TRACKING THE SPECIFICITIES OF TRANSDISCIPLINARITY IN AN EDUCATIONAL PROGRAM BASED ON INTEGRATED MUSIC-PROGRAMMING TEACHING: A LONGITUDINAL STUDY

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ABSTRACT

The objective of this study was to analyse the specificities of transdisciplinarity and to identify their presence in students' thinking by examining their reflections following a 24-lesson educational program that integrated music and programming. The opinions of 63 students, aged 10 to 11 and drawn from three successive generations of fourth-grade classes, were collected through a questionnaire. The integrated teaching approach was designed around the specificities of transdisciplinarity, such as content unification, the "cosmetic effect", knowledge fusion, and a future-oriented educational focus, these elements being consistently reflected in the students' responses over time. Based on these benchmarks, the resulting learning process can be situated both between disciplines, through the unification of content and evidence of knowledge fusion, and beyond them, as the learning activities fostered holistic development.

KEY WORDS

transdisciplinarity; computer programming; curricular integration; music technology; Sonic Pi.

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MONITORIZANDO AS ESPECIFICIDADES DA TRANSDISCIPLINARIDADE NUM PROGRAMA EDUCATIVO BASEADO NO ENSINO INTEGRADO DE MÚSICA E PROGRAMAÇÃO: UM ESTUDO LONGITUDINAL

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RESUMO

O objetivo deste estudo foi analisar as especificidades da transdisciplinaridade e identificar a sua presença no pensamento dos alunos, examinando as suas reflexões acerca de um programa educativo de 24 aulas que integrou música e programação. As opiniões de 63 alunos, com idades compreendidas entre os 10 e os 11 anos e provenientes de três turmas sucessivas do quarto ano, foram recolhidas através de um questionário. A abordagem de ensino integrado foi concebida em torno das especificidades da transdisciplinaridade, como a unificação de conteúdos, o "efeito cosmético", a fusão de conhecimentos e um foco educativo orientado para o futuro, elementos que se refletiram de forma consistente nas respostas dos alunos ao longo do tempo. Com base nestes parâmetros, o processo de aprendizagem resultante pode ser situado tanto entre disciplinas, através da unificação de conteúdos e evidências de fusão de conhecimentos, como para além delas, uma vez que as atividades de aprendizagem promoveram o desenvolvimento holístico.

PALAVRAS-CHAVE

transdisciplinaridade; programação; integração curricular; tecnologia musical; Sonic Pi.

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Monitoreo de las Especificidades de la Transdisciplinariedad en un Programa Educativo Basado en la Enseñanza Integrada de Música y Programación: Un Estudio Longitudinal

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RESUMEN

El objetivo de este estudio fue analizar las especificidades de la transdisciplinariedad e identificar su presencia en el pensamiento del alumnado, examinando sus reflexiones sobre un programa educativo de 24 lecciones que integraba música y programación. Se recogieron las opiniones de 63 alumnos, de entre 10 y 11 años, de tres clases sucesivas de cuarto grado, mediante un cuestionario. El enfoque de enseñanza integrada se diseñó en torno a las especificidades de la transdisciplinariedad, como la unificación de contenidos, el "efecto cosmético", la fusión de conocimientos y un enfoque educativo orientado al futuro; elementos que se reflejaron consistentemente en las respuestas del alumnado a lo largo del tiempo. Con base en estos parámetros, el proceso de aprendizaje resultante puede situarse tanto entre asignaturas, mediante la unificación de contenidos y la evidencia de la fusión de conocimientos, como más allá de ellas, ya que las actividades de aprendizaje promovieron el desarrollo holístico.

PALABRAS CLAVE

transdisciplinariedad; programación; integración curricular; tecnología musical; Sonic Pi.

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Tracking the Specificities of Transdisciplinarity in an Educational Program Based on Integrated Music-Programming Teaching: A Longitudinal Study

Marius Bănuț [1]

INTRODUCTION

In modern conceptions of the instructional process, a key question arises: can learning be facilitated beyond the models and examples provided by textbooks, in order to make the taught discipline more functional and relevant to students' needs? This includes applying knowledge in learning situations created by other disciplines or in real-life contexts: at home, in society, or even in the context of future employment, this question becoming even more pressing given the often-stark contrast between formal schooling and the realities of children's lives (Burnard et al., 2021). In this context, it becomes essential to identify actionable strategies for monodisciplinary trained teachers, that should enable the transfer and connection of the taught subject to real-world situations, while also opening the possibility for a transdisciplinary expansion of the taught field.

