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# QUALIFYING MATHEMATICS TEACHERS TO DESIGN INTERDISCIPLINARY LEARNING ACTIVITIES OF MATHEMATICS AND MUSIC

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## Abstract

Interdisciplinary learning of mathematics and arts is often acknowledged as supporting the development of students' problem-solving skills, encouraging student involvement in learning, and fostering students' creativity. However, for teachers to acknowledge the benefits of interdisciplinary learning of mathematics and arts, and express willingness to apply it in their classrooms, they must first experience such learning for themselves. To that end, they have to take part in dedicated training courses.

The study described in this paper followed the experience of twenty-seven elementary school mathematics teachers who participated in an annual professional development program that took place once every two weeks and was designed to qualify them to implement an interdisciplinary approach to teaching mathematics and arts. The course included four interdisciplinary modules: math-music, math-painting, math-photography, and math-dance. None of the teachers had prior knowledge of interdisciplinary teaching and learning. The mathematical topic chosen was fractions, as this topic entails numerous difficulties of various kinds both for the teachers and the students.

In what follows we focus on the teachers' experience with module no. 1, math-music. Before we explicitly exposed the teachers to the rationale of interdisciplinary learning of mathematics and music, they were asked to design learning activities that integrate fractions and music. No specific instructions were given, as we aimed at allowing the teachers to examine their initial perceptions and interpretations regarding interdisciplinarity, and then adapting the contents of the professional development program to the teachers' early perceptions and knowledge. After completing the design of the activities, the teachers presented them, explained their considerations, and provided mutual feedback. They also rated the extent to which interdisciplinarity was expressed in the activity, according to criteria they had developed themselves. The study indicated that teachers who knew how to play a certain musical instrument and read notes produced more mathematically significant content. Moreover, activities based on considerations relating only to common student mistakes in performing arithmetic operations in fractions did not lead to the design of activities characterized as having a high extent of interdisciplinarity. In case the considerations included general mathematical knowledge and knowledge of the mathematics curriculum, the extent of integration increased. Following these findings, the professional development program focused on deepening the teachers' mathematical knowledge and musical knowledge relevant to the subject of fractions. This approach has proven to be effective in terms of teachers' ability to produce meaningful interdisciplinary math-music activities, thus indicating the feasibility of teacher training for implementing an interdisciplinary approach.

***Keywords:*** *Interdisciplinarity, mathematics, music, interdisciplinary learning activities, teacher training.*

## 1. Introduction

In recent years, there is a growing interest in integrating the STEAM (Science, Technology, Engineering, Art, and Mathematics) disciplines (Chu, Martin, & Park, 2019), recognizing this integrative approach as enhancing cognitive as well as emotional skills (Swaminathan & Schellenberg, 2015). However, since the dominant teacher training programs focus on qualifying teachers to teach one major discipline, the possibility of implementing integrative STEAM education by a single teacher in his/her class seems unworkable (Shriki & Lavy, 2017). But what about the likelihood of implementing a multi-disciplinary approach, namely, studying a specific topic in a specific discipline through the lens of another discipline and solving problems by applying both disciplinary approaches? As mathematics

teacher educators, this pondering led us to examine the feasibility of qualifying mathematics teachers to apply the multi-disciplinary approach in the case of mathematics and arts. For this purpose, we have developed a designated professional development program [PDP] for teachers who teach mathematics in 4th-6th grades. The program included 4 modules, each of which demonstrated the integration between mathematics and a different field of art- music, drawing, photography, and dance, where the mathematical topic incorporated in the modules is concerned with fractions. Since we ascribe importance to designing PDPs based on teachers' preconceptions and knowledge regarding teaching and learning (Shriki & Lavy, 2012), the designated PDP began with exploring the participating teachers' interpretations concerning the concept of STEAM education, in general, and in particular the integration of mathematics and music, drawing, photography, and dance in the case of fractions. In this paper, we describe teachers' preconceptions regarding the nature of the integration between mathematics and music in the case of teaching fractions.

