Music Cognition and Affect in the Design of Technology-Enhanced Music Lessons

Elena Macrides* and Charoula Angeli*

Department of Education, University of Cyprus, Nicosia, Cyprus

The present study addresses the lack of an instructional design methodology that guides the integration of technology in music listening and composition activities, and enriches the framework of Technological Pedagogical Content Knowledge (TPCK)—an essentially cognitive model– with the affective domain. The authors herein provide many examples that illustrate the music design principles and the expanded Technology Mapping instructional design process that have been proposed in previously published work. The practical examples provide concrete ideas on how to transform the musical materials into more understandable forms and how to associate them with emotions using technology. Besides its practical contribution, the research has also a theoretical significance for the theory of TPCK as it examines the interrelations between music content, technology, cognition, and affect, and identifies discipline-specific aspects of TPCK that include the affective domain. The empirical evidence of 191 secondary school students presented within the context of a music composition task using the software MuseScore, supports that both the TPCK framework as well as the proposed music guidelines can effectively guide teachers in designing lessons with technology while incorporating effect. Through the 4E perspective, technology and the proposed approach are viewed as agents of a distributed system that can support the embodied minds to develop musical and emotional understanding.

Keywords: affect, instructional design, music creativity, MuseScore, technology, technological pedagogical content knowledge

INTRODUCTION

Despite the fact that the transformative (Beckstead, 2001; Brown and Dillon, 2007; Ruthmann, 2007) and efficiency (Beckstead, 2001; Brown, 2007; Savage, 2007; Webster, 2007; Mroziak and Bowman, 2016) role of digital technologies has long been established in music education research, technology's use in the classroom is still limited while its potential is not utilized to serve curricular objectives but often peripheral purposes, such as preparing handouts, musical scores, or presentations, showing videos, and recording student classroom activities (Bauer et al., 2003; Savage, 2010; Greher, 2011; Wise et al., 2011; Mroziak and Bowman, 2016). This is attributed to teachers' lack of knowledge relating to the affordances of music and non-music technologies and to insufficient guidance on instructional approaches for incorporating technology in music pedagogy (Savage, 2007, 2010; Webster, 2007; Bauer, 2014; Mroziak and Bowman, 2016).

About 15 years ago, Technological Pedagogical Content Knowledge (TPCK or TPACK) has been proposed by researchers in the field of instructional technology as a framework for guiding in systematic ways the integration of technology in teaching and learning (Angeli and Valanides, 2005, 2009, 2013, 2015; Mishra and Koehler, 2006; Niess, 2011). While different TPCK models have been introduced in the literature during the last 15 years, this study took on the TPCK framework proposed by Angeli and Valanides (2005; 2009; 2013) in order to investigate within the field of music education subject-specific aspects of the model. The authors herein identified that the focus of the existing body of research associated to TPCK was on the cognitive domain of learning, and, appraised that the affective domain is severely overlooked (Macrides and Angeli, 2018a,b).

Aiming to extend the framework reported by Angeli and Valanides (2005; 2009; 2013), Macrides and Angeli (2018a; 2018b) proposed a set of instructional design guidelines and an expanded Technology Mapping model situated in music learning. The methodology, which constituted an approach for musical learning and creativity using technology, addressed the role of affect in the design of learning activities, and, uncovered connections between emotions, cognition, musical content, pedagogy, and technological tools.

The terms affect and emotions are used according to the definitions provided by Juslin and Sloboda (2011) in their introduction of the *Handbook of music and emotion* (2011: 10). According to these authors, affect is used as an "umbrella" term that covers different affective states, including, emotions, moods, feelings, preferences, and aesthetics. The term emotion is referred to an "intense affective reaction" that typically involves a number of manifestations –including, subjective feeling, physical stimulation, expression, action tendency, and regulation– that more or less happen simultaneously (e.g., happiness and sorrow) (Juslin and Sloboda, 2011). The term "musical emotions" denotes emotions that are somehow induced by music and include emotions felt or perceived (Juslin and Sloboda, 2011; Juslin et al., 2011).

Despite the broad definition of the term affect, in practice the field is still referred to as Music and Emotion (Juslin and Sloboda, 2011). This is reflected in many journals (e.g., *Cognition and Emotion, Motivation, and Emotion*) and books (e.g., *Music and emotion*, 2001), *Handbook of music and emotion* (2011) that use the word "emotion" rather than the word "affect." Hallam's article on "Music Education: the role of affect" (2011) is an example in which both terms are used interchangeably (2011). In the present article, the term affect is used to denote affective phenomena in general, while more precise terms (i.e., emotion, mood, and feeling) are used to refer to specific emotional states that are evoked by music.

Embodied music cognition (EMC) is a theory that considers the human body as a mediator between mind and physical environment in which music can be heard and assumes that musical perception is formed through bodily movements (Leman, 2008; Leman and Maes, 2014). Furthermore, multimedia interactive technologies and sensor interfaces are viewed as extensions of the human body and can serve as supporting mediating vehicles in forming cognitive and emotive musical

understanding and in shaping mental representations through corporeal actions (Camurri et al., 2005). The EMC approach relies on the supposition that musical understanding and production is based on an embodied sensory motor engagement and is thus the result of corporeal actions (bodily movements) of the listener/performer, including, dance movements, tapping the beat, expressive-supportive gestures of a performer, expressive-responding gestures of a listener, feeling emotional empathy with the emotions expressed by the music, and so on.

Although the EMC is an interesting and widely cited theory, critical views on the embodied music approach to cognition indicate that the EMC hypothesis is rather abstract, narrow and self-contradictory, and requires clarification on various issues (Schiavio and Menin, 2013; Matyja, 2016). The assumption that understanding is formulated through the actions of a physical mediator, i.e., the body, and its interactions with the music is quite undefined and unclear especially for pedagogical purposes. For example, the theory does not explicitly identify (methodologically, theoretically and empirically) how embodiment and specific bodily movements influence specific cognitive processes and musical understanding, and does not clearly define the boundaries of disembodied musical processing from the embodied musical perception (Matyja, 2016). Critics point out that (1) by focusing more on the music listener the theory does not sufficiently account for a broad range of musical experiences; (2) the action-oriented process described does not overcome the dualistic perspective of mind and matter as it claims it does, but reinforces the subjective (mind)-objective (music) dualism creating an inconsistency in the proposed theory; and (3) the theory lacks support from substantial empirical evidence (Matyja and Schiavio, 2013; Schiavio and Menin, 2013; Geeves and Sutton, 2014; Matyja, 2016). Thus, unless the theory of EMC becomes more precise as to how the musical content can be better facilitated, explained, and understood, it is difficult to translate and apply the EMC approach into the teaching practice.

The 4E perspective (embodied, embedded, enactive, and extended) considers cognition as a dynamic, social, distributed and interactive procedure in which mental operations, bodily or psychomotor movements, and environmental agents, such as, collaboration with peers, use of instruments, and computers, interrelate and contribute to learning, creativity and sense-making in music (Van der Schyff et al., 2018). According to the 4E approach, the *embodied* minds or human beings (in which mind and body are neither detached nor one commands the other, but rather act together as one entity) are *embedded* (or exist) with in an environment or physical and socio-cultural system. In this musical system or context, embodied minds can *enact* (engage, initiate, relate, adapt, interact, negotiate, and so forth) with the environmental agents, and at the same time can be *extended* by the agents of that system (e.g., technological tools and approaches), thus contributing to the generation of musical ideas, emotions, and musical learning. In music education literature, i.e., textbooks, teacher guides and research, music cognition may be demonstrated and assessed in many different ways, such as describing musical characteristics, critically reflecting on different forms, interpreting the meaning of music verbally or with bodily movements, creating visual representations or

concept maps, and so on (Statton et al., 1980, 1988; Bond et al., 1995, 2003; Dunn, 2008; Kerchner, 2013; Bauer, 2014).

This study explores musical cognition and emotions in a dynamic, distributed and interactive process where students interact with computers, their peers, the musical materials and their emotional effects, and investigates the interrelations of emotional understanding, feeling and expression with the musical content, the development of musical ideas, and technology. For the purposes of this study, we consider cognitive aspects of music that are related to the use, manipulation, and interpretation of musical materials (such as, melody, rhythm, timbre, texture, tempo, dynamics) and features (i.e., musical instruments, sounds, constructs, and forms) within the context of musical listening-and-analysis and composition activities. Using the notation program MuseScore, the authors illustrate the proposed music guidelines with examples that show how various uses, combinations, and changes in certain elements and constructs can influence different emotion inductions.

In addition to its practical significance, this research study also has a theoretical contribution for the conceptualization of TPCK. Firstly, the study promotes the theory about the technological knowledge element (TK) of the TPCK construct by identifying the affordances of technological tools with which educators can create powerful and understandable representations of the content, an aspect which is currently underexplored (Angeli and Valanides, 2018). Second, this study explores the links between basic elements of the TPCK structure, including, cognition or musical content, technology, and pedagogy, and the affective domain. Lastly, the learning outcomes of student compositions support that both the TPCK model as a construct as well as the proposed music instructional guidelines for music can provide effective guidance in the design of music lessons.

BACKGROUND

Technological Pedagogical Content Knowledge and Music Education

About 15 years ago, when different researchers introduced Technological Pedagogical Content Knowledge (TPACK or TPCK) as a framework for guiding technology integration in teaching, they extended Shulman's (1986) theoretical model about Pedagogical Content Knowledge (PCK) by adding the component of technology (Angeli and Valanides, 2005, 2009; Koehler and Mishra, 2005; Niess, 2005, 2011; Mishra and Koehler, 2006). These initial models, as well as others that were proposed some years later, have different theoretical views about the composition, nature and growth of TPCK. These differences include the components of the framework, i.e., the forms of knowledge required to teach effectively using digital technologies and their relationships, how teachers need to be trained in order to better develop their personal TPCK, and how TPCK is measured and assessed (Angeli et al., 2016; Angeli and Valanides, 2018). Among these models, two were the most prevailing, namely, the model proposed by Koehler and Mishra (2005); Mishra and Koehler (2006) which is more linked to the TPACK nomenclature and the integrative conceptualization,

and the model suggested by Angeli and Valanides (2005; 2009; 2013) which is usually referred to as TPCK and the transformative interpretation.