For such a sustainable development within the educational landscape, this study aims to review the existing literature regarding the defining characteristics of transdisciplinarity and account these abstract theoretical principles into a concise framework of indicators that can be operationalized as measurable variables within the teaching process. By converting complex transdisciplinary theory into quantifiable metrics, it could allow us to assess the depth of integrated learning more effectively. As a follow up to the literature review, the empirical stage will be sought to identify in students' thinking the presence of transdisciplinarity specificities by examining their reflections following a 24-lesson educational program that integrated music and programming, and which allowed the establishment of permanent connections between these two domains. In order to support teachers in designing similar cross-curricular initiatives or help them with insights about the design and the subject matter, we provide a detailed structural overview of our unified curriculum, highlighting the way some specific content from music and programming can be synthesized. Through a questionnaire meticulously constructed upon the established theoretical frameworks of transdisciplinarity and aligned to five principles deduced from the previously conducted literature review, the opinions of 63 fourth grade students, and drawn from three successive generations, were collected. The significance of this study is positioned on different levels. On a micro-scale, we evaluate the efficacy of our specific music-programming model to determine if transdisciplinary principles are successfully embedded in the learning process. On a macro-scale, we argue that once the transdisciplinarity specificities have been identified, they can be used as evaluative framework for the existing educational programs and as elements of a strategic guide for the orientation of future curricula in an increasingly complex and interconnected society.

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The itinerary of this article will start with the theoretical background of the topic, afterwards it will outline the methodology for the longitudinal study, presenting even the content of the intervention for responding, also, to some didactic interests. After presenting the results of the investigation, the article will conclude with discussion and final conclusions.

THEORETICAL BACKGROUND

Since 1985, when Nicolescu (2014) suggested the use of the term "transdisciplinarity" to mean "beyond disciplines", a substantial body of scientific literature has emerged on the topic, but this literature lacks a unitary, one-dimensional conceptual framework (van Baalen et al., 2021). Therefore, in the following section, we aim to outline a series of specificities that define transdisciplinarity.

Avoiding monodisciplinary approaches is a key strategy in creating effective learning environments, and in Switzerland (Klein, 2004), for example, primary schools have a long-standing tradition of transdisciplinary learning, particularly in the study of environmental science. Transdisciplinarity, because it has no borders (Nicolescu, 2014), seeks to disrupt the conventional learning context of a subject, offering newer, broader, and more accurate perspectives on the same phenomenon through extra ways of learning (Burnard et al., 2021). For a specific example, the musical field offers a feasible context for deploying the educational process beyond the boundaries of the discipline, because it offers a universal language capable not only of stimulating and involving the student in his own emotional and social development, but also of cognitive development, in relation to a wide range of disciplines, including mathematics and languages (Di Paolo & Todino, 2025). Because it operates without strict disciplinary borders, transdisciplinarity allows the unification of content, and this is the first outlined specificity of transdisciplinarity.

Students tend to evaluate educational content through three main lenses: interesting vs. boring, necessary vs. unnecessary, and easy vs. difficult (Váradi, 2018). A monodisciplinary approach has difficulties addressing and covering all these dimensions effectively, while a transdisciplinary approach brings together complementary forces that can positively influence each of these aspects. For example, when a subject integrates content from a preferred curricular area with another that is typically less favoured, the latter may become more acceptable due to what we refer to as the "cosmetic effect", understood as a positive influence of the student's existing interest in the more appealing subject. This effect can motivate students who are passionate about one subject to engage more willingly with others (Bell & Bell, 2018), because transversality and transdisciplinarity (Guzmán-Valeta et al., 2024) foster qualities such as empathy and creativity, traits that transcend disciplinary boundaries (Burnard et al., 2021), and in such enriched learning environments, high levels of student engagement have been observed (Gold et al., 2022). On a specific case, where the students were involved in learning music and programming under an inductive strategy of teaching (Bănuț & Albulescu, 2024), their academic performances were noted, in the context of a reduced effort. One explanation is that the students became interested in the creative activity of music making, evoking student-centred design principle (Treß, 2024), primarily for its immediate, appealing "cosmetic effect". We therefore add a second defining feature to the list of transdisciplinarity's specificities: the "cosmetic effect", which emerges as a derivative of unified content.

In a study conducted during a summer school program using the Sonic Pi app (Burnard et al., 2016), the “cosmetic effect” extended beyond the boundaries of two academic subjects, showing that the enjoyment of participating in a transdisciplinary creative activity significantly boosted students’ confidence in learning music, computing, mathematics, and in their overall understanding of these subjects. This supports the view that transdisciplinarity has become an essential way of thinking and acting in education (Klein, 2004). This is a natural development, as the “surplus of meaning” (Burnard et al., 2021) generated by unified content aligns more effectively with diverse learning conditions and caters to a wider range of cognitive styles (Borzea, 2017), and in such conditions, transdisciplinary approaches act as facilitators, helping children engage more easily in the process of understanding the world (Burnard et al., 2021). By contributing to the meaning construction of the educational message, we add a third defining feature to the list of transdisciplinarity’s specificities: the facilitation of understanding.

Understanding reality is a core objective of transdisciplinarity, with the “unity of knowledge” serving as a guiding imperative (Nicolescu, 2014). In a study (Burnard et al., 2016) where students engaged in musical composition and expression, linked to mathematics through the digital creation of audio materials using programming, it was observed that this approach enabled students to connect a wide range of subjects seamlessly, often in a way that students didn't even realize they were learning such cross-disciplinary concepts. In transdisciplinary approaches to knowledge, learning objectives can appear counterintuitive (van Baalen et al., 2021), as they stimulate diverse forms of logic and reasoning, as Burnard et al. (2021) noted on these aspects following the connection of arts and sciences. For example, music maker education promotes an unfragmented learning through its interdisciplinary links (Treß, 2024), and digital technologies improve more the learning experience in music education not only under normal teaching conditions, but also under emergency conditions, such as the Covid-19 pandemic (Ma & Wang, 2025). Teachers must adopt divergent thinking and guide students toward unfragmented learning, if we consider that. Their role is to help students perceive the deep connections underlying varied content, even at the most complex levels of integration. In this regard, Borzea (2017) claims that true transdisciplinary integration is achieved when knowledge fusion occurs, the fusion of knowledge representing another key specificity of transdisciplinarity.