## 2. Literature background

The STEM (Science, Technology, Engineering, and Mathematics) disciplines are widely acknowledged as the pillars of innovation, which will ensure the future well-being of the world economy (Chu et al., 2019). In recent years, there have been calls for the integration of the arts (A) within the STEM fields to generate the STEAM pedagogy, pointing to the potential of arts in improving spatial reasoning, abstract and divergent thinking, nurturing creativity and curiosity (Swaminathan & Schellenberg, 2015), and fostering skills required for collaboration, communication, and adaptability (Liao, 2016). In general, it is common to refer to four main types of disciplinary integration: transdisciplinarity - fully merged disciplines without boundaries; interdisciplinarity - bringing together some disciplines under a shared theme, but each discipline remains separate; multi-disciplinarity - a collaboration between two or more disciplines; and cross-disciplinarity - studying one discipline through the lens of another (Vílchez-González & Perales-Palacios, 2021). Nonetheless, a review of the literature dealing with STEM and STEAM education indicates a lack of consistency regarding the conceptualization and the implementation of the integrative approaches, leading to the absence of agreed goals and objectives of STEAM education. Furthermore, within the framework of the common teacher training programs, prospective teachers are often specializing in one major discipline, thus making it difficult to implement either a transdisciplinarity or interdisciplinarity approach to teaching and learning (Shriki & Lavy, 2017).

Given the nature of regular teacher training programs, we have chosen to explore the feasibility of implementing the multi-disciplinary approach to teaching mathematics, integrating mathematics with four types of art: music, painting, photography, and dance. The mathematical topic we chose to focus on was fractions. Knowledge and insights concerning fractions comprise a fundamental component of the school mathematics curriculum, however, the topic constitutes one of the central sources of difficulties (OECD, 2016). Therefore, any approach that can help students better understand the topic is important.

In this paper, we focus on integrating mathematics and music. Mathematics and music share common characteristics, such as the use of figurative language and symbolic notations, as well as the use of the part-whole concept and identification of patterns (Papadopoulos, 2002), and in recent years there are various intervention programs integrating mathematics and music (e.g., Azaryahu, Courey, Elkoshi, & Adi-Japha, 2020). Specifically to teaching fractions, Azaryahu et al. (ibid) found that studying fractions combined with studying rhythm, melody, and writing musical notes, contributes to an increase in fourth-grade students' achievement in mathematics, and their ability to transfer knowledge from familiar to unfamiliar fractions.

## 3. The study

In this section, we present the framework of the study, information about the study participants, the goal of the study, research methods and tools, and means for data analysis.

### 3.1. The framework of the study

Our premise was that if we want to guarantee the implementation of a multi-disciplinary approach over time, mathematics teachers should be trained to do so on their own so that they would not be dependent on collaboration with music teachers. However, in order for mathematics teachers to possess the required professional knowledge as well as the readiness to apply learning activities that integrate mathematics and art, they should first experience such activities, both as learners and as designers of appropriate activities.

The current study was conducted in the framework of a PDP for teachers who were teaching mathematics in 4th-6th grades. The PDP included exposure to various approaches to STEAM education

and the four main types of disciplinary integration. In addition, the participants experienced genuine learning and designing of four modules of multi-disciplinary teaching units that integrate mathematics and arts: mathematics and music, mathematics and drawing, mathematics and photography, and mathematics and dance. Prior to the formal study of each module, the teachers were asked to design an activity that, in their opinion, constitutes an example of an integrative approach to the teaching of mathematics and music/drawing/photography/dance in the case of fractions. Based on these preconceptions and interpretations we have refined the modules we developed. After experiencing each module as learners, the teachers were asked to develop multi-disciplinarity learning units that concern fractions, presented them to their colleagues during the PDP sessions, and provided mutual feedback. Some teachers applied the units in their classrooms and shared insights with their colleagues. In this paper, we relate to the first module - mathematics and music. As mentioned, before explicitly exposing the teachers to content related to STEAM education in general, and the multi-disciplinary approach to the teaching of mathematics and music, the teachers were asked to design a learning activity that integrates mathematics and music in the case of fractions. No specific guidelines were given, and the teachers were allowed to choose any platform and any source of information. In addition, they were asked to document the rationale underlying the activities they designed, as well as their thoughts, feelings, deliberations, and the insights they gained as a result of the process. The purpose of this preliminary phase was to allow the teachers to reflect on their preconceptions about the multi-disciplinarity of mathematics and music and to build on these teachers' preconceptions for further design of the PDP.