This research study adopted the model of Angeli and Valanides (2005; 2009; 2013) because it explicitly guided the design process of technology-enhanced learning with clear instructional design guidelines. These principles include:

(1) Identify content for which teaching with technology can have an added value, i.e., topics that students have difficulties in grasping or teachers have difficulties in presenting/teaching.

(2) Identify representations for transforming the content to be taught or learned into more understandable forms that are not possible to implement without technology.

(3) Identify teaching methods that are impossible or difficult to implement with traditional means and without technology.

(4) Select appropriate tools with the right set of affordances.

(5) Design and develop learner-centered activities for integrating technology in the classroom.

Along with these five principles, Angeli and Valanides (2013) developed an instructional design approach, known as Technology Mapping (shown in **Figure 1**), aiming to provide further guidance for the complex procedure of creating learning designs with technology. The main objective of this design process was to support teachers in mapping or identifying the necessary connections between the content or subject area, pedagogical affordances of a particular technology and possible representations, pedagogical approaches, students' content-related misconceptions and difficulties and context (Angeli and Valanides, 2009, 2013; Ioannou and Angeli, 2013).

Furthermore, other researchers indicated that investigating discipline-specific aspects of TPCK, including the affective domain, was necessary for developing the theory around the TPCK framework and for better supporting teacher educators and practitioners in their efforts to create effective technology-enhanced teaching designs (Chai et al., 2013; Voogt et al., 2013; Angeli et al., 2016).

While investigating whether the TPCK theory was sufficient to guide music teachers through their learning designs, the authors identified that the model did not provide any guidance on how to incorporate affect in teaching music with technology, an all important aspect for music pedagogy, because the model was –and remains– essentially cognitive (Macrides and Angeli, 2018a,b). However, the authors in this study were challenged with yet another gap, because likewise in the area of music education they encountered lack of substantial research relating to the inclusion of emotions in teaching and learning. Therefore, although the authors herein adopted the general TPCK instructional design principles proposed by Angeli and Valanides (2005, 2009), they were geared to search in another field, and specifically that of music psychology, in order to find guidance regarding the affective domain.

Music and Emotional Response

According to the literature the two main contexts in which music listening experiences take place are: (a) in everyday life or ordinary contexts, such as managing jobs, traveling, shopping, exercising, studying, relaxing from work, and (b) in

FIGURE 1 | Technology Mapping model (adopted from Angeli and Valanides, 2013).
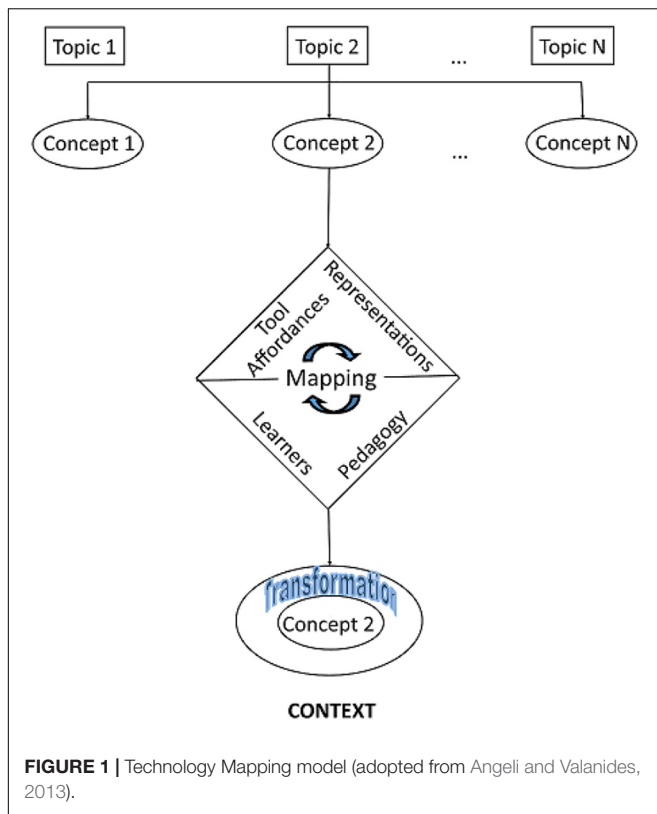
specialized music-listening contexts, such as concerts, weddings, and funerals (Sloboda, 2011; Sloboda et al., 2011). In the first category, music plays a background or supporting role and emotions arise from the surrounding materials, context and activities of the listener, whereas in the second category music is at the foreground and emotions elicit from the nature of the musical materials and aesthetic reactions to the music itself. Hence, everyday musical emotions are less memorable, brief and multiple, have basic content and are self-referral (i.e., happy, sad, calm), have low intensity and a higher proportion of negative force, are listener-focused, and are influenced by non-musical content. On the other hand, in specialized musical settings emotions are high on intensity, more memorable, sustained and integrated, more complex, mainly positive, music-referenced, music focused, and are influenced by musical content (Sloboda, 2011; Sloboda et al., 2011).

Musical emotions can be stimulated mainly by the musical works and their particular characteristics (e.g., singer's voice, tempo, melody, virtuosic performance), the listeners' situations, circumstances, and pre-existing moods (e.g., a significant event, the weather, the social environment), memory influences (emotions elicited from memories or imagination that the music evokes) and the lyrics (Juslin et al., 2011). In addition to these conditions, emotions evoked during classroom listening activities are also associated to students' musical preferences and familiarity with the pieces and styles presented (Todd and Mishra, 2013), the mode of activity (auditory, visual, kinesthetic) and students' learning style and abilities (Dunn, 2008).

Several researchers identified a distinction between perception and arousal of emotion and supported that the process of how listeners perceive emotions expressed in the music, differs from the process of how music arouses felt emotions in listeners (Gabrielsson, 2002; Zentner et al., 2008; Juslin, 2019). Perceiving the emotional meaning or expression in a musical work involves a cognitive identification of a musical emotion, such as understanding that a specific piece expresses sadness. Whereas the induction of a felt musical emotion involves information that has emotional effects and elicits an emotional reaction which may or may not be related to the perceived emotion, such as a personal emotional memory triggered by the music (Juslin, 2019). For example, the emotion perceived in the music (e.g., sadness) might be different from the emotion induced by the same music (e.g., nostalgia).

Although the perceived and felt emotions are different psychological processes, they both take place "in the listener" and both depend on the musical features or acoustic and structural qualities of the music. Perceived and felt emotions may both occur together and sometimes influence each other while listening to music, or they may overlap generating the contagion mechanism. Contagion is an internal emotional reaction to musical features that matches the emotion expressed in the music, i.e., feeling empathy or mirroring the perceived emotion (Juslin, 2019).

Gabrielsson and Lindström (2010) suggested that there are certain factors in musical structure that contribute to the perceived emotional expression, including various devices and constructs (e.g., repetition, variation, transposition) and musical features that are usually represented by designations in a musical score, such as tempo markings, dynamics markings, pitch, intervals, mode, melody, rhythm, and harmony. Numerous studies investigated the emotional effects of single musical factors (musical elements) either individually or in additive and interactive ways (e.g., mode × tempo), however, musical expression in a piece of music is usually influenced by various musical features.

According to empirical research, the most distinct results regarding the expression of emotion in music are related to the effects of tempo, mode, loudness and timbre/spectrum, i.e., tone quality of a sound based on its frequency-amplitude content (Gabrielsson, 2009). An increase in any of these elements results in higher activation. Faster tempo is associated with happier states while slow tempo is associated with sadness (Juslin and Sloboda, 2001). For the effects of mode, researchers reported happy states for major mode and sad/melancholic for minor mode, but when interacting with faster tempo, the emotional states change (Juslin and Laukka, 2004; Webster and Weir, 2005). In an empirical investigation, Webster and Weir (2005) found that increasing tempo clearly increased ratings of happiness for both modes, although there is a different critical speed for each mode at which the influence of tempo on happiness is weakened (for major mode) or strengthened (for minor mode). Studies of musical timbre have mainly focused more on the underlying acoustical properties (spectrum, transients, etc.) than on the perceived timbre as such, and thus there is still little research on the role timbre (instrumental/vocal tone color)

plays in musical structure and musical expression (Gabrielsson, 2009; Gabrielsson and Lindström, 2010). Regarding more typical musical elements, results are less clear or there is little empirical research available. For example, ascending melody may be associated with dignity (pride), serenity, tension, happiness, fear, surprise, anger, and potency (power, energy, strength), and loudness with intensity/power, excitement, tension, anger, joy (Gabrielsson, 2009; Gabrielsson and Lindström, 2010).

A theoretical framework, known as the BRECVEM model (Juslin and Vastfjall, 2008; Juslin et al., 2011) was introduced to address the gap regarding how musical emotions are evoked. This model features seven underlying mechanisms which are responsible for the induction of emotion through music listening: (1) brain stem reflexes (basic acoustical characteristics of the music, such as, dissonance or sudden changes in loudness and speed induce arousal in the listener); (2) rhythmic entrainment (synchronization/adjustment of an internal body rhythm—e.g., heart rate or respiration—to a strong musical rhythm and dissemination of this arousal to other components of emotion—e.g., feeling, expression); (3) evaluative conditioning (linking a musical stimulus to a non-musical stimulus or event because they occurred several times simultaneously); (4) emotional contagion (feeling empathy or psychological identification with the presumed emotional expression of the music); (5) visual imagery (imagining visual images about the music, such as, a beautiful scenery); (6) episodic memory (eliciting affectively loaded memories from the past, e.g., a nostalgic event); and (7) musical expectancy (perceiving expected or unexpected musical events in the discourse of musical structure relating to the building up of tension and resolution). The BRECVEM framework was later expanded to BRECVEMA in order to explain both "everyday emotions" and "aesthetic emotions" (Juslin, 2013). The updated model includes an additional mechanism labeled as (8) aesthetic judgment to better account for typical "appreciation emotions" such as admiration and awe.