In today’s digitally interconnected world, the fusion of knowledge through education has become increasingly important. Consider the Internet of Things (IoT), which links various digital devices to deliver services, often in automated ways. In such a context, societal challenges are growing in complexity and reflect the ancient principle of universal interdependence: everything is connected (Nicolescu, 2014). These challenges don’t belong to specific sectors or disciplines, nor are they easily predictable (Klein, 2004), and such interrelated issues in the extracurricular space are a plea and a strong case for transdisciplinary approaches within the school environment. This is precisely why an integrated curriculum should aim not only at knowledge acquisition but also at fostering learning in environments that can meaningfully impact students’ future (Burnard et al., 2021), by aligning instruction with the specificities of transdisciplinarity, such a curriculum connects learning to real-world contexts, focuses on shared societal issues in a way that reflects the kinds of problems people face (Borzea, 2017) in relation to the science–technology–society triad (Nicolescu, 2014).

Transdisciplinarity considers the understanding of reality through the knowledge and practices that shape how people think and act in everyday life, emphasizing the need to anchor teaching and learning in the complexity and authenticity of real-world experiences (Lenoir & Hasni, 2016) by increasing the border points of connection between different fields of knowledge (van Baalen et al., 2021). As such, grounding the

learning process in real-life contexts and orienting it toward the future are, also, specificities of a transdisciplinary approach. Studying in a transdisciplinary way involves uncovering interrelated and interdependent knowledge, where learning begins with students' own questions and concerns, and its continuity relies on ensuring that the skills developed in school are transferable to future real-life situations (Borzea, 2017). Integrating the arts at a transdisciplinary level can also reflect broader societal, economic, and cultural implications (Burnard et al., 2021), offering valuable lessons that prepare students for the future (Gold et al., 2022), as in the case of integration with computer science education, where arts and programming are seen as associations that allow cultivating transversal abilities, like computational thinking (Roberts & Horn, 2025).

In summary, and without claiming to be exhaustive, the following specificities of transdisciplinarity have been identified: the unification of content, the "cosmetic effect", the facilitation of understanding, the fusion of knowledge, and the future of students, the latter including, in a broad sense, school orientation, and the focus on solving real-life, common problems. For ease of reference, we will refer to these as the 5 Key Specificities of Transdisciplinarity (5KSoT).

PURPOSE OF THE RESEARCH

To identify meaningful learning contexts, this research aimed to analyse the specificities of the highest level of curricular integration (transdisciplinary integration) and to determine whether these specificities could be observed in students' thinking. This was done by longitudinally examining their reflections following participation in an instructional program designed to create connections between music and programming.

Music has the potential to be a switch or a central element in the interdisciplinary dialogue (Di Paolo & Todino, 2025), but in relation with computer programming a link is created, which is useful for a landscape that needs to highlight the existing bidirectional influences (Roberts & Horn, 2025) and a transdisciplinary approach of teaching could activate information exchange. From a pedagogical perspective, scientific literature notes that traditional teaching of music, that relies on consumer technologies, could deviate from the educational goals (Treß, 2024), that include, among others, music improvisation and creativity expression. Moreover, studies are focused on short-term usage and impact of technology in music education (Ma & Wang, 2025), and this longitudinal study relates to such issues from the transdisciplinarity perspective.

RESEARCH QUESTIONS

RQ1: To what extent are the 5 Key Specificities of Transdisciplinarity (5KSoT) reflected in the thinking of students who participated in an educational program designed according to these principles?

RQ2: Can it be claimed that a fusion of knowledge has been achieved between the integrated subject areas, and if so, what evidence from students' feedback supports this claim?

MATERIALS AND METHODS

THE DESIGN OF THE INTEGRATED APPROACH TO TEACHING MUSIC AND PROGRAMMING, ACCORDING TO THE 5KSOT

As there is a need to rethink the application of music and digital technologies in schools, from teachers to researcher's opinions, it is necessary to develop new approaches that stimulate new forms of thinking (Ludovico & Mangione, 2015). One such approach is the use of the Sonic Pi app (Aaron et al., 2016), which offers a unique musical experience while fostering creativity through programming activities. By blending sound and code, Sonic Pi allows students to explore complex concepts in a playful and engaging way. It does not compromise the joys of childhood in favour of future career preparation; rather, it enables students to interact with the same rigorous ideas that adults engage with, ideas that can later be integrated into more advanced educational and professional pathways. This way, the activities built around Sonic Pi are inherently future-oriented, aligning them with the key specificities of transdisciplinarity and grounding the teaching in its principles.

