another, which is a more important goal from the top of the hierarchy, where individuals can act creatively using digital technology. In the chapter "creativity", the EU Council Recommendation on key competences for lifelong learning presents digital competence with an emphasis on the importance of understanding how digital technologies can support creativity (The Council of the European Union, 2018). Digital technologies can also support creativity in this way, helping students advance in the complexity of cognitive processes. Creative thinking is the type of thinking that allows students to rescale their knowledge by applying imagination, anchored in theory, to generate ideas. In this sense, the scaffolding with digital technologies for the realization of music education represents the support that can be offered and withdrawn at the time when learning objectives have been met on the route from theory (memorization, understanding) to practice (creativity). Escalation on the dimension of cognitive processes, as presented in the Digital Competence Framework for Citizens (DigComp 2.1.), represents the advancement in levels of competence according to the cognitive challenge in which the student engages (Carretero et al., 2017). This cyclical progress in interacting with information and knowledge for developing digital competence from memorization to creation is supported by digital technologies through a scaffolding presence. In terms of integrated learning, in relation to the field of music, "if children do not know the joy of creating […], then they will not be educated into music" (Váradi, 2018: 67).

Analyzing digital technologies in relation to the scaffolding support they can provide in the classroom, Kang (2018) states that this is a possibility by which students can be given the support they need to better understand and complete tasks in a setting where teachers shape student progress using digital tools. Kim and Hannafin (2011) provide a few examples of technology-enhanced scaffolding, including contextualized learning, vivid descriptions, and visualizations, taking over lower-order tasks, helping students diagnose their misconceptions, and many others. As for the complete or partial taking over of lower-order cognitive tasks by the computer, this frequently happens, for example in cases where statistical research is carried out, the researcher does not have to remember all the formulas for calculating some statistical indices but only apply the formula that the statistical interpretation software will give him, to analyze and interpret/ evaluate the results. Likewise, in the classroom, in a computing context where the student has not memorized all the formulas behind some theorems in Mathematics, they are accessible through the computer, and it is important for the student to find them, recognize them, apply them, and complete the task or flesh out their idea towards a creative outcome. These are examples where lower-order thinking skills can be deliberately delegated wholly or partially to the computer, and the support offered by the computers can be gradually withdrawn as the student works with higher-order thinking skills, which is a desirable aspect of human personality development since individuals should be able to creatively solve everyday problems. As the student moves up the scale of technology-enhanced thinking scaffolding, outlined in Figure 1, without assuming that the computer support is the same amount for each level, the higher-order thinking skills that the individual puts into work increase progressively as the computer support is withdrawn. This action has the characteristics of scaffolding support. It is a formula that supports creativity and imagination. At the same time, a greater contribution of the computer on the higher levels of thinking can act as an enemy of imagination, which is why, in terms of creativity, the computer is desirable to represent only an instrument by which the human being creates. In this regard, "scaffolding allows children to form cognitive structures so that they can operate at high levels of thinking and work more effectively toward their potential" (Webster, 2002: 233) so that, through an orientation in the work task, its solution is as close as possible, which represents the guidance of students in the space of knowledge to a development area possible to reach with the help of external guidance.