Scherer (2004) proposed that music can provoke emotions through five routes of emotion induction, three central and two peripheral. The central mechanisms include cognitive appraisal, memory, and empathy (contagion), while the peripheral processes are the proprioceptive feedback (due to rhythmic entrainment, i.e., synchronization of the body's internal rhythms or motor external rhythmic motions to the music's rhythm and beat) and expression of pre-existing emotions. Apart from apprehending the processes underlying the induction of emotions when listening to music, researchers in music psychology devoted efforts in understanding the nature of the musically induced emotion itself. They supported that multi-purpose models and approaches applied for the description of everyday non-musical emotions in the field of emotion research, such as, the dimensional and categorical methods, are not adequate measures for grasping the core of and characterizing musically induced emotions (Scherer and Zentner, 2001; Scherer, 2004).

After a systematic investigation of describing emotions evoked by different genres of music among a wide range of listeners, Zentner et al. (2008) derived the Geneva Emotional Music Scale (GEMS), a taxonomy of forty-five labels or characteristic feeling terms that can be used to classify, characterize and measure music-evoked emotional states. In addition, these emotive labels can be grouped into nine musical emotion factors or categories, including wonder, transcendence, tenderness, nostalgia, peacefulness, power, joyful activation, tension and sadness, that in turn can be reduced in three greater factors.

Recent research concerning music emotion recognition (MER) invested efforts in training a machine to automatically recognize the emotion of a musical piece. The purpose of MER systems is to organize and retrieve musical information from large online music playlists, streaming services, digital music libraries, and databases using emotions (Yang and Chen, 2012). Although emotion-based music retrieval has received increasing attention in both academia and the industry, there are still many open issues to be resolved. These include the lack of consensus on the conceptualization and categorization of emotions, the different factors influencing emotion perception, and the absence of publicly accessible ground-truth data on musically induced emotion (Yang and Chen, 2012).

The categorization of emotions is problematic because there is no consensus on the approach or model (i.e., dimensional and categorical) and the number of taxonomies that should be used for accurately describing emotions, especially since each model or approach accounts for different aspects of emotions (i.e., arousal or intensity of emotions, valence or positive-negative impact, and labeling). Whether emotions should be modeled as categories (categorical approach) or continua (dimensional approach) has been a long deliberation in psychology. Nevertheless, Yang and Chen (2012) suggested that since each approach describes different qualities of emotions which are complementary to each other, it would be possible to employ both approaches in the development of MER systems and in emotion-based music retrieval.

Another problem in the development of MER systems is the subjectivity of emotion perception. Emotional responses to music are dependent on the interplay between musical, personal, and situational factors (Juslin and Sloboda, 2001; Gabrielsson, 2002; Hargreaves, 2012; Hargreaves et al., 2012), including musical materials, cultural background, age, gender, personality, musical training, familiarity, and personal musical preferences. A characteristic example that illustrates the complexity of the matter, is that even a single person's emotion perception of the same song could vary depending on personal and situational factors. Furthermore, another parameter that perplexes the identification of musical emotions is that, although different musical elements are usually associated with different emotion perceptions, emotion perception is rarely dependent on a single musical factor but a combination of them (Juslin and Laukka, 2004; Gabrielsson, 2009).

Thus, in order to accurately represent the acoustic properties of individual musical pieces, MER systems utilized various musical features, such as aspects of melody (pitch and mode), timbre (spectrum and harmony), loudness, and rhythm (meter, tempo, and phrasing). Through different computational methods, these musical features are extracted from audio signals (i.e., songs or musical pieces) existing in the database of a system, and are inputted in learning machines as machine learning

algorithms. These algorithms are applied to teach/train the machine the association between the extracted musical features of each song and its corresponding emotion label(s) that has been assigned by listeners during an emotion annotation process. The ground truth emotional labeling of the songs in a music dataset is usually obtained by averaging the emotional responses of all the participating subjects, which are categorized in the system according to a specified musical emotions taxonomy model. In addition to the information on musical characteristics, some MER systems employ algorithms that take into consideration listener and situational characteristics, such as a listener's mood or the environment's loudness. In conclusion, MER systems apply computational methods to explore the underlying mechanisms (musical features) in the perception of musical emotions, and subsequently use them for automatic emotion-based classification and retrieval of music (Yang and Chen, 2012).

Models and Practices for Teaching Composition and Musical Creativity

The term creativity creates confusion not only because it has many possible meanings and is complex and versatile (Saetre, 2011; Burnard, 2012; Nielsen, 2013), but also because teaching approaches and methods of creative activities lack consistency (Webster, 2009) and are wide-ranging and diverse (Saetre, 2011; Burnard, 2012). Furthermore, while it may be easy to explain practical aspects of composition work, it is difficult to describe the process itself (Gall and Breeze, 2005).

According to Hickey and Webster (2001) the creative thinking process begins with an idea or intention and ends with a creative product. One of the earliest studies on the process of creativity was the work of Wallas (1926) who proposed four stages of creative thinking and greatly influenced the views of Webster (Hickey and Webster, 2001; Gall and Breeze, 2005). Webster's model of creative thinking process in music represents the entire process of composition and also consists of the four stages conceived by Wallas (1926): *preparation*—thinking of materials and ideas; *incubation* (*or time away*)—mixing and assimilating ideas subconsciously; *illumination* (*working through*)—generating a great idea in mind; and *verification*—bringing ideas together and trying out the creative product (Webster, 1990, 2003). After initially verifying the creative idea by listening to the entire piece, the creator(s) should edit or revise their work by going through the four thinking stages again.

Creative music making is an interactive process between the participants' musical experience and competence, their cultural practice, the tools, the instruments, and the instructions (Nilsson and Folkestad, 2005). Hickey and Webster (2001) suggested the use of a memory aid (paper manuscript or computer notation software) to keep track of ideas during the illumination stage and a hearing run-through of the composition at the final stage, performed either by students or by a synthesizer. Similarly, other authors (Reimer, 1989; Beckstead, 2001; Freedman, 2013) supported that technology can better facilitate the creative process and can be more efficient than traditional settings with musical instruments, particularly for students with limited notation and performance skills. Using computer software

enables students to create, recall, revise, and develop musical ideas in succeeding lessons, and facilitates the process of providing meaningful and constructive peer and teacher feedback on specific places in the music (Breeze, 2011; Freedman, 2013; Nielsen, 2013).

Although creative thinking and creative activities in music have been discussed by music educators since the inception of public music education, there are major differences between the past, the present and the future of creative thinking activities in music classrooms (Hickey, 2001). First, our knowledge about how children learn with regards to active, meaningful, contextual, authentic, and collaborative learning from both within and outside the field of music education has expanded greatly over the past 30 years. For example, there is a growing interest in the literature about the social and collaborative aspects of creative musical activities (Green, 2007) and especially concerning the use of online collaborative technologies (Burnard, 2007). Second, advances in music and other digital technologies provide more powerful and easily accessible tools than ever (Brown, 2007; Bauer, 2014). Third, our understanding about the role of emotion in creative activities has been expanded over the past years (Webster, 2002; Hallam, 2011).

Wiggins (2007) suggested that when designing activities for composing in music education, teachers and researchers need to recognize and validate the following principles: (1) the holistic nature of the compositional process (embedding the generation of musical ideas in the context of a whole musical work with an intended character, structure, and meaning); (2) the intentional and cognitive nature of the conception and generation of musical ideas; (3) the need for personal agency within socio-cultural and musical contexts; (4) the need for setting composition assignments that are as close as possible to the composers' ways of practice; (5) the need for engaging learners in compositional experiences to foster musical thinking; (6) the knowledge constructed from musical experiences both in and out of school; and (7) the dynamic qualities of collaborative composing experiences.

Researchers agree that providing restrictions, guidelines, or a pedagogical framework for the process triggers the initiation of the creative procedure more easily than composing a free task (Folkestad, 2005; Hallam, 2006; Bauer, 2014). Folkestad (2005) suggested that it is crucial to formulate instructions that are feasible to implement in the creative activity and in ways that prompt creativity and transform a pedagogical framing into a musical framing enabling musical identity, self-expression, and communication in music. Thinking in sound involves imagining and remembering sounds or sound structures (Hickey and Webster, 2001) and hearing or conceiving music in one's mind (Swanwick, 1988; Wiggins, 2007). Hickey and Webster (2001) suggested activities and strategies for nurturing the creative thinking processes, which include opportunities for sound exploration, manipulation, organization of musical material through composition, playing around with sounds, and brainstorming solutions to musical problems. Furthermore, Hickey and Webster (2001) recommended that reflective thoughts and revisions are crucial in developing intentionality in a student.

Barrett and Gromko (2007) advocated that the process of creativity emerges in a system involving social interaction, joint interpretation and creative collaboration. Other studies (Burnard and Younker, 2002, 2004; Wiggins, 2007) revealed that students' composing processes or "pathways" may vary according to a number of factors, including socio-cultural practices and students' musical background, and suggested that teachers should take into consideration their particular educational settings and context of learning.

In her book *Musical Creativities in Practice* (2012), Burnard presented creative practices of music bands, singer–songwriters, DJ culture, and new technologies that do not belong to one genre or culture. She proposed a framework for understanding musical creativities through a sociological context and a pluralistic view in which different types of creativities are essentially varied pathways of composing situated in real word contemporary practices. In this view of musical creativity, Burnard suggested incorporating current and divergent musical practices into traditional music curricula that are drawn from the diverse collection of case studies presented in the book. The author supported that in educational practice musical creativities can be fostered by utilizing digital technologies in the same way that technologically mediated music practices (such as DJ practices, computer games audio design, live coding, etc.), digital societies and music making communities arise through interconnections between cultures, communities and consumers (Dobson, 2015).