## 3.2. The study methodology

*Study participants.* Twenty-seven in-service teachers who teach mathematics to fourth-grade students took part in the annual PDP, four of whom had a musical background. None of the teachers had prior knowledge of STEAM education.

*Research goals.* The study intended to examine elementary school mathematics teachers' perceptions regarding the meaning of multi-disciplinary instruction of mathematics and music prior to being formally exposed to the notion of STEAM education, and how these perceptions are reflected in the characteristics of activities they design for teaching the topic of fractions.

*Research methods and tools.* For the purpose of the study, we employed a qualitative approach. In particular, we implemented a grounded theory design, which is one of the most common qualitative approaches in the context of educational studies (Chong & Yeo, 2015). Data were collected through four tools: the activities designed by the teachers; teachers' reflective journals in which they documented their thoughts, feelings, and deliberations while designing the integrative activities and the insights they gained as a result; In-depth open-ended personal interviews.

*Data analysis*. As typical of grounded theory, data collection and data analysis were interwoven throughout the research process. To analyze the data we employed three stages of coding: open coding, axial coding, and selective coding (Creswell, 2012). The categories and subcategories generated throughout the coding process related to the teachers' perceived meaning of multi-disciplinarity, in general, and in particular in the case of mathematics and music, and its connection to teacher pedagogical content knowledge (Ball, Thames, & Phelps, 2008; Shulman, 1987).

# 4. Results

In this section, we present the characteristics of the activities designed by the teachers before they were formally exposed to the idea of multi-disciplinary instruction of mathematics and art, as well as representative utterances taken from the teachers' reflective journals.

## 4.1. Teachers' learning activities

The characteristics of the activities developed and the frequency of activities with the same characteristics are presented below (the number of teachers who designed the discussed type of activity appears in parentheses). In addition, the teachers were asked to rate the degree of integration between mathematics and music, according to their perceptions. Below is the ranking, in ascending order, as agreed by the teachers, where "level 1" represents the lack of integration, and "level 7" represents a high level of integration: Level 1- Studying fractions while some classical music playing in the background (2 teachers); Level 2- Learning fractions while watching a video on YouTube in which fractions are taught through a song (3 teachers); Level 3- A workshop in which the students are asked to select a well-known melody, write new lyrics for it that relate to fractions, record it and present it to the class (5 teachers); Level 4- Write lyrics and compose a song about an arithmetic operation related to fractions (5 teachers); Level 5- Engaging the students with tapping on glasses filled with varying amounts of water and exploring the relationship between the resulted melody and the amount of water in the glasses

(8 teachers); Level 6- Presenting concrete examples of connections between fractions and music (e.g. the connections described by Pythagoras) (3 teachers); Level 7- Using music terms to demonstrate the logic behind adding fractions and a common denominator (1 teacher).

As can be seen, the perception of four teachers regarding the integration between mathematics and music concerned listening to music or watching videos of songs about fractions. This type of integration was ranked as 1 or 2. Writing songs (either merely lyrics or lyrics and melody) related to fractions was suggested by 10 teachers, and was ranked as 3 or 4. Activities that were ranked as 5, 6 or 7 used terminology from the field of music (e.g. notes, tune, scale frequency). Among the twelve teachers who suggested such activities, four teachers had a musical background.

## 4.2. Teachers' rationale underlying the suggested learning activities

Below are selected representative utterances taken from the reflective journals. The utterances are presented according to the degree of integration between mathematics and music, as rated by the teachers: Level 1- "When students have to cope with a new mathematical topic that is considered difficult to understand, such as fractions, most of them get stressed, and this hinders comprehension. So I thought of putting classical music in the background, which would induce a relaxing atmosphere and reduce students' tension."; Level 2- "Since this is a topic [fraction] that is not easy to understand, I thought of incorporating a video where the topic is presented using animations and music. In 4th-grade, students need a concrete mediation, and the video I chose provides the students with a concrete joyful, and simple approach to adding fractions. Students do many mistakes while adding fractions, and this video will facilitate the memorization of this operation."; Level 3- The best way to motivate students to learn math is through their engagement, especially when they collaborate in small groups. So I thought of dividing them into groups, where each group would choose which aspect of fractions to focus on, write a rap song, practice it and present it in class."; Level 5- "I wanted the students to experience something tangible. I came across a video of tapping on glasses filled with different amounts of colored water, representing fractions. It fascinated me, and I started to try it out. I'm sure this will spark students' curiosity to understand what's going on there, and this will increase their involvement in the topic and motivate them to discuss ideas related to fractions, where a full glass represents a unit"; Level 6- "From my experience as a teacher I have realized how important is to connect mathematical topics with their historical origins. Since I have a musical background, I remembered that Pythagoras dealt with fractions in music. So I searched the Internet for information, however, everything was in a very high level of mathematics, so I adapted it to my students. It is so nice!"; Level 7- "After reading about the STEAM education approach, I developed an activity that would start with a musical idea and then lead to the concept of a common denominator. It starts with presenting notes and the various options for playing a note (as a part of a whole) in a complete box (the whole). I'll play notes in different durations and then ask the students to address the difference between the lengths of the sounds. This will naturally lead to the topic of the whole and the sum of its parts, and the need for a common denominator."