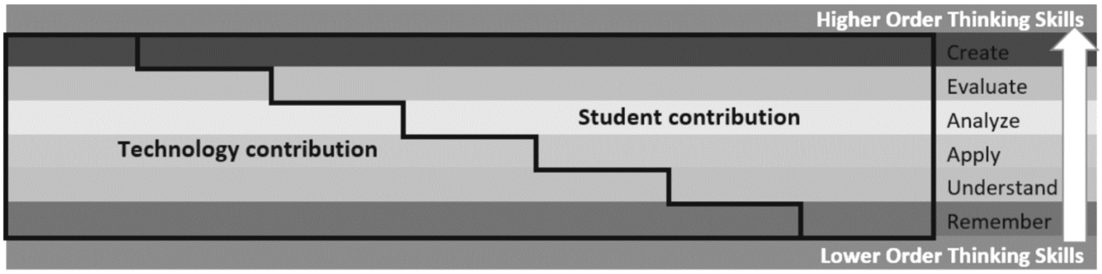

Figure 1: Technology-enhanced thinking scaffolding scale

Considering all these aspects in the relationship of digital technologies with scaffolding support in learning, "the ultimate goal of all teachers should be to facilitate the use of computers and computing technologies as mind tools (cognitive tools) to accompany thinking, reasoning, creating, learning, and inventing" (Hamza et al., 2000: 73). One such relationship is described by Seymour Papert who "argued programming can be used to support the fundamental ability to understand one's own thought processes, and thus suggested integrating simple elements of computer science, such as programming, into primary education" (2005, as cited in Leifheit et al., 2018: 345). Inclusively "at the core of Piaget's theory of development is the process he calls assimilation: when a child takes in new ideas they are first reconstituted to fit the child's mental structures. […] School has to assimilate new ideas to its own structure before these structures can change" (Papert, 2005: 366). Whether it is at an institutional level or an individual level, technologies have the capacity to support creative processes, leading to new products and new or restructured information, situations for which "researchers have studied alternatives to designing and using technologies to scaffold learning" (Kim and Hannafin, 2011: 407).

It is known that today, assessment design focuses on lower-level thinking skills, measuring what the students have memorized, which is opposed to the expression of creativity. (Ben-Jacob, 2017). In the spirit of constructivist theories, where students reframe their knowledge based on meaningful learning experiences, it is much more plausible that they keep in mind and apply what they have learned (Nand et al., 2019), which is also the goal of the current study, that the students store information at the end of a long process of practical training. Retaining and retrieving information stored by memorization in a knowledge base that is formed and can be accessed and retrieved from long-term memory is a process that Krathwohl (2002) calls remembering, while understanding is defined as the meaningful interpretation of the signification and importance of instructional messages. The student's development perspectives are broadened, starting from the assumption that the stored information is a source for new ideas generation, which most likely leads to more creative outcomes (Rominger et al., 2019).

As in any other field, cognition is also present when working with sound, and the tasks tackled by the students fall into one of the six types of cognitive effort included in the dimension of cognitive processes. In music, processing sound information is a natural process that underlies the realization of musical education. Because information determines how human beings think, information can turn into knowledge if it is assimilated and can be capitalized on various levels of thought processes: memorization, understanding, and creation, these being the cognitive processes that the paper is referring to.

PURPOSE OF THE STUDY

The study aims to use the *Sonic Pi* application to analyze the capacity of digital technologies to provide scaffolding support in the cognitive processes involved in the realization of music education for 4th grade students in the mainstream education system in Romania. In relation to the application that is being used in this study, "This makes *Sonic Pi* a language with a steep learning curve, which allows novices to focus on key concepts for which they can see immediate results, and this encourages a creative learning approach" (Traversaro et al., 2020: 144). Regarding the key concepts in the field of music education addressed in this study, these are elements of music theory and notation, which will be processed in a programming language with the help of the *Sonic Pi* application to get immediate audio results for the meanings of the concepts written on a musical stave. Symbols are used in the field of music, and these "are only static representations on a flat surface of dynamic mental processes" (Devlin, 2014, p. 78) of ideas. In fact, these are visual languages, and their recognition will be found in the practical activities in the classroom, which, carried out over a long period of time, aim at memorizing certain elements of musical notation. By transposing the symbols of a music stave into a digital audio product through programming, the musical notation will be transposed into another symbolism, that of codes, the programming being the one that will dynamize the static symbols from the stave and correlate the visual language with the auditory one, also favoring the understanding of the musical notation which students have operated with.

The use of the *Sonic Pi* learning tool is part of a strategy to activate the potential of students and to form a profile of a creative person. This digital tool, used in this study to provide learning support, has been chosen because it provides immediate sonic feedback for the conceptual knowledge a student is using, regardless of whether it is processing musical symbols from a musical stave or operating with certain basic principles in programming and, of course. After all, *Sonic Pi* is a path to the heart of the principles of electronic music and is also a great way to boost creativity, as it allows students to design and implement personal musical ideas, feelings, or experiences in a relatively immediate way (Agostini, 2020).

The processing of sound information is a basic activity in realizing musical education. In such a context, the presence of sound information causes human beings to make current use of the skills in the hierarchy of cognitive processes. In this sense, the present study aims to analyze technology-enhanced thinking scaffolding for the achievement of music education, which can be provided and withdrawn when learning objectives have been met. The learning objectives, in this context, are represented by the memorization and understanding of certain elements of musical notation, for which the input of digital technologies could be withdrawn later, using the technologies later only as a musical instrument or toy to create melodic fragments.

In summary, the objectives proposed in this study are:

O1: the integration of computer science education contents with music education for the application of musical theory concepts through playing with the *Sonic Pi* application at the primary education level.