The huge diversity of creative practices, the complicated view of creativity with its many types, and the lack of formalized models of composition processes makes the design of experimental investigations and quantitative methodologies extremely difficult (Lefford, 2013). Furthermore, the lack of an overarching working definition of creativity, and the ambiguity and lack of greater specificity of the creative process, prevents the inclusion of detailed and clear attributes of creativity into music curricula (Lefford, 2013).

Challenges in Teaching Music and the Importance of Affect

The three fundamental activities in music education are musical performance, including singing and playing instruments, composition, including improvisation, and listening (Paynter, 1992; Swanwick and Franca, 1999; Swanwick, 2011). Creative thinking or thinking in sound is a central cognitive ability to the art of music and an essential principle of music teaching and learning and is therefore linked to any type of musical activity, i.e., listening, composing or performing (Hickey and Webster, 2001).

Despite the fact that composition has been long established as a core curricular activity, understanding creativity in student compositions continues to be a complicated matter (Burnard and Younker, 2002; Webster, 2016). Teachers consider composition as the most problematic and admit difficulties or lack of knowledge in planning and implementing creative activities that can promote music learning and creative thinking in the classroom (Dogani, 2004; Saetre, 2011; Coulson and Burke, 2013; Bauer, 2014). The realization of creative activities, whether

these are improvisatory based or short structured composition tasks, is also problematic for students. For example, Coulson and Burke (2013) report difficulties of elementary students in incorporating the same rhythmic/melodic motifs in their antecedent-consequent improvisations using bar instruments and lack of ability in hearing the music in their head before playing it. Some researchers support that students' difficulties in carrying out creative tasks are related to lack of confidence in playing musical instruments and in using them to explore and engage in creative processes, lack of musical skills and knowledge, and lack of effective modeling and support from teachers (Burnard and Younker, 2002, 2004; Crow, 2008). Other authors refer to a large percentage of students in music classrooms that do not have a musical background as "the other 80%" (Bauer, 2014; 60). As a consequence, students limited musical training and understanding of musical notation constrains imaginative and expressive use of musical materials (Burnard and Younker, 2004), and also restricts them from writing down their creative work.

Music listening activities (also known as audience-listening, or listening-and-analysis), is another area of the music practice that poses problems. Most students do not remain focused during listening activities because, of all the arts, music is the most abstract and requires a period of time to unroll in order for the listener to experience it (Kravitt, 1972; Deliege et al., 1996; Todd and Mishra, 2013). Furthermore, students' personal preferences in specific genres of music interfere with their receptiveness and influence negatively their attentiveness and engagement (Swanwick, 2011; Todd and Mishra, 2013). Thus, students struggle to identify and describe musical elements and constructs, to retain musical events and compare sections of the music, or to critically reflect on the music (Tan and Kelly, 2004; Dunn, 2008; Todd and Mishra, 2013). Although the process of "thinking in sound" is considered as a cognitive task, it also includes another essential aspect, that of communicating feelings or being inspired by feelings. People listen to music because of its ability to influence emotions, i.e., to change moods, to release emotions, to have a fun or relax, to match their current emotional state with the music, etc. (Juslin and Sloboda, 2011). Performers and composers use musical elements and structure to communicate, induce, and express emotions in all aspects of music making. Well-renowned music educators supported that both cognition and emotion are essential in the process of musical composition (Webster, 2002), and that students should have control of the musical materials, form, and the expressive character of music in all core activities (Swanwick, 2011). Therefore, a real musical experience, i.e., musical performance, audiation, or composition, should not separate the music's expressive character and emotional influence from the learning of its cognitive aspects (Paynter, 1992).

Despite the wide acceptance about the emotional impact of music and its importance in music education, there is lack of substantial guidance relating to the inclusion of affect in music learning, including studies that deal with self-expression and emotion in student compositions (Dogani, 2004; Hallam, 2011). Hallam (2011) suggested that by initiating positive emotional experiences and personal fulfillment in the classroom, encouraging expression of emotions and identity, and placing

the emphasis on the enjoyment throughout the basic activities, would increase engagement and positively influence learning and attainment in music. She also supported that motivation and enthusiasm will grow by placing the emphasis on understanding the role of emotion in music rather than on the acquisition of skills (Dogani, 2004; Hallam, 2011).

Juslin (2019) supported that music is constantly interpreted by the listener—whether implicitly or explicitly—and that music and emotion are both linked to musical meaning and perception. According to Swanwick (2016) music is a symbolic language that uses metaphors to convey meanings and emotions. Music can be experienced and understood through engagement and interaction with its musical materials, expressive character and structure (Swanwick, 2016). The empirical findings in psychology of music and neuroscience suggest that music activates and moves us both intellectually, emotionally and physiologically (Koelsch, 2014). Thus, emotions and intellect in music are interdependent and interwoven. The problem, however, is not with making our musical thinking and engagement (composing, listening, or performing) more "embodied" to facilitate better understanding because musical thought and understanding is a full-bodied affair due to the nature and features of the music. Musical creativity, composition, listening and performing entail embodied, embedded, enactive and extended forms of participation and sense making activities that take place within a dynamic, distributed, multi-organism living system. In this system or context, interacting, self-organizing agents influence each other and use tools which extend musical understanding and scaffold them. The issue at stake thus, is discovering approaches and tools to make musical properties more understandable and participants more aware of the qualities of the music and more efficient in using them creatively.

Teaching Music Composition and Listening-and-Analysis With Technology

The most commonly documented composition technologies include either the use of musical notation software and sequencers or music production and digital audio applications (Bauer, 2014). Websites for online music production and collaboration[1][2][3][4] and "apps" (such as, GarageBand, Logic Pro, Reaper, Studio One, Pro Tools or any other audio software) can be used offline or over a network, enabling users to record and upload their musical ideas, invite others to collaborate, explore and remix music of others, and sell their finished collaborations. Some researchers suggested that this kind of informal experiences are very promising and can transform music education (Brown and Dillon, 2007; Ruthmann, 2007; Gall and Breeze, 2008). Digital music applications and devices, including loop-based technologies that use chunks of pre-recorded music, DJ mixing programs, MP3 files, and composition tools that generate algorithms, are also attractive to young people because they do not require reading notation and performing skills (Crow,

2006; Gall and Breeze, 2008; Mellor, 2008; Wise et al., 2011). However, these approaches were criticized because they involve a limited number of musical materials and styles, do not support a deep understanding about musical characteristics and structure, while they produce long, automated music that lacks imagination, originality, and expressiveness (Crow, 2006; Savage, 2007; Swanwick, 2011). Therefore, some authors suggested that these technologies should be used at a starting level and then familiarize students with more creative approaches (Freedman, 2013; Bauer, 2014).

According to research evidence, compositional approaches that use music notation or sequencing applications enable the development of musical literacy and knowledge and allow students who do not read musical notation to fully engage in the creative process (Nilsson and Folkestad, 2005; Breeze, 2011). Because of their immediate playback feature, these technologies allow students to easily follow their saved musical ideas, and to edit, extend, and share them with others for feedback (Savage, 2010; Breeze, 2011; Wise et al., 2011; Freedman, 2013).

Bamberger (2003) investigated the compositional processes of non-musically trained college students using the interactive program "Impromptu." The application supports musical analysis and composition activities, such as the reconstruction and composition of melodies without harmonic accompaniment (Downton et al., 2012; Portowitz et al., 2014). In addition to the immediate playback feature, the software enables multiple representations of melodies, including patterned blocks which symbolize melodic fragments of 5−8 notes, a graphical illustration of the melodic contour that documents pitch and note duration, and a notebook in which students take notes of their decisions, thinking processes, steps taken in making their melodies, and reflective comments. According to research evidence, this software can promote the development of musical conceptual knowledge, including the production of coherent tonal melodies, and reveal cultural perceptions of music (Bamberger, 2003; Downton et al., 2012; Portowitz et al., 2014).

Composition activities using algorithmic and electroacoustic techniques require sound processing technologies and programing skills, and therefore their application in secondary education classrooms is rare (Brown and Dillon, 2007; Field, 2007), while to the best of these authors' knowledge their efficiency has not been examined.

Kassner (2007) described listening maps as graphical depictions of musical works that are used during listening activities as a means to draw students' attention and perception to important events, elements and sections of the music. Listening maps may include pictures, text, piano-roll representations, musical signs and elements, musical notation, and various lines and shapes representing pitch, duration of notes, and melodic contour. Animated maps have an added value compared to static maps because they feature musical events and musical concepts the same time as the music progress. In addition, they intrigue learners through interesting graphics, images, cartoons, line drawings, and colors (Kassner, 2007). Animated or interactive listening maps can be found in music textbook series, such as *Spotlight on Music* (Bond et al., 2006, 2008, 2011), or in multimedia CD sets, such as *Making Music: Animated*

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[1] www.soundbetter.com

[2] www.procallabs.com

[3] www.kompoz.com

[4] www.vocalizr.com

Listening Maps (Burdett, 2006), and may incorporate interactive games and activities in addition to the animations of musical works. Existing publications examined the effectiveness of static listening guides, proposed related teaching strategies (Gromko and Russell, 2002; Tan and Kelly, 2004; Dunn, 2008; Kerchner, 2013), or investigated the creation of musical maps as a tool for developing students' musical understanding while listening to music (Gromko and Russell, 2002; Blair, 2007). However, there is a lack of studies that investigate the teaching of music with animated and interactive listening maps taking into consideration affect.

AFFECTIVE GUIDANCE IN TEACHING MUSIC WITH TECHNOLOGY: A DESIGN METHODOLOGY BASED ON AN EXTENDED VIEW OF TPCK

The research procedures of this study, shown in **Figure 2**, began with a design process of five lessons in the domain of music taking as a basis the design guidelines of the general TPCK framework (Angeli and Valanides, 2009, 2013). This design process which focused on the activities of listening and composition, aimed at investigating the adequacy of the model in guiding the instructional design in music education. However, the weakness of the TPCK framework to guide the inclusion of affect and the lack of substantial studies that addressed the integration of emotions in the process of composition and the teaching and learning of music (Webster, 2002; Hallam, 2011), shifted the investigation in the area of music psychology.