## 5. Discussion and conclusions

The analysis of the teachers' interpretations regarding the integration between mathematics and music for the further development and refinement of the PDP was based on Shulman's (1987) theory of Pedagogical Content Knowledge and the theory of Ball et al. (2008) dealing with Mathematical Knowledge for Teaching. Activities that were ranked as "Leve 1" concerned mainly mathematical content knowledge and knowledge about students, and in particular the emotional aspects of learning fractions. However, relying merely on such considerations does not lead to meaningful integration of mathematics and music. Activities that were ranked as "Level 2", were based on both mathematical knowledge and knowledge for teaching associated with selecting examples that will improve students' knowledge of fractions and help them avoid mistakes related to arithmetical operations. Nonetheless, the focus was on mediating the learning through memorization. This approach also did not lead to a high level of integration. Activities that were ranked as "Level 3", considered knowledge about students in addition to mathematical knowledge and knowledge for teaching. In this case, the design of an activity aimed at motivating the learning of fractions through engagement in music was based on choosing the proper format for the experience (collaborative group work) and the type of experience (writing a song about some operation related to fractions). This contributed to the increase in the degree of integration. The same was in the case of the activities that were ranked as "Level 4". The last three utterances presented above were made by teachers with a musical background, and it is evident that they took into account their knowledge of music. The rationale underlying the activities that were ranked at "Level 5" and "Level 6" indicates considerations arising from broad content knowledge, and the reference to the emotional aspects of learning. The desire to generate a meaningful integration and the insight regarding the need to

adapt the information found on the Internet to the students' mathematical knowledge indicates considerations that stem from an amalgamation of content knowledge, knowledge about students, and knowledge about teaching mathematics. The activity that was ranked as "Level 7 is based on several types of teacher knowledge: As a background for preparing the activity, the teacher read about the idea of STEAM education and linked it to the fractions curriculum. This implies a combination of content knowledge and curricular knowledge. Connecting between sound lengths and fractions, and in particular, the relationship between a whole and the sum of its parts indicates considerations derived from general content knowledge and knowledge specific to the teaching and learning of fractions.

To conclude, the results of the study point out the relative advantage of teachers' knowledge in both fields, mathematics and music. Moreover, considerations that were based solely on addressing students' emotional responses to dealing with complex mathematical topics or common student mistakes in performing arithmetic operations in fractions did not lead to the design of activities characterized as having a high extent of interdisciplinarity. When extensive knowledge of mathematics was added to the considerations, the degree of integration increased. However, as can be seen in the case of the activity that was ranked as "Level 7", the teachers ascribed importance to considering both curricular and mathematical knowledge (either general or specific to the teaching of fractions). These findings led us to focus broadly on the types of Mathematical Knowledge for Teaching that were expressed in the teachers' reflections mentioned above, and in particular, deepening their mathematical knowledge and musical knowledge relevant to the teaching and learning of the topic of fractions. Indeed, upon completion of the math-music module, the activities of 18 teachers were rated 6 or 7, suggesting the feasibility of training teachers to take a multi-disciplinary approach, and in particular, the importance of basing PDPs on teacher preconceptions related to the content of the PDP. It is proposed to conduct a follow-up study that focuses on the impact of teaching and learning fractions in a multi-disciplinary manner on fourth- to sixth-grade students' understanding of the topic.

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