O2: Outlining a framework (educational project) for the achievement of integrated learning and music programming within the discipline *of music and movement* from the Romanian core curriculum for the 4th grade.

O3: Functionality testing of digital technologies as scaffolding support in cognitive processes carried out in the didactic process aimed at achieving music education.

RESEARCH METHODS

The Hypothesis of the Study

The analyzed problem raised two research questions, for which the study's hypothesis tries to anticipate possible answers. The aspects involved in the teaching-learning processes are complex and dynamic, and precisely through the prism of the dynamism of the stages and influences during a lesson, the specialized literature analyzed shows that, in the classroom, various types of support, such as the teacher, colleagues or technologies participate in this complex information processing action called learning. All these forms of support, which also include technologies leading to the same goal, have a systemic character, a character also attributed to the concept of scaffolding. Thus, these complex and dynamic aspects, which include technologies in the context of the teaching-learning process carried out for the achievement of musical education, are found at the basis of the hypothesis of the study, which we will express in the following:

By using the *Sonic Pi* application, a tool intended for playing with music composition, students can transform the playing, in a practical-applicative way, into acquisitions of music theory. This is due to the scaffolding support provided by digital technologies for learning objectives such as memorizing or understanding elements of musical notation.

The hypothesis is verified by applying Sonic Pi software in teaching practice, for which a long-lasting didactic scenario was designed. This scenario was carried out during 24 lessons of the object *Music and movement* in the 4th grade Romanian curriculum, implemented through an educational project, the characteristics and participants of which are presented in the following.

Participants and Research Design

The study tracked the extent to which a group of 4th grade students understand and remember a series of elements of musical notation used in a practical-applicative process of learning music theory. A knowledge test was conceived for this, aimed at developing musical knowledge regarding the pitch of the sounds and their duration deduced directly from the musical notation or indirectly from the tempo and the measure. These elements of musical notation are checked through 8 questions, each rated with 1 point, and the test is presented in the Appendix. The measurement tool is, at the same time, a traditional assessment test aimed, like most tests, at what the students remember (Ben-Jacob, 2017), but what differs in the learning framework outlined for this research is the memorizing process that comes at the end of practical activities that will be described in the presentation of the educational project. So, the research method is the test method, and the instrument used is the knowledge test, which was integrated within a quasi-experimental quantitative research design.

The test was applied at two different moments in time: before starting the activities with the students (pre-experimental stage) and after the designed activities had finished (post-experimental stage). It aims to evaluate the contribution of the technologies used in memorizing and understanding the symbols encountered on the musical staves at the end of a practical application process of creating some digital melodic fragments.

The integrated music-programming learning activities were carried out with 3 classes of the 4th grade from Romanian compulsory education. The sample of participants was 87 students (N = 87). They were part of the same school in an urban environment (Cluj-Napoca). In the Romanian education system, students turn 11 years old in the 4th grade. The group of 87 participants included 45 girls and 42 boys.

The collected data was processed and analyzed using the JASP statistical interpretation program (Version 0.16.3; JASP Team, 2022).

The Educational Project Is Designed for Integrated Music-Programming Learning

To have access to the sample of participants from public education, an educational project was developed in partnership with a state pre-university education institution between September 2021 and March 2022. Therefore, the partnership achieved was approved, being designed to have an impact on the educational process, in the context of the priorities set out in the European strategic documents, from the perspective of developing digital competence and achieving the objectives of the Romanian education system, from the perspective of the achievement of musical education. Thus, 24 lessons have been taught, spanned over 24 school weeks in the previously mentioned time frame. The lessons took place within the *Music and movement* object, a discipline subordinated to the Arts curriculum area and compulsory at the level of the 4th grade in the Romanian educational system.

The contents specific to music education applied in the 4th grade and processed over 24 lessons of the educational project were grouped into 12 themes: musical sound/ noise, musical notes/ MIDI notes, musical stave/ octaves, the durations of musical notes, pitch, range/ chords, the timbre of sounds, measures, intensity/ dynamics of sounds, tempo/ rhythm, arpeggio/volts and tone/ semitone/ alterations. At the end of the project, the lesson sheets used in the activities were published in Romanian.