Thus, the need for considering both the cognitive and the affective domains in the design process of music lessons from the very beginning of this effort, resulted in the development of a new *design methodology* for music elaborated by a set of five instructional design principles and the expansion of Technology Mapping to include affect. The term *design methodology* refers to the development of a method or process for designing technology-enhanced learning within the domain of music education which constitutes an approach of teaching musical content and concepts and relating them with emotions through the use of technology. The proposed design methodology is the outcome of an extended literature review integrated with personal teaching experiences and individual design processes. The proposed instructional principles clarify for music teachers and designers the second and third general design principles proposed by Angeli and Valanides (2009, 2013).

The inclusion of affect in the design methodology was grounded on the GEMS framework (Zentner et al., 2008), Hallam's (2011) model of how emotion could enhance commitment and attainment in music, and music psychology experimental research on emotional responses (Gabrielsson, 2009; Gabrielsson and Lindström, 2010). Many of the emotional labels included in the GEMS model, the only instrument for classifying musically induced emotions, were used in student handouts to help learners describe more accurately the emotions induced during listening activities. More explicitly, a list of

musical emotions (or synonyms), taken from the nine categories of the GEMS scale, were provided in student handouts to help them select the appropriate emotional expression during the hearing of listening selections, while there was an option for supplying one's own emotional description. The principles of Hallam's (2011) model "*understanding emotion in music*" and "*expressing oneself through music*" have been infused in the design methodology, guidelines and activities that were implemented in this research. Specifically, the proposed guidelines and the designed activities require that students recognize emotions expressed or felt, relate cognitive and emotional aspects of the music, or express moods or feelings through their compositions.

In psychology of music there is also a body of experimental research that investigated the emotional effects of single musical elements, such as texture, tempo, melody, mode, and dynamics (Juslin and Laukka, 2004; Gabrielsson, 2009). Few studies also investigated the interactions among two or three of such musical elements (Webster and Weir, 2005). The researcher borrowed the idea of experimenting with different dimensions of musical parameters in some of the designed activities in order to help students understand both the cognitive aspects and the emotional effects of certain musical elements. An example of such an activity is described later in this section for the element of tempo and its interactive effect with mode.

Part of the consideration for the inclusion of the affective domain in the design methodology, focused on understanding the relationship between music cognition, technology, and affect, according to the guidelines of the original Technology Mapping process depicted in **Figure 1**. **Figure 3** shows a representation of the design methodology proposed by Macrides and Angeli (2018a; 2018b; **Figures 4**, **5**) denote the interactions occurring between musical content, emotions and technology during the learning process. The authors elucidated the design methodology with instructional guidelines (Macrides and Angeli, 2018a,b) a final set of which is presented herein. The examples provided further illustrate the expanded Technology Mapping model and the proposed guidelines as well as some pedagogical affordances of MuseScore, including the piano-roll depiction, the tempo slider, the transpose function, the Palettes, and the Mixer window.

As **Figure 3** shows, during the first hearing of a listening selection (upper circle) students identify felt or expressed emotions that the music elicits (inner circle) without having any visual stimuli. In subsequent hearings, visualizations through digital technologies, such as animated listening maps and notation software, support the exploration and understanding of the cognitive aspects of music, according to the learning objectives (right hand side circle). While supporting music learning through experimentations and transformations of the content, technology supports the association of emotive expressions with different and contrasting treatments of musical characteristics and promotes the understanding of feelings with respect to specific musical materials or mixes of them (inner circle). At the final stage of this process, students engage in a short composition activity using technology (left hand side circle). Students are guided to decide about how to use the musical materials and constructs learned to communicate the desired emotion or feeling (inner circle).
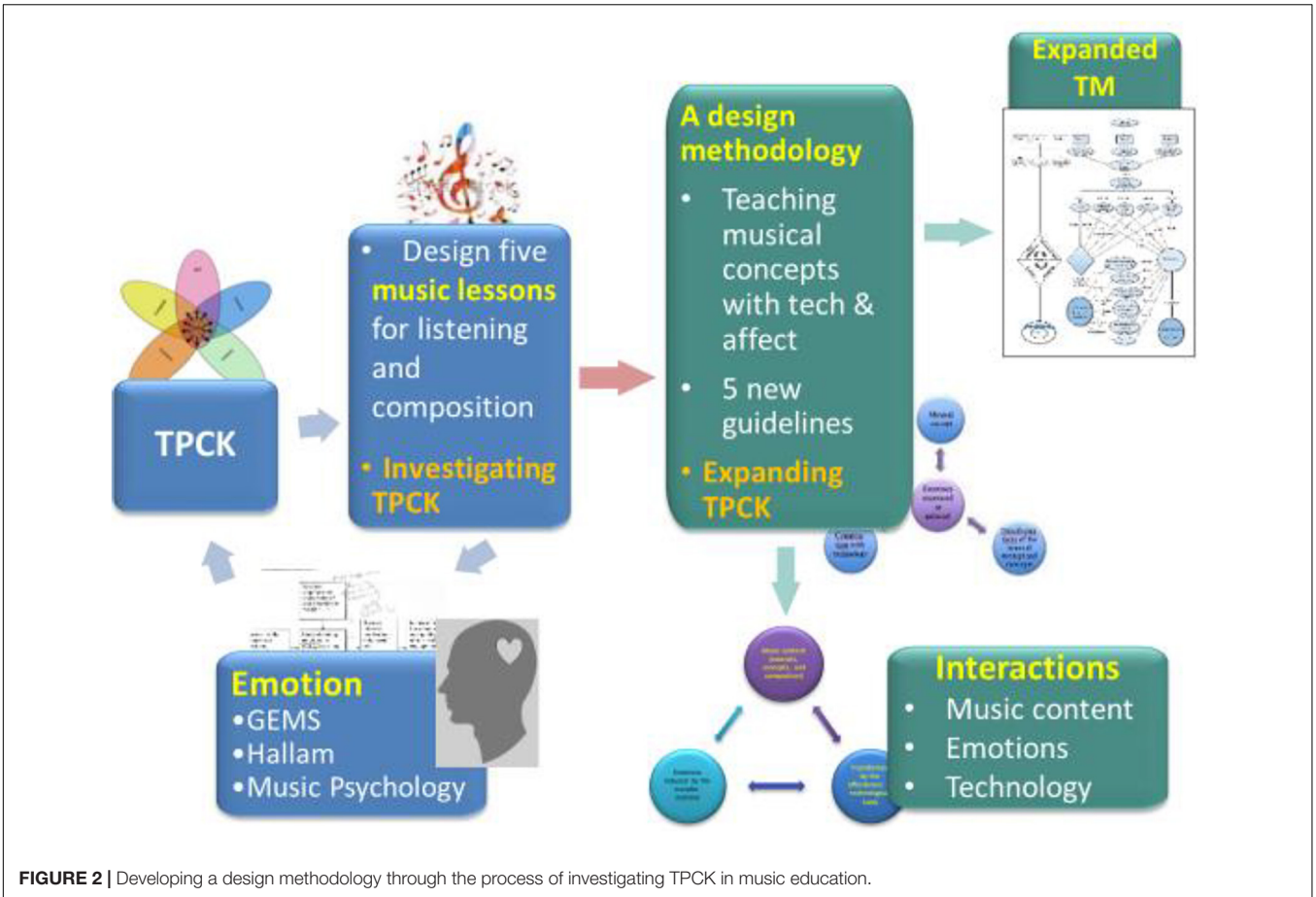
FIGURE 2 | Developing a design methodology through the process of investigating TPCK in music education.
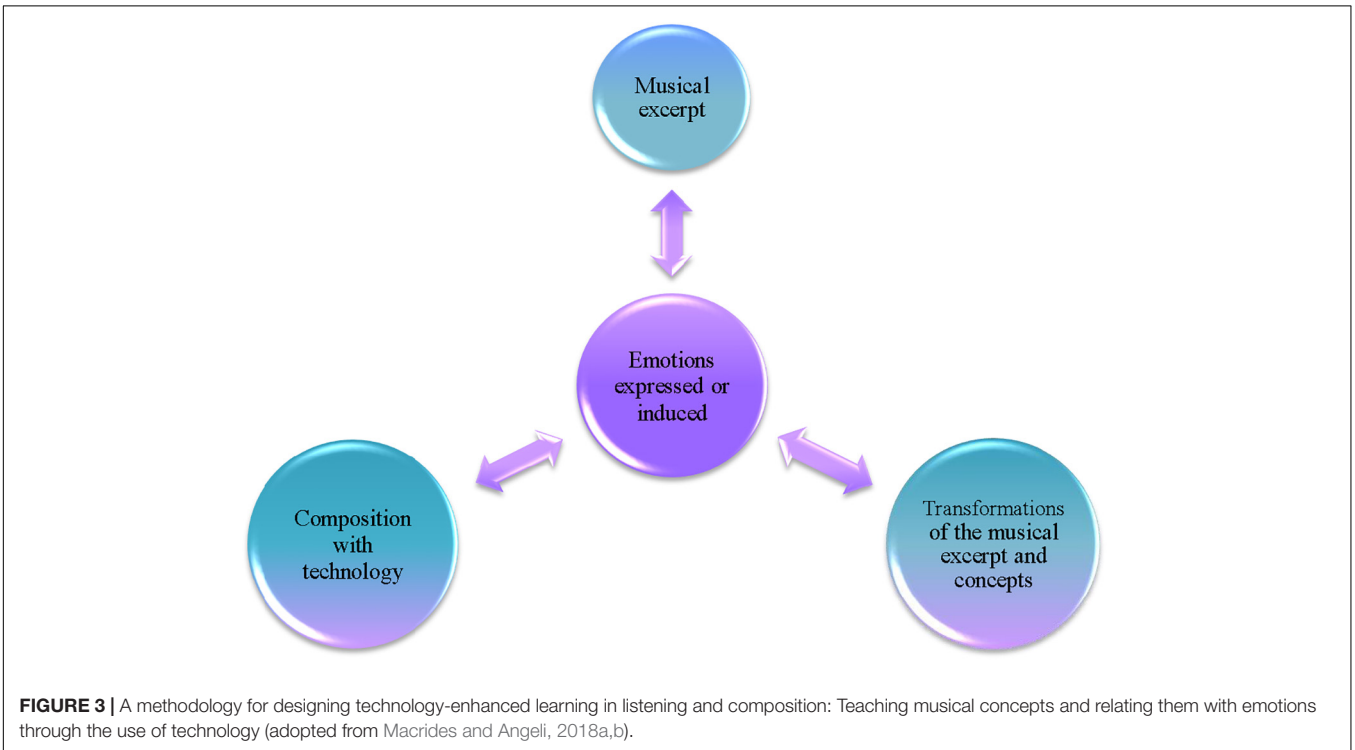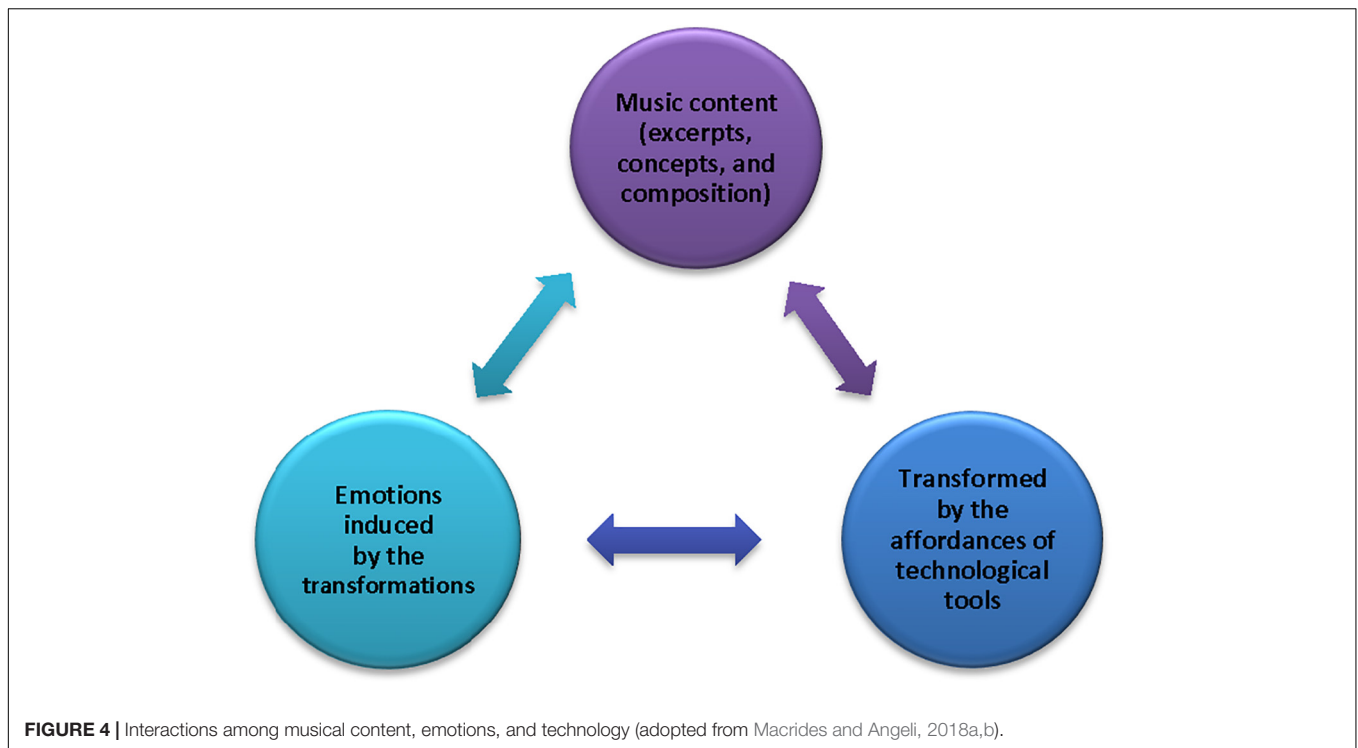