The resulting educational product serves as a source of knowledge that both complements and exceeds beyond the boundaries of traditional music education materials, by unifying content from music and computer science. This reflects another key specificity of transdisciplinarity (content unification) highlighted through the 12 thematic units that structured the 24-lesson teaching process. Importantly, transdisciplinarity does not exclude disciplinary thinking (Burnard et al., 2021), and in this regard, the program identified a series of discussion topics that could be incorporated into the curriculum to make programming more accessible to students, with music acting as a "cosmetic effect" that enhances engagement with programming. The educational pathway was planned to integrate these elements both vertically (across the curriculum) and horizontally (within each lesson), and its structure is presented in Table 1.

Table 1
The structure of the educational program with unified contents (music-programming)

Lessons	Topics specific to music education	Programming concepts	Implications of unified contents in relation to the goal of knowledge fusion
1, 2	Musical sound or noise	Integrated Development Environment (IDE)	Students will be introduced to the Sonic Pi application and will generate their first sounds, while learning that the application they are using to write and edit code is an Integrated Development Environment (IDE).
3, 4	Musical notes, MIDI notes, Notation systems	Instructions	Students will learn musical notes across various notation systems, with the understanding that generating a musical note through programming is essentially giving an instruction to the computer.
5, 6	Stave, SOL key, Octaves	Sequential structures	On the musical stave, students will identify a sequence of musical notes. The corresponding code, which plays these notes in the same order as they appear on the stave, follows a sequential structure, executing instructions exactly in the order they are written.

Lessons	Topics specific to music education	Programming concepts	Implications of unified contents in relation to the goal of knowledge fusion
7, 8	The duration of a musical note, Break, Musical note values	Repetitive structures	Many songs include notes of equal duration or repeated musical phrases. The code structure that enables a musical note to be repeated multiple times, while maintaining the same sound parameters, by writing the instruction only once, is known as a repetitive structure.
9, 10	The pitch of musical notes, Tonality, Registers: low, medium, high	Alternative structures	Alternative structures can control the pitch of sounds based on specific conditions. For example, a repeating melodic fragment might end with an ascending pitch on the first repetition and a descending pitch on the second. This conditional variation is an example of an alternative (or conditional) structure in programming.
11, 12	Chords, Range, Orchestra	Threads	Threads allow multiple sounds to be produced simultaneously (much like in an orchestra) enhancing the process of musical creation.
13, 14	Instrumental timbre, Synthesizers, Effects: echo and reverb	Inheritance	Multiple musical sounds can be assigned to the timbral characteristics of different instruments. In programming, this behaviour is described by the concept of inheritance, where certain properties, such as sound attributes, can be passed down or shared across different elements.
15, 16	Measures Rehearsal mark	Procedures, Functions	Measures provide a framework for organizing sounds within a song. In programming, when a sequence of code is used to reproduce a specific musical phrase and is given a name, it becomes a function. This function encapsulates the procedure that organizes the sounds associated with that musical phrase.
17, 18	Intensity, Amplitude of a musical note, Dynamics (shades)	Parameters, Variable	Intensity is a parameter of sound. In programming, variables, which are memory spaces used to temporarily store data under a user-defined name, can hold parameters that change during program execution. The intensity of sound is one such parameter that can be stored and modified using variables.
19, 20	Number of beats, Tempo Rhythm	Recursion	Tempo refers to the breakdown of a musical piece into beats per minute, helping to determine the duration of each sound and ultimately influencing the speed at which the entire piece of music is performed. In programming, a similar concept is found in recursion, which involves breaking down a complex problem into smaller, more manageable parts. These fragments are solved individually, and once resolved, they collectively lead to the solution of the original problem.
21, 22	Verse, Refrain Arpeggios	Data Structures, Algorithms	Verses and choruses often contain repeating musical patterns, which can be stored using list data structures. These lists can then serve as input for algorithms that perform various operations, enabling the generation of a wide range of musical outcomes.

Lessons	Topics specific to music education	Programming concepts	Implications of unified contents in relation to the goal of knowledge fusion
23, 24	Melody Alterations: sharp, flat and beaker, Ranges: ton-semitone	Debugging	Using Sonic Pi and the Ruby programming language, students create not only a song but also a musical program. Within the song, certain sounds can be slightly modified through alterations, which adjust the pitch by a semitone. In the music program, however, changes to the code can lead to execution errors, requiring debugging to identify and fix the issues.