For the operationalization of these contents, in an educational project designed for integrated music-programming learning, the *Ruby* programming language was used alongside the *Sonic Pi* application, which is an integrated development environment created by Sam Aaron, Research Associate at the University of Cambridge Computer Laboratory (Aaron, 2016). Through the *Sonic Pi* software and the lessons, they took part in, students have explored informatics concepts and interacted with the musical notation and scores of 22 songs, which they transformed into digital audio products. This way, students have corroborated conceptual knowledge with procedural knowledge in the field of music education by reproducing the melodies from the musical score of songs from children's folklore or cultural heritage, using the *Sonic Pi* applications all the time. These songs include *Bingo* (the dog), *A Ram Sam Sam* (Moroccan folk song), *Ode to Joy* (music: Ludwig van Beethoven), and other children's songs used at the national level. All this repertoire was obtained with the support of informatics in education, the students exploring, along with the pleasure offered by the musical domain, various programming structures written in the *Ruby* programming language, as seen in Figure 2.

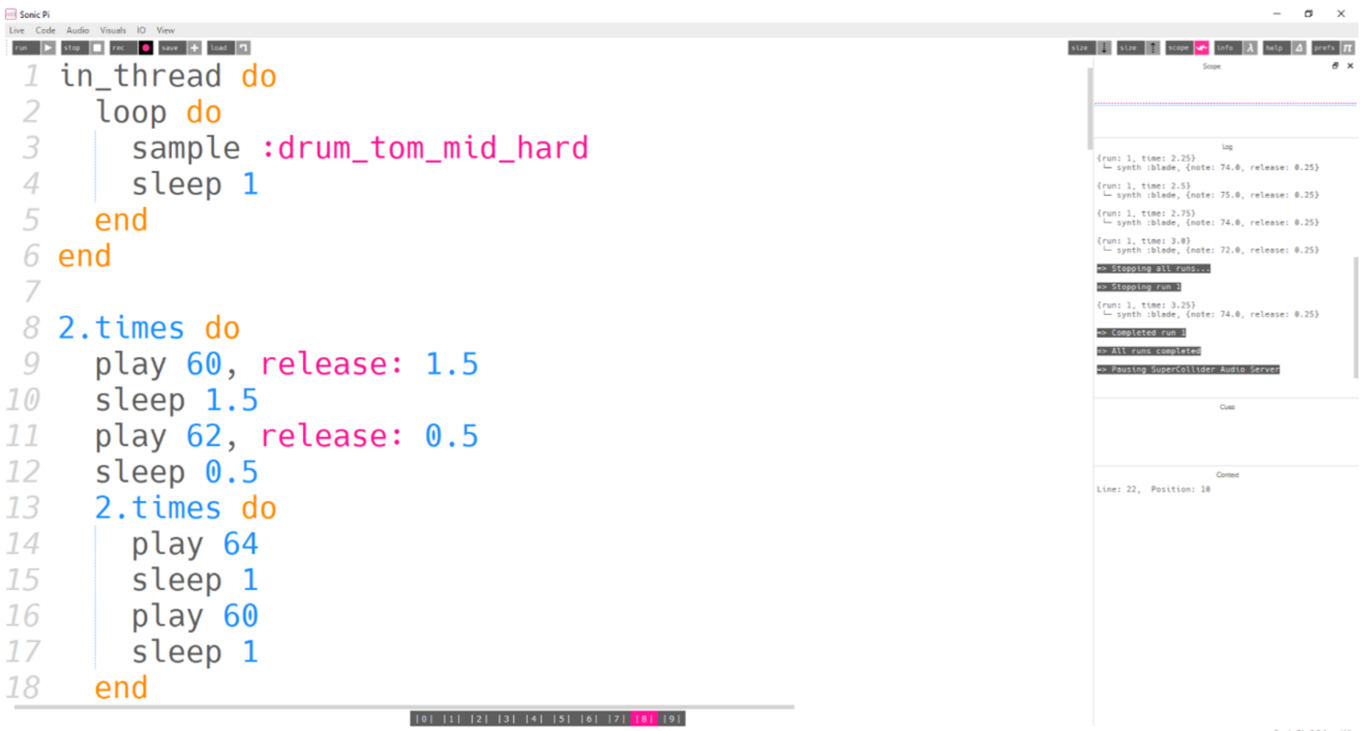

Figure 2: Sonic Pi application interface (version 3.3.1.) with an example of a melodic fragment written with *Ruby* programming language elements

In integrated music-programming learning, *Sonic Pi* has the ability to determine meaningful learning experiences. It makes the connection between two different fields, music, and programming, with the possibility of mutual support for the student's actions, improving knowledge in both domains.