FIGURE 3 | A methodology for designing technology-enhanced learning in listening and composition: Teaching musical concepts and relating them with emotions through the use of technology (adopted from Macrides and Angeli, 2018a,b).

FIGURE 4 | Interactions among musical content, emotions, and technology (adopted from Macrides and Angeli, 2018a,b).

In the procedure presented above, there are interactions among musical content, emotions, and technology which are designated in **Figure 4**. Due to the affordances of technology to isolate and experiment with musical materials using multiple dynamic representations, and immediately observe, hear and feel the modifications made, including, changes in the tempo, sounds, rhythmic patterns, pitch, dynamics, articulation, etc., students can relate the particular changes with respective changes in moods or emotions. Thus, technology can facilitate more clearly and immediately not only the understanding of the cognitive aspects of music but also the understanding of their emotional effects. Empirical findings of students' experimentation with tempo using MuseScore were reported by Macrides and Angeli (2018a; 2018b). In an experimental study, they found that students investigating tempo through technology scored higher in both the understanding of tempo (i.e., the speed of the music) and its emotional effects than students carrying out the same activity with musical instruments.

Furthermore, since the computer can play back whatever users create, students can focus on the creative process and how to shape their ideas and communicate feelings instead of concentrating or even struggling to perform their works and synchronize with each other. Lastly, technology's rich resources and affordances facilitate the creation of new emotions and ideas during the entire composition process.

Accordingly, based on the processes described in **Figures 3, 5**, the authors herein propose a design methodology consisting of a set of design guidelines that extend the second and third instructional design guidelines proposed by Angeli and Valanides

(2009, 2013), providing, this way, explicit guidance in the application of TPCK theory in the teaching of music.

(1) Use affect (emotion elicited from a musical excerpt) to motivate students to engage in analysis and exploration of musical excerpts and related concepts.

(1.1) Ask students to identify emotions felt or expressed by the music and write them on their handout without having any visual stimuli.

(2) Use technology to help visualize, explore, and support understanding of the cognitive aspects of music (structures and elements) according to curricular objectives, such as melodic contour, dynamics, melodic motives, ostinato, phrases, sections, etc.

(2.1) Present an interactive/animated listening map of a *short* musical excerpt.

(2.2) Include pre-listening visualizations and explorations of individual musical features.

(2.2.1.) Students, working in dyads, explore the animation's resources and complete short questions on their handout. They are also provided with a printed version of the map.

(2.3) Alternatively, play reductions of musical excerpts using a notation software, and/or provide different representations of concepts using the affordances of the software (i.e., piano-roll editor view, mixer, palette).

(2.3.1) Students identify contrasting or different treatment of musical materials and complete very short questions.

(3) Use the different transformations that become possible with the affordances of technology to relate cognitive and emotional aspects, i.e., understand how musical elements influence emotion induction (affect).
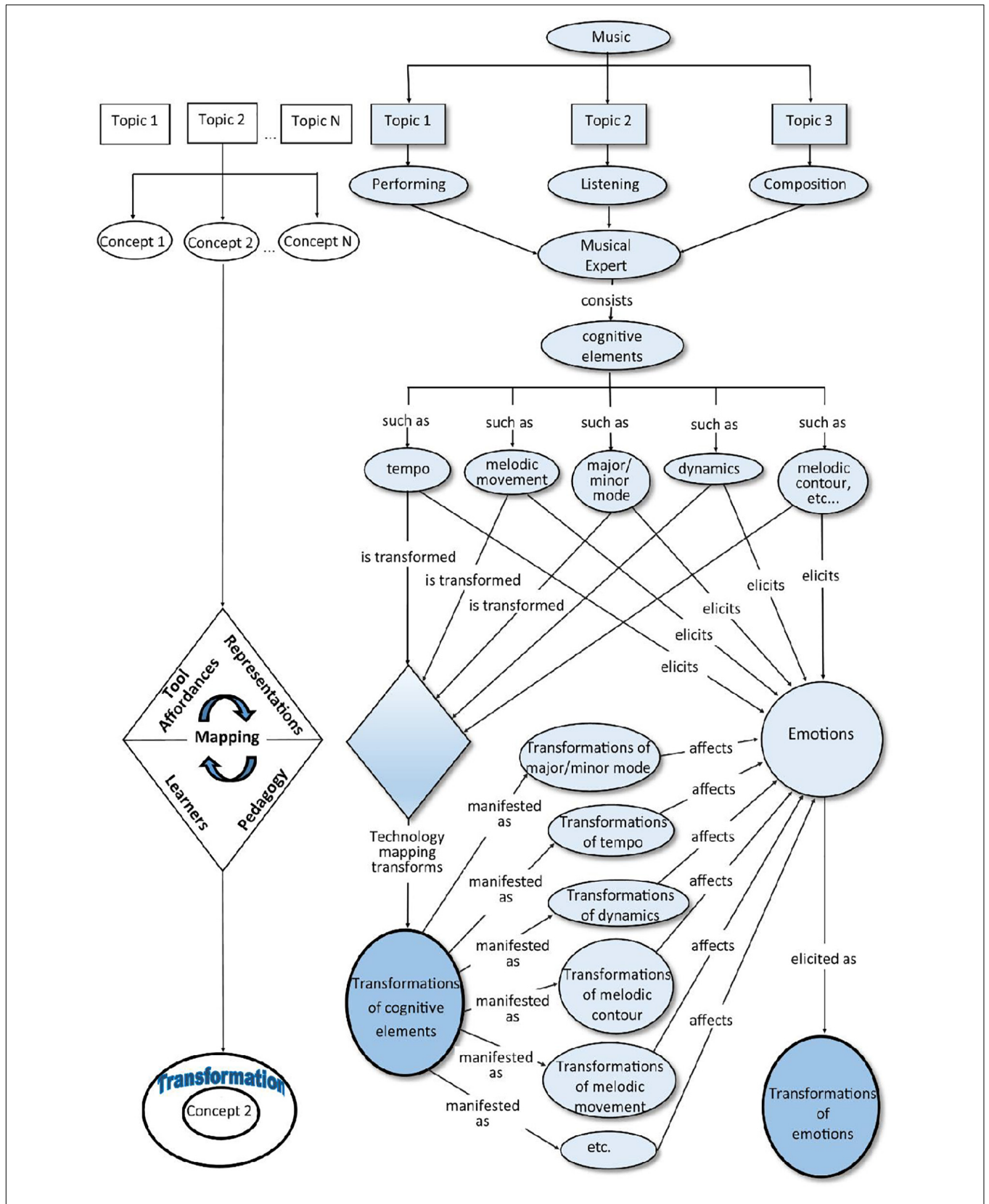
FIGURE 5 | An expanded model of Technology Mapping showing the interrelations of musical elements and concepts, technology, and affect (adopted from Macrides and Angeli, 2018a,b).