This instructional approach introduces a solid pedagogical model, shaping a curriculum that continuously connects new content with previously taught material, emphasizing the practical development of skills through the use of computer programming for educational purposes. By integrating computer science into music classes, students have the opportunity to deal with a specific programming language (*Ruby*), analyse code, and use it to improvise their own songs or reproduce pieces from cultural heritage, referencing to their musical scores, these allowing students to identify fundamental programming structures and concepts. A well-known example is the popular Moroccan-origin song *A Ram Sam Sam*, which can be used to demonstrate how a melodic line is written using *Ruby* and the *Sonic Pi* digital instruments (Bănuț, 2022):

```
define :a_ram_sam_sam do
  play 60
  wait 1
  3.times do
    play 65
    wait 1
  end
end

define :guli_guli_1 do
  play 64, release: 0.5
  wait 0.5
  play 65, release: 0.5
  wait 0.5
  6.times do
    play 67, release: 0.5
    wait 0.5
  end
  play 65, release: 0.5
  wait 0.5
  play 67, release: 0.5
  wait 0.5
  play 69
  wait 1
  play 65
  wait 1
  play 65
  wait 1
end

define :a_ra_fig do
  play 72
  wait 1
  play 72, release: 2
  wait 2
  play 69
  wait 1
end

define :guli_guli_2 do
  play 67, release: 0.5
  wait 0.5
  play 69, release: 0.5
  wait 0.5
  6.times do
    play 71, release: 0.5
    wait 0.5
  end
  play 69, release: 0.5
  wait 0.5
  play 71, release: 0.5
  wait 0.5
  play 72
  wait 1
  play 69
  wait 1
  play 69
  wait 1
end

define :moroccan_song do
  a_ram_sam_sam
  a_ram_sam_sam
  guli_guli_1
  a_ram_sam_sam
  a_ram_sam_sam
  guli_guli_1
  a_ra_fig
  a_ra_fig
  guli_guli_2
  a_ra_fig
  a_ra_fig
  guli_guli_2
end

use_bpm 80
moroccan_song
use_bpm 120
moroccan_song
use_bpm 160
moroccan_song
use_bpm 200
moroccan_song
use_bpm 240
moroccan_song
```

This song can be performed in three different ways, each demonstrating distinct programming concepts. Analysing the code used in each version helps identify and understand these underlying concepts:

Sequential structure

```
74  use_bpm 80
75  moroccan_song
76  use_bpm 120
77  moroccan_song
78  use_bpm 160
79  moroccan_song
80  use_bpm 200
81  moroccan_song
82  use_bpm 240
83  moroccan_song
```

Repetitive structure and a variable

```
74  my_tempo = 80
75
76  5.times do
77    use_bpm my_tempo
78    moroccan_song
79    my_tempo = my_tempo + 40
80  end
```

Alternative structure and two variables

```
74  reps = 1
75  my_tempo = 80
76  use_bpm my_tempo
77
78  5.times do
79    if reps <=1
80      moroccan_song
81    else
82      use_bpm my_tempo
83      moroccan_song
84    end
85    my_tempo = my_tempo + 40
86    reps = reps + 1
87  end
```

The instructional delivery of the 24-lesson curriculum was managed by the researcher, who served as the substitute instructor for the duration of the subject's implementation, replacing, temporarily, the role of the generalist primary school teachers typically assigned to the respective classrooms across the three-year implementation period of the educational program. The delivery of the music-programming content coincided with the duration of the COVID-19 pandemic, necessitating adaptive instructional modalities: (1) Year 1 (2020–2021) - Instruction was delivered exclusively via remote synchronous learning activities, lessons being conducted through the Google Meet platform, with the researcher and students connected online. Student participation was classified as either fully remote, fully in classroom or hybrid, where some students connected individually from home while others participated from the classroom using the existing technology infrastructure (videoprojector and the primary school teacher's institutional account); (2) Year 2 (2021–2022) - The teaching modality remained predominantly remote synchronous for 23 lessons. One lesson, however, was conducted in-person within the classroom environment due to the relaxation of pandemic-related restrictions; (3) Year 3 (2022–2023) - All 24 instructional sessions were conducted in-person, with both the researcher and students present in the classroom.

The educational program was formalized and implemented under a project approved locally by the County School Inspectorate. The coordinating institution for the project was the pre-university school, with the researcher holding the primary responsibility for the instructional design and delivery. To ensure adherence to ethical standards attention was paid to informed consent, equitable access and data privacy. Parental consent was secured via the coordinating pre-university school through the respective primary school teachers. The consent acquisition timeline ranged from two weeks to three months prior to the beginning of the first lesson, varying by implementation year. The pre-university school ensured equitable access to the program by providing each student with an institutional Google account, facilitating uniform participation in the remote and hybrid instructional sessions. The researcher guaranteed the protection of student privacy rights by employing data segregation techniques, ensuring the secure storage of research data, and implementing the removal of all personally identifying information prior to data analysis and presentation.

SAMPLE OF PARTICIPANTS

The sample of participants selected to follow the program, designed according to the principles of transdisciplinarity, was drawn from the fourth-grade student population in an urban area of Romania. The study included 63 students (N = 63), aged 10 to 11 years, comprising 24 girls and 39 boys, and was conducted over three academic years, from 2020 to 2023. Specifically, 15 students participated during the 2020–2021 school year, 27 students in 2021–2022, and 21 students in 2022–2023.

RESEARCH INSTRUMENT

A thorough search across major academic and educational databases confirms that no existing, validated instrument currently evaluates or captures the specificities of transdisciplinarity that can be applied to the design and implementation of an educational program.

For the purposes of this exploratory research, a custom instrument (opinions gathered through a questionnaire) was developed to capture participants' perspectives on the 5KSoT elements of the program they followed. Since, for variety, the use of different types of closed-ended items is practiced (Creswell, 2008; Gold et al., 2022), and to ensure variety and depth in the responses, the questionnaire included both dichotomous (yes/no) questions and multiple-choice items.