RESULTS

To test the functionality and effectiveness of digital technologies as a scaffolding support in the cognitive processes involved in the realization of music education, the initial level and the level reached in terms of understanding and memorizing certain elements of musical notation were evaluated. So, the same test was applied at the beginning (pre-test) and at the end (post-test) of an educational project aimed at developing integrated music-programming learning, a project carried out over 6 months.

The digital training, dedicated to the processing of sound parameters and musical notation elements through the *Sonic Pi* application, which took place between September 2021 and March 2022, was marked by the Covid-19 pandemic, so at the date of the test, out of the total of 87 research subjects, in the pre-test stage 82 students were present at school (N_1 = 82), registering five absences, and on the date of the test application in the post-test stage, 76 students were present at school (N_2 = 76), recording 11 absences. George and Mallery (2001; as cited in Creswell, 2008) claim that if up to 15% of the data are missing, the statistical results will not be affected, and in this case, the missing data can be replaced by mean scores. In our case, the absentees from the pre-test are 6% of the subjects and 13% in the post-test, which is why an equally conservative data analysis option was chosen in terms of average scores, without including in the analysis the cases for which data are missing. These cases can be found in the Missing line in Table 1.

	Pre-test	Post-test
Valid (*N*)	82	76
Missing	5	11
Mode	3.000	6.000
Median	3.500	6.000
Mean	3.598	5.474
Std. Deviation	1.617	1.259
Minimum	1.000	2.000
Maximum	7.000	7.000

Table 1: Descriptive statistical analysis of students' pre-test and post-test results

The eight items structured in the test presented in the Appendix represent the eight tasks to be solved included in the configuration of the research tool. So, 8 points is the maximum possible score, and the best score obtained by the tested students was 7 for both stages of the test. If at the upper limit, there are no differences, at the lower limit, there is a difference, the lowest score obtained in the pre-test stage being 1, and in the post-test stage being 2, the score obtained by a single student. Regarding the limits of the scores obtained by the subjects tested in the two moments separated in time, they are slightly different. The descriptive statistics, along with the mean, the median, and the mode and the variation trend of the data, are distinct. For example, the mean of the initial test scores is 3.598 (M_1 = 3.598) with a standard deviation of 1.617 (SD_1 = 1.617), and the average of the scores obtained in the final testing is 5.474 (M_2 = 5.474) with a standard deviation of 1.259 (SD_2 = 1. 259), which is a noticeable difference.

The mean obtained in the post-test becomes a landmark in achieving the goal of analyzing the computer's efficiency for the support offered to students in understanding the symbols on the musical stave. Still, because a descriptive statistic was created in which the results describe a trend for the student's progress with a high degree of generality, the individual results of the subjects will be analyzed in more detail. For this reason, the results were placed in an extended picture like Figure 3. We will analyze these results by observing the absolute frequencies of the scores recorded in the two test stages, which suggest the training of memorization and understanding of the notations on the musical staves, decoded in a digital training process for later use in the creation of melodic fragments with the help of the *Sonic Pi* application. The results obtained in the pre-test and the post-test were compared to highlight the changes that occurred following the implementation of music education in the integrated music programming approach. Thus, the entire distribution of the scores achieved in the two stages is presented in the (a) and (b) parts of Figure 3 by dot diagrams displaying the absolute frequencies of the scores achieved, i.e., how many times a certain score was achieved in each stage.