(3.1) Provide a mapping or round up of the emotional expression(s) with the musical features identified in the listening selection.

(3.2) Discuss which musical or structural elements most likely affected the emotions identified earlier, or how the mood might change if these elements change.

(3.3) Use a notation file that has been prepared before the lesson, and have students (a) experiment with contrasting dimensions of a musical element in order to understand how a change of feeling or mood can be induced, and/or (b) apply the new device or element in a short task using a semi-completed template file so that students can become more familiar with technical, cognitive, and affective aspects of a particular concept, or, combination of two-three concepts (i.e., soft vs. loud dynamics, thin vs. thicker texture, ascending vs. descending melody, conjunct or disjunct melody, etc.).

(4) Prompt students to create musical compositions with emotions in order to express or communicate feelings and mood, using elements and structural devices explored in the unit.

(4.1) Use a template composition file and provide a handout with restrictions and guiding questions about the treatment of musical characteristics explored in the unit.

(5) Repeat steps 1—4 to teach new concepts, gradually engaging students in more musically and emotionally coherent and technically informed compositions.

To better illustrate the preceding discussion and guidelines, the authors henceforth provide

several examples. In the first example, students experiment with tempo (guideline 3) through the MuseScore application. They are provided with a file containing a melancholic folk song in A Minor set at the actual tempo (70 bpm) of the song. After hearing the song at the original slow speed, students are guided to open the Play Panel from the View Menu (see **Figure 6**), adjust the tempo slider at 130 bpm, and listen again to the same song. Due to the interactive effects of tempo × mode, students experience a happier mood at the second hearing (i.e., faster speed) despite the minor mode of the song. Then students are asked to write how can tempo changes evoke different emotions. Similarly, other explorations can be carried out with various elements or combinations of elements using short excerpts in MuseScore. For example, students may explore the emotions elicited by sequentially trying out soft and then loud dynamics on a single melody, and, hence, by repeating the process on a harmonized melody. Exploration may continue by adding a third parameter, i.e., by changing the instrument sounds in the given arrangement.

The second example provided shows how the software MuseScore can help in identifying changes in the melody (i.e., melodic rhythm, motion, and contour) and in relating these changes with emotions. Before using this notation program, students jot down their emotions while listening to a recording of the song "Money Money" [from the musical Cabaret] composed by John Kander without having any visual stimuli (guideline 1), and, afterward they sing or play the song. Subsequently, they view a short piano reduction (guideline 2) of the same song played through the software's notation view, which consists of two sections. The first section is made up of an eight-measure verse,

while the second section includes a three-measure transition leading to the refrain, which is repeated at a higher pitch and different tonality. **Figure 7** shows the first four-measure phrase from each section.

After viewing the reduced version, students recognize subtle emotional changes that may occur between the verse and refrain due to differences in the melodic shape and rhythm, and then identify the durations employed in the melody of each section (i.e., primarily quarter notes and some eighths in the verse and a dotted eighth followed by a sixteenth note figure in the refrain). In order to better help students visualize the changes in the melodic motion, shape, and rhythm, the teacher mutes the accompaniment from the Mixer window, and switches to the piano-roll-editor view, which is a graphical representation of the melody as shown in **Figure 8**. In the verse, students can observe a five note stepwise descending melodic motion followed by upward and downward leaps (i.e., major and minor sixth intervals) that form a "V" shaped melody. In contrast, the melodic movement in the second section is very conjunct, consisting, primarily, of descending chromatic semitones (see **Figure 9**). The prominent dotted eight-sixteenth note rhythmic figure in the refrain is repeated three times on the same pitch before reiterated more times down a step and then again down a third, creating a terraced falling shape. Jeanneret and Britts (2007) supported that piano-roll representation can improve students' attentiveness, support the identification of pitch patterns, and enable the development of students' abilities to verbalize what they are hearing, including structural and textural aspects. Thus, students can better visualize, hear, feel, and understand how contrasts in the melody amongst the two musical sections, including different rhythmical activity, different melodic motion, and, shift in pitch, can elicit a change in mood (i.e., in this case a more cheerful or agitated feeling).

Underneath the piano-roll views in **Figures 8**, **9**, a piano keyboard view is shown in which the corresponding piano keys are highlighted as the melodic theme is played. This representation can be used additionally but not simultaneously to support an understanding of some melodic intervals or as a simulator for learning to play the tunes on keyboard instruments.

Apart from enabling visualization and identification of musical materials and emotions, the software can further enhance cognitive and emotional understanding through creative tasks. The authors provide an example of a semi-completed task (guideline 3) aiming to help students understand and feel how changes in rhythm, meter, and accompaniment influence emotions. In this exercise, students can work in dyads to complete a different arrangement of the previously studied song by re-writing the melodic theme of the verse in 3/4 time instead of 4/4. Students are provided with a MuseScore file (see **Figure 10**) that contains a new accompaniment for the verse, namely a variation of the theme in eighth notes with a bass line, while the refrain remains unchanged in 4/4 time.

Students also have at their disposal two types of files: (a) a MuseScore file of the previously studied example in 4/4 from which they can copy the melody notes, and (b) an audio recording file or a link to a video of a performance for hearing the song in triple time. The melody in 3/4 time
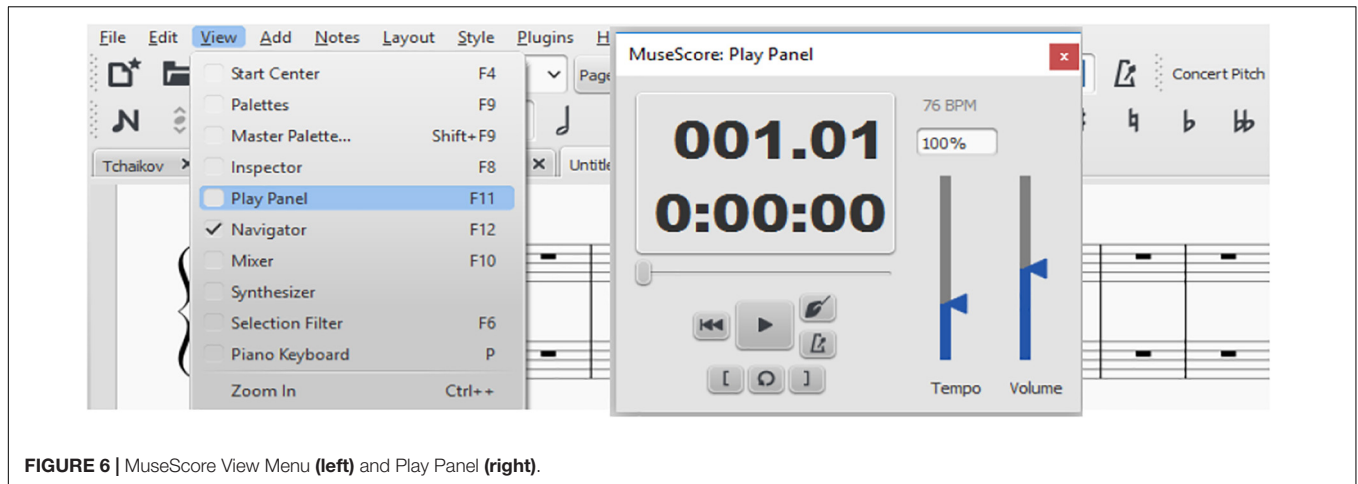
FIGURE 6 | MuseScore View Menu **(left)** and Play Panel **(right)**.

FIGURE 7 | Verse and refrain themes from the song "Money Money."

consists of longer notes, i.e., half notes followed by quarter notes, and therefore, a more relaxed or lyrical feeling is elicited as opposed to the rigid quarter-note verse melody and the jovial refrain in quadruple time. Thus, this arrangement reinforces the juxtaposition of the two sections (verse-refrain) by creating greater contrasts in moods and also in musical materials, including different accompanying rhythmic patterns (an eighth note counter melody vs. the "oom-pah" pattern), changes in meter (triple vs. quadruple), and different melodic figures. An optional extension to this activity may include exploration of other musical elements that create contrasts, while at the same time familiarizing students with various functions of the software. These may include applying different dynamics and tempi in the two sections (from the Palette) or creating thicker texture by easily adding a rhythmic ostinato

or a vocal pedal note melody in the refrain, as shown in **Figure 11**.