The validity of the instrument, in the sense that the questionnaire items can provide information regarding the evaluated variables (specificities) was approached in two stages. Firstly, the foundation of this instrument is meticulously constructed upon the established theoretical frameworks of transdisciplinarity, aligned to the five principles deduced from the literature review previously conducted. The five principles (5KSoT) helped us to operationalize the complex concept of transdisciplinarity, and the instrument's structure, presented along the results of this study, reflects this precise, theory-driven delineation. Each aspect of transdisciplinarity identified in the reviewed literature was addressed through one or two questions, related even to the context of online activities, as part of the research coincided with the educational constraints imposed by the Covid-19 pandemic. Secondly, the content validation was passed through review with scholars that have recognized expertise in educational science, disagreements being resolved through discussion.

ANALYSIS OF THE COLLECTED DATA

Since the research was conducted between 2020 and 2023, a period significantly impacted by the Covid-19 pandemic, it was challenging to achieve a high response rate, which is why a longitudinal study design of the trend studies type was used. This type of study examines changes over time within a population (Creswell, 2008), and the present research aimed to identify and describe trends in students' thinking regarding the 5KSoT components of the educational program they experienced.

Students' opinions were collected longitudinally over three academic years and analysed using JASP statistical software, version 0.19 (JASP Team, 2025). The analysis focused on identifying students' relative perceptions of the integrated music-programming teaching approach, using descriptive statistics that accounted for the 5KSoT components. The results generated by JASP were organized and presented in a table using Office tools.

To confirm the presence of transdisciplinary elements in the integrated music-programming approach, a fixed evaluation criterion was applied, whereby a minimum acceptable threshold was established: at least 75% of total responses needed to be favourable for a given item to be considered as confirming the presence of a followed specificity of transdisciplinary.

RESULTS

Since no existing research was found that specifically monitors the 5KSoT within the teaching process, no correspondent instrument was available to suit the novelty of this study, which is why adapted questions were developed based on the 5KSoT elements identified in the reviewed literature. A total of 10 items were designed to target these specificities, and Table 2 presents these transdisciplinary specificities, along with the corresponding results, either confirmatory (indicating a favourable response for the associated specificity) or contradictory (indicating an unfavourable response for the associated specificity), for each question across the three academic years during which the three student cohorts were surveyed.

Table 2

The percentage distribution, over three years of schooling, of students' perceptions over their experience in an educational program with transdisciplinarity specificities (n=63)

Item	Specificity	Answer	2020/ 2021	2021/ 2022	2022/ 2023	Total
1. Do practical examples help me in learning? (example: music helps me in learning programming or vice versa, programming helps me in learning music)	Unified content	Confirmatory	87%	85%	90%	87%
		Contradictory	13%	15%	10%	13%
2. Have you learned new things through these music and programming lessons?	Unified content	Confirmatory	73%	81%	100%	85%
		Contradictory	27%	19%	0%	15%
3. What did you like most about the new format of the Music and Movement classes?	"Cosmetic effect"	Confirmatory	93%	78%	95%	89%
		Contradictory	7%	22%	5%	11%
4. Did you find it difficult to understand the combined information: music and programming?	Understanding	Confirmatory	33%	74%	100%	69%
		Contradictory	67%	26%	0%	31%

Item	Specificity	Answer	2020/ 2021	2021/ 2022	2022/ 2023	Total
5. As for the Music and Movement classes, do you think that taking them online would affect you?	Understanding	Confirmatory	60%	70%	48%	59%
		Contradictory	40%	30%	52%	41%
6. Regarding the new content, parents know programming to support you with some information that helps you in learning?	Understanding	Confirmatory	20%	41%	67%	43%
		Contradictory	80%	59%	23%	57%
7. Do you think that you have improved your personal knowledge through the new format of Music and Movement classes?	Fusion of knowledge	Confirmatory	73%	81%	100%	85%
		Contradictory	27%	19%	0%	15%
8. Based on your new experience of studying music, what do you think you can do better?	Fusion of knowledge	Confirmatory	47%	52%	76%	58%
		Contradictory	53%	48%	27%	42%
9. Do you find useful the information received through these lessons, for the digitized life we live?	The students' future	Confirmatory	67%	74%	90%	77%
		Contradictory	33%	26%	10%	23%
10. Which of the areas do you want to improve your knowledge in the future?	The students' future	Confirmatory	60%	70%	95%	75%
		Contradictory	40%	30%	5%	25%

For example, the first transdisciplinary specificity addressed was the unified content, and according to *Item 1* in Table 2, its relevance is consistently reflected across all three student cohorts, with unanimous "Yes" responses, the lowest percentage recorded being 85%.

The effectiveness of practical examples in supporting student learning was assessed through *Item 2*. The students' responses confirmed the relevance of unified content, with 73% of participants from the 2020–2021 school year responding affirmatively, 81% from the 2021–2022 school year, and 100% from the final year of the project.