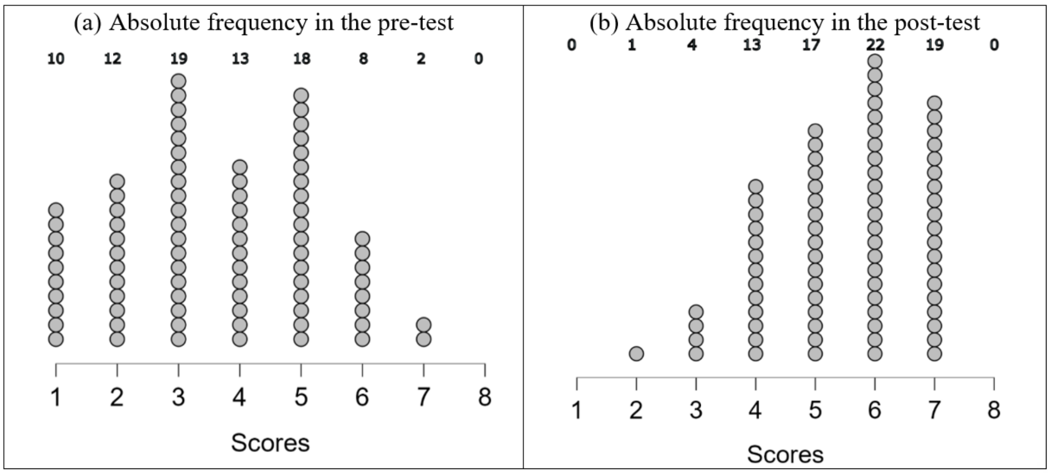

Figure 3: (a) & (b) the density of obtained scores, in absolute frequency, represented for the pre-test and post-test stages

The density of the obtained scores explains the better mean obtained in the post-test when the students' results, unlike in the pre-test stage, tend to move from the lower values of the test to the higher ones. The elements of the descriptive analysis for the two test stages show better results for the subjects in the post-test, and the comparison diagram of this evolution, related to the two means of the group scores, is presented in Figure 4.

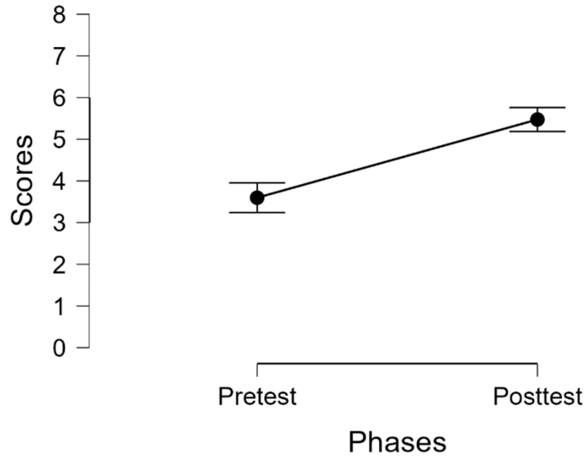

Figure 4: Comparative statistical graph of the average scores obtained during testing in the pre-test and post-test stages

The diagram synthetically shows the two levels of knowledge, initial and final, established by testing and corresponding to the mean scores obtained by students in the pre-test and post-test stages. So, the average score obtained after completing the educational project, which is supposed to be an integrated music-programming learning process, is noticeably higher than the average score obtained before the implications of the digital training process. Of interest in this situation is if there are recorded statistically significant differences between the three classes following the activities carried out on a long-term intervention. The *ANOVA* facility provided by the JASP software was used for statistical interpretation. The alternative hypothesis was formulated (H_1), assuming that there are differences between the three classes, and the null hypothesis (H_0) is the situation where there would be no differences. The significance level was set at 5% (α = .05), which allows only 5 cases out of 100 to be associated with results due to chance. The result obtained, following the analysis of variance, is presented in Table 2.

The result obtained with *ANOVA* shows a probability $p > .05$ that verifies and rejects the alternative hypothesis, which will be neglected, so the null hypothesis is accepted. However, before interpreting the *ANOVA*, the assumption that the student's scores have equal variances within the three classes should be checked first, this being the assumption of homogeneity of variance. The results of this check are presented in Table 3.

The probability value (p = .251) is non-significant, and the class variability is not statistically significantly different. This matches the assumption that the classes have homogeneous variance. Because no deviations were found, the assumption of homogeneity of variance was not violated.

Thus, following the *ANOVA* analysis, it can be stated that after the digital training period, *there are no differences between the three classes, with F(2.73) = 0.755 and p = 0.473*. Because there are no differences between the classes, so a post hoc test is unnecessary.

Following the same type of *ANOVA* analysis, for the students' scores obtained before the start of the digital training process, we notice statistical differences (p = .001) in terms of the variation of results between the 3 classes (according to Table 4), while within the classes there are no notable differences (p = .141), the homogeneity of the variations being noticed (according to Table 5).