The following example is an excerpt from Tchaikovsky's Pas de Deux, Intrada from the Nutcracker ballet (see **Figure 12**). The excerpt further demonstrates how various accompanying types influence different emotion inductions by featuring another accompaniment pattern (guideline 2). Moreover, this reduction highlights three timbres (harp, cellos, and flute), high and low registers, and two types of melodic motion, which also evoke different feelings. The harp accompaniment opens the excerpt (as in the original piece) with arpeggiated sixteenth-note triplets that form an arched shaped pattern (shown in **Figure 12**), while the cello and later the flute join in with a descending-scale melody that forms repeated falling line shapes. Although, the sixteenth-note triplets create a busy rhythmical activity, the slow
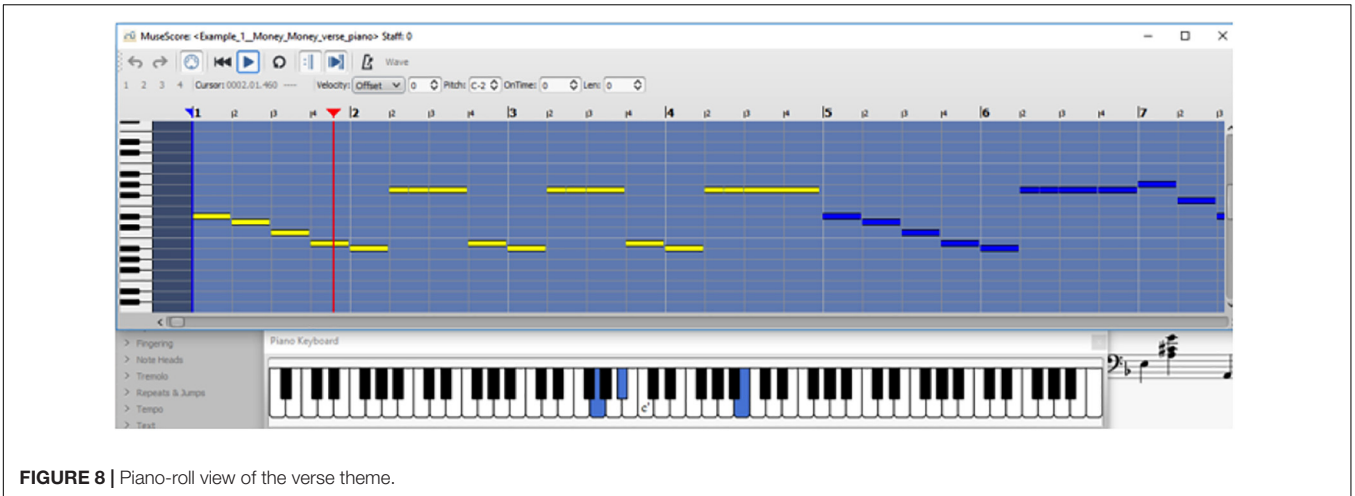
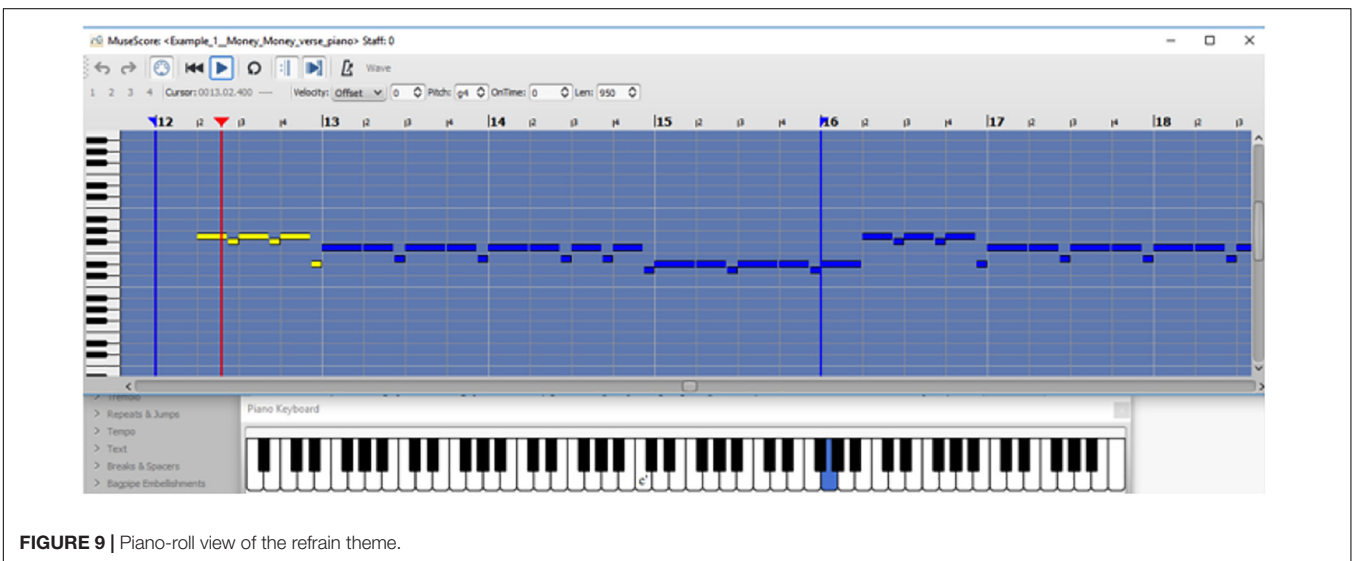**FIGURE 8 |** Piano-roll view of the verse theme.

FIGURE 9 | Piano-roll view of the refrain theme.

tempo, the harp sound, and the arpeggiated motion create a romantic or dreamy mood.

In addition to identifying specific musical elements with the above file, students can also experiment with them using the same file (guideline 3). For example, they can shift registers or change the sounds of melodic instruments and experience how these changes may affect their feelings. Specifically, using the Transpose window, students may easily move up or down a selected passage by a specified interval, as shown in **Figure 13**. Furthermore, they can explore sounds for a particular instrument line through its "Sound" drop-down menu in the Mixer window (shown on the right-hand side of **Figure 13**).

However, since the example presented here is an excerpt, containing only the theme of the piece, it cannot convey the increasingly dramatic character of the music as the work progresses. Consequently, an animated listening map (guideline 2) can provide a better understanding of the musical work's structure and of how musical materials are used to evoke emotions as the music evolves, including changes in dynamics, mode and tonality, instrument sounds, pitch, and register.

The goal of simplifying and reducing original musical pieces is to help students zoom in on specific elements and constructs for the purpose of understanding and learning to manipulate them. However, the procedure of eliminating musical materials from large-scale works and studying or exploring them independently, entails the danger of oversimplification and fragmentation. Therefore, while it is helpful to work with excerpts and reductions using the software, a zoom out to the authentic musical pieces is also necessary in order to better relate the musical devices studied to the works from which they were extracted, and to experience the full breadth of emotions and character of the music.

At the end of the unit, students should be able to create a short composition applying the knowledge, skills and experiences acquired (guideline 5). To save time and set some limits, students can work with a template file (guideline 4) that contains the number of measures, key and time signatures, and
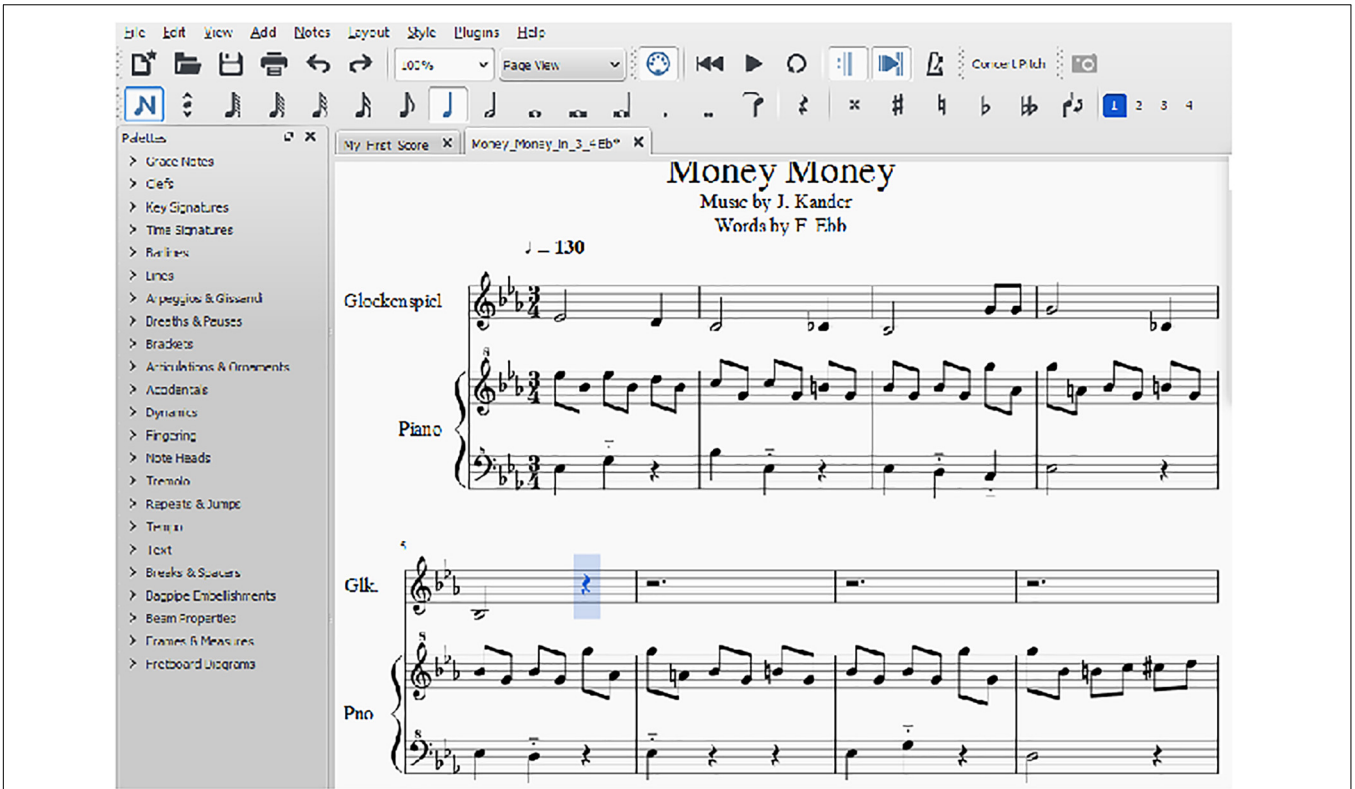
FIGURE 10 | Re-writing a melody in 3/4 time on a given accompaniment.