Beyond the relevance of content unification, the literature (Burnard et al., 2016; Treß, 2024) suggests the premise for obtaining an appealing effect referred to as "cosmetic effect" (a synergistic enhancement) between unified content areas, an aspect that was explored through *Item 3*. The educational program was implemented within the *Music and Movement* discipline, and students appreciated most the audio creations they produced. Since all audio outputs were generated through programming using the Sonic Pi application, and students enjoyed the process of creating them, it can be argued that music exerts a "cosmetic effect" on programming, which even if it falls into the category of the more difficult subjects to digest, can thus be accepted more easily. *Item 4* aimed to assess whether this "cosmetic effect" at the content level facilitated understanding. The results show a shift over time in students' responses, where there is no longer a trend, the result being initially inconsistent. In the first cohort, only 33% reported understanding the unified content without

difficulty, compared to 74% in the second year and 100% in the final year. This progression may be explained by the format of instruction: the first two years were conducted online due to Covid-19 restrictions, while the 2022–2023 school year was held entirely in person. It appears that in-person instruction offers a more effective educational experience, even if students did not perceive online learning as a major drawback. According to responses to *Item 5*, 59% stated that they would not be negatively affected by online classes.

Since a single factor is insufficient to draw definitive conclusions, given the complexity of the educational process, which involves multiple contributing elements such as identifying students' zones of actual development, their motivation, and support from more experienced individuals, these aspects were analysed from an additional perspective. To explore the correlation between adult support and students' understanding of new content, *Item 6* was introduced. Overall, only 43% of parents had the necessary knowledge to provide effective learning support, and this suggests that when students have greater access to support at home, their comprehension of the content improves (as reflected in *Item 4*). Therefore, understanding educational content is not an exclusive specificity of transdisciplinarity. It results from a combination of factors, including the format in which lessons are delivered and temporary support from adults. Nevertheless, the fact that 100% of students in one cohort responded favourably to *Item 4*, indicating full comprehension of content designed according to transdisciplinary principles, is a noteworthy outcome that should not be neglected.

In relation to content understanding, aspects concerning the fusion of knowledge, another specificity of transdisciplinarity, were examined through *Item 7*. Students were given the option to choose whether they found the knowledge specific to music, programming, both, or neither to be valuable, and the majority selected both. These responses align with the principles of transdisciplinarity, indicating that the educational program successfully avoided drawing boundaries between the two fields, their integration being a productive one. Even the fact that some students reported improving their knowledge specifically in music, while others noted gains in programming, reinforces this idea. If strict boundaries had existed between the disciplines, students' responses would likely have clustered around a single domain, but the diversity of responses suggests that the program encouraged a flexible and interconnected learning experience.

These findings are further supported by the responses to *Item 8*. In primary education, vocal performance is typically the main activity associated with music (Váradi, 2018). Regarding this, and as a result of the integrated teaching approach, only a quarter of the students believed they had improved their singing abilities. In contrast, 58% felt they had become better at composing music or at both singing and composing, while the remaining 16% identified improvements in other skills, this shift suggesting that the integrated program encouraged broader musical development beyond traditional vocal practice.

A final transdisciplinary specificity addressed in this study is the anchoring of the educational process in real-life contexts and its orientation toward students' future, aspects that were examined through two questions, the first being *Item 9*. According to the results, the majority of respondents (78%) believe that the educational program they participated in has the potential to provide them with the necessary skills and knowledge to solve real-world problems.

To explore students' educational future, *Item 10* examined their interest in continuing along learning paths aligned with the current integrated approach. Notably, 75% of respondents expressed that they are not satisfied with their current level of

knowledge in the two integrated fields and showed a desire to further develop their skills. This indicates that the educational program reflects this final transdisciplinary specificity, anchoring learning in real-life contexts and orienting it towards future personal and professional growth.

DISCUSSION AND CONCLUSIONS

This paper aimed to highlight a series of transdisciplinary specificities that can be leveraged as key attributes in creating an effective learning environment, where the fields of study are seamlessly interconnected. These insights provide a foundation for drawing conclusions about the implementation and impact of integrated teaching at the highest possible level.

In this study, specific content from music education and computer programming was structured in an integrated manner, one of the key transdisciplinary specificities explored being "cosmetic effect", the idea that combining content from different fields can enhance the engagement. There are many programming courses, but the usual teaching of algorithms does not make them very accessible for anyone to learn, even more it is not appealing or engaging. However, by integrating music into the learning process and using tools like Sonic Pi, programming becomes more engaging and enjoyable, because music is a creative field that has a playful influence in motivating students to learn and supporting the development of their digital competence. This integrated approach aims to produce a "cosmetic effect" whereby students who may not initially enjoy programming but have a passion for music can discover the joy of coding through musical creation, or vice versa.

The soul is a human dimension often ignored in learning, which is typically seen as an individual cognitive effort, but the integrated music-programming approach, by acknowledging this human dimension, can be framed within a holistic model of learning. To support such learning, regardless of whether a person processes information more effectively through visual (iconic) or auditory means, this type of integrated approach addresses both, incorporating visual elements (coding) and auditory elements (music), while also opening possibilities to engaging all human dimensions: the mind, the body, and the spirit. Learning and creating music trough programming aligns with the idea that maker music education is a multimodal practice (Treß, 2024), where visual and auditory elements overlap.