Cases	Sum of Squares	*df*	Mean Square	*F*	*p*
Classes	2.412	2	1.206	0.755	0.473
Residuals	116.535	73	1.596		

Note. Type III Sum of Squares

Table 2: ANOVA analysis of variance between the three classes of the sample of participants relative to the data obtained in the post-test (after the digital training process)

Test for Equality of Variances (Levene's)			
F	*df1*	*df2*	*p*
1.410	2.000	73.000	0.251

Table 3: Assumption about homogeneity of variance within the three classes at the end of the digital training process

Cases	Sum of Squares	*df*	Mean Square	*F*	*p*
Clasa	32.479	2	16.239	7.157	0.001
Residuals	179.241	79	2.269		

Note. *Type III Sum of Squares*

Table 4: ANOVA analysis of variance between the three classes of the sample of participants relative to the data obtained in pre-test (before the digital training process)

Test for Equality of Variances (Levene's)			
F	*df*1	*df*2	*p*
2.007	2.000	79.000	0.141

Table 5: Assumption about homogeneity of variance within the three classes at the beginning of the digital training process

Differences between the three classes were found at the beginning of the digital training program, and a post hoc test would have been required to see where the differences came from, but this is not necessary, given the purpose of the study. Of interest are the differences at the end of the digital training program, and at that moment, there are no differences between the three classes, an aspect that falls within the study's objectives and which will be discussed in the following.

DISCUSSION

Regarding the applicability of the integrated music-programming learning in the process responsible for the achievement of musical education, the second research question (Q2) sought evidence that primary school students can convert electronic sound generation play with *Ruby* programming language and the *Sonic Pi* software into acquisitions of musical theory learning, it was found that those records are the good results obtained in the post-test stage. Due to the fact that the teaching-learning process, which spanned over 24 weeks in which the educational project took place, was based on the game of musical creation, we can consider that learning musical concepts at an elementary level can be done in an intuitive, accessible way. From the curricular perspective of achieving music education, the use of the *Sonic Pi* application, starting from 10-11 years, leads to results in direct relation to the educational requirements of the object *Music and movement*, the contents processed through the lessons' themes being those specified by the school curriculum in use (MEN, 2014).

Under the incidence of the study limits, carried out during the Covid-19 pandemic and characterized by the sporadic permutation of activities carried out from the classroom to the online space, the study provides empirical evidence on some possibilities of learning music theory, starting with primary education, in the assisted version of technology. For this and to answer the first research question (Q1), which aimed at finding out the extent to which digital technologies can provide scaffolding support in the thought processes involved in the realization of music education. Descriptive statistics were realized, and the role and effect of digital technologies on the processes of memorizing and understanding certain elements of musical notation used in obtaining digital audio products were of interest. The comparative analysis of the mean scores of the subjects at the two test moments distinct in time shows that the digital training process leads to their progress. However, an essential element of analysis is the extent to which didactic actions produce uniform learning across the entire sample of students. Conducting an *ANOVA* analysis, it was found that, at the end of the digital training period, there were no statistically significant differences between the three classes. Even if it was found that there are variations between the three classes at the beginning of the educational project, these are not of interest to us because they are the result of traditional teaching carried out up to the 4th grade. On the other hand, the lack of variations between groups identified by the *ANOVA* test at the end of the digital training period is of interest because, in conjunction with the good results obtained, allowed the verification of the hypothesis, which assumed that if the *Sonic Pi* application is used as a tool for playing with the music composition, the students can transform the playing, as practical-applicative, in acquisitions of learning music theory, a fact that is due to the scaffolding support offered by digital technologies, for learning objectives such as memorizing or understanding elements of musical notation. These are aspects of a meaningful learning experience at the end of a practical learning process.

The study leads to a larger series of findings and conclusions drawn through the lens of the hypothesis. For example, the changes brought about by technological advances occur at high speed and frequency, so that accessing memorized data is not so valuable because that data, to a large extent, is no longer relevant after a short period, which is why it is more important to support actions that require the training of higher thinking skills, such as creativity. *Sonic Pi* is also a stimulus for students' creativity and imagination, useful in scaling up cognitive processes. It has been found that, when used in the classroom, it is a support for memorizing and understanding certain elements of musical notation. Thus, the application's implications can be treated as scaffolding support because once certain learning objectives in the sphere of memorization and understanding have been achieved, the support can be withdrawn and used for another learning objective altogether, more valuable in the cognitive process hierarchy, the musical creation. This route is similar to the route of an individual studying a traditional musical instrument in real life, where the first experiences with the instrument do not lead to a harmonious processing of the sound. Yet, they are a necessary stage for memorizing and understanding some elements of musical theory. The following experiences will lead to much better sound processing and, finally, include playing a musical work without access to the musical sheet because the memorization stage has been overcome and the instrument could be used for musical performance or creation. Experiences of the same nature are also obtained through digital technologies, which is why "computer science is not primarily about computers. The famous aphorism *Computer science is no more about computers than astronomy is about telescopes*, widely attributed to Dijkstra, slightly overstates the case. Still, it has the right idea" (Jones et al., 2013: 4) because both telescopes and computers are heuristics, and the fields to which they belong do not deal with the instruments themselves but their role and applicability on the dimension of knowledge, the present study is an example of computers supporting the knowledge of music.

This means that informatics should not leave students with only assimilated knowledge and memorized information. It should also prepare them for future studies, a consideration found in the statement of Balanskat and Engelhardt (2015), which corresponds, in the context of the present study, to the concept of scaffolding. From a psycho-pedagogical perspective, the hypothesis of the study is confirmed by the fact that the scaffolding represented by digital technologies and used to achieve certain learning objectives in the field of memorization and understanding can be moved once these objectives have been achieved to support and achieve other learning objectives, such as creation. With *Sonic Pi* putting computational thinking into motion and computational thinking supporting music education learning objectives, this form of support is how technologies and informatics help stimulate thinking in the musical domain.

CONCLUSION

In an integrated approach, reciprocity is a defining characteristic. In real life, it is applied to maintain diplomatic, cultural, or other types of relations, the popular moral lesson of which has on its basis the support. In the present case, music helps the application of programming, and computer programming, in a relation of reciprocity, returns the favour in that it supports and helps students to understand music. These aspects are a conclusion of the use of the *Sonic Pi* application in didactic activities, an application that has the ability to contribute to the assimilation of new knowledge, as well as to transfer it to tasks that require a modern, playful, and different approach to learning, solving problems or creating products.

The use of digital technologies in the study of music represented a way of electronically generating sounds related to a series of their relevant parameters coded in musical symbols and to the contents of the object *Music and movement* for the 4th grade. Computer programming, as a way of generating sounds electronically, helps the meaningful processing of musical information. The classroom practice and the results obtained show that *Sonic Pi* allows students to retain and use, in an applied way, variables related to the quality of sounds (pitch, duration, etc.), as well as to understand the relationships with musical notation. The retained aspects fall under the charge of cognitive processes such as memorization or understanding, for which computer programming is supported in terms of scaffolding music theory learning. Thus, programming, as a scaffolding element, seems to support this development because it participates in the awareness of the relationship between musical notation and its sound meaning when musical language elements symbolized on the musical stave are processed. This way, the contents approached are integrated with the cognitive processes, a characteristic aspect of meaningful learning.

Sonic Pi aims to relate past learning experiences to future experiences and connections between learning outcomes specific to different domains. Thus, future studies could be continued in the musical field, with computers being only a road opener and temporary support, which resonates with the concept of scaffolding. Until the support is removed, this is a context for "the study of music experience with the support of computer technology as an active agent for the young child" (Webster, 2002: 231). By the nature of the study, ways of effectively integrating technologies into everyday teaching practice were considered. The results encourage the continuation of these efforts because, in the context of the simultaneous and interdisciplinary practice of some computer programming skills, the results can be translated into more efficient use of the teaching time and increased flexibility of interactions. These are important points in the development of future adults for a complex life in which existential problems are interdisciplinary, and the involvement of technologies in solving problems is increasingly consistent.

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APPENDIX

Knowledge test 

1. What is the syllabic name of the following musical note?

a) Do	b) Re	c) Mi	d) Fa	e) Sol	f) La	g) Si

2. The lengthening point causes the duration of the musical note to ...?

a) increase	b) decrease	c) does not change

3. Which of the following musical notes has a higher pitch?

a) La 	b) Si 

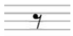
4. How many beats does the next musical note get in $\frac{2}{4}$  measure?

a) 4 beats	b) 2 beats	c) 1 beat	d) 0.5 beats	e) 0.25 beats

5. How many beats does the measure of $\frac{3}{4}$ have? 

a) 1	b) 2	c) 3	d) 4

6. Which of the following breaks has a shorter duration:

a) The quarter break 	b) Halftime break 

7. In which of the following musical measures, the duration of the musical notes is longer?

a) $\frac{2}{8}$	b) $\frac{3}{4}$	c) $\frac{4}{2}$

8. If the tempo increases, the duration of the musical notes ...

a) increases	b) decreases	c) does not change

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