The responses collected through the questionnaire also allow us to address the first research question (RQ1). From the analysis of the collected data, only the facilitation of the understanding of the contents could not be recorded as an exclusive result of the new learning conditions, this being, in fact, a product of *n* factors determined by the learning conditions. However, several transdisciplinary specificities, such as content unification, the "cosmetic effect", knowledge fusion, and future-oriented teaching, were clearly identified in students' feedback on the integrated music-programming educational program, each with a favourable response rate exceeding 75%. An educational process that incorporates these specificities operates both between and beyond disciplines. In this case, it is placed between disciplines, because the contents have been unified and indications regarding the fusion of knowledge have been identified. These findings align with previous research (Bănuț & Albulescu, 2024), which concluded that an inductive pedagogical strategy in the interconnected fields of music and programming fosters a synergy of knowledge

(fusion of knowledge), this integration ultimately enabling students to execute practical tasks with high levels of proficiency in evaluative settings. Such an integrations is also placed beyond disciplines, because the learning activities carried out are heavy learning activities that deserve to be put in the forefront of the didactic projection, because they are part of a holistic learning in which the development of students from multiple perspectives is facilitated in close relation to human dimensions: mind (understanding computer principles, codes), body (movement on self-composed melodies) and soul (creating enjoyable digital audio products). The pleasure derived from this process stems from the "cosmetic effect" of integrating music with other subjects, an effect that can be subordinated to transdisciplinarity, that places the didactic act beyond disciplines. Similarly, the program's orientation toward students' future reinforces this transdisciplinary nature, as founded in the present study and providing added value to the educational process in the context in which it is argued that enhancing educational effectiveness is anchored in the correlation of learning activities with professional ones (Ma & Wang, 2025).

In the integrated music-programming approach, the benefits of learning extend beyond the boundaries of music education. By improvising melodic fragments using computer programs, students not only develop music-specific skills but also gain transferable technical skills and build confidence in their abilities (Hernández-Bravo et al., 2015), because computer-based learning is accessible to anyone interested in learning, not only to the people with artistic talent. This is an attribute of the integrated approach which can address the problem related to the preconception that music education is the discipline where only the talented students can perform, risking to waste each student's potential (Di Paolo & Todino, 2025). Learning through the Sonic Pi application embodies these qualities, offering a creative and engaging experience that makes programming content more accessible by unifying it with musical elements. The enjoyment students find in creative musical activities helps them grasp programming concepts with the potential to apply them in solving real-world problems or in future personal and professional endeavours. Importantly, this relationship works both ways: programming can also enhance creative expression in music and support musical learning, exemplifying the fusion of knowledge. This is an important result, as it had been stated that the field needed more theoretical foundation to highlight music and programming bidirectional influence (Roberts & Horn, 2025). Because no clear boundaries were identified between the two fields, it allows us to answer the second research question (RQ2). The high cumulative percentages in student feedback support the conclusion that a genuine fusion of knowledge between music and programming was achieved by the students through this integrated approach.

An integrated curriculum that emphasizes the specificities of transdisciplinarity is closely connected to real-world contexts, focusing on meaningful problems as they arise in everyday life, problems that individuals and society must face (Borzea, 2017; Lenoir & Hasni, 2016). Specificities such as content unification, the "cosmetic effect", knowledge fusion, and the orientation of educational goals toward students' future formed the foundation for designing the integrated music-programming approach. This framework not only enriched the project with high-quality digital content but also offers valuable principles that could be used to evaluate educational programs in schools.

The scholarly contribution of this article to the field of educational research is multifaceted, primarily focused on the operationalization and application of transdisciplinarity principles within pedagogy. Specifically, the study contributes by: synthesizing transdisciplinary principles for educational design, bridging the digital integration gap in music education, confirming educational congruity and documenting lifelong learning and teacher development. The research collects principles of

transdisciplinarity that are directly applicable to the development of meaningful learning contexts, the systematic evaluation of existing educational programs, and the strategic orientation of future curricula. This is particularly relevant, given the proposals suggesting that future curricula should prioritize the expansion of knowledge links between music and coding, exemplified by the undergraduate course, "Sound Thinking", implemented via Scratch (Roberts & Horn, 2025). The findings address the gap between rapid digital advancements and their practical integration into music education (Ma & Wang, 2025), and a step forward would be revealing whether music creation with technologies can be achieved in actual classroom environments (Treß, 2024). The present study confirms this idea, along with the benefit of offering meaningful musical education to all the students (Di Paolo & Todino, 2025), whether gifted or not. Furthermore, by presenting a structure of the educational program with unified contents (music-programming), the research serves as a substantial contribution to the documentation of lifelong learning in the knowledge society. It identifies specific, teachable content that bridges disciplinary divides, and potential content of digital continuous professional development (CPD) for teachers.

Discussed specificities, treated as fundamental elements of transdisciplinarity, were observed consistently throughout the longitudinal study, while acknowledging the study's limitations. These limitations include the fact that, during the first two years, the research was conducted exclusively online due to the pandemic, the relatively small sample size, and the focus on only two areas of knowledge. Future research could address these limitations to further validate and expand upon the findings.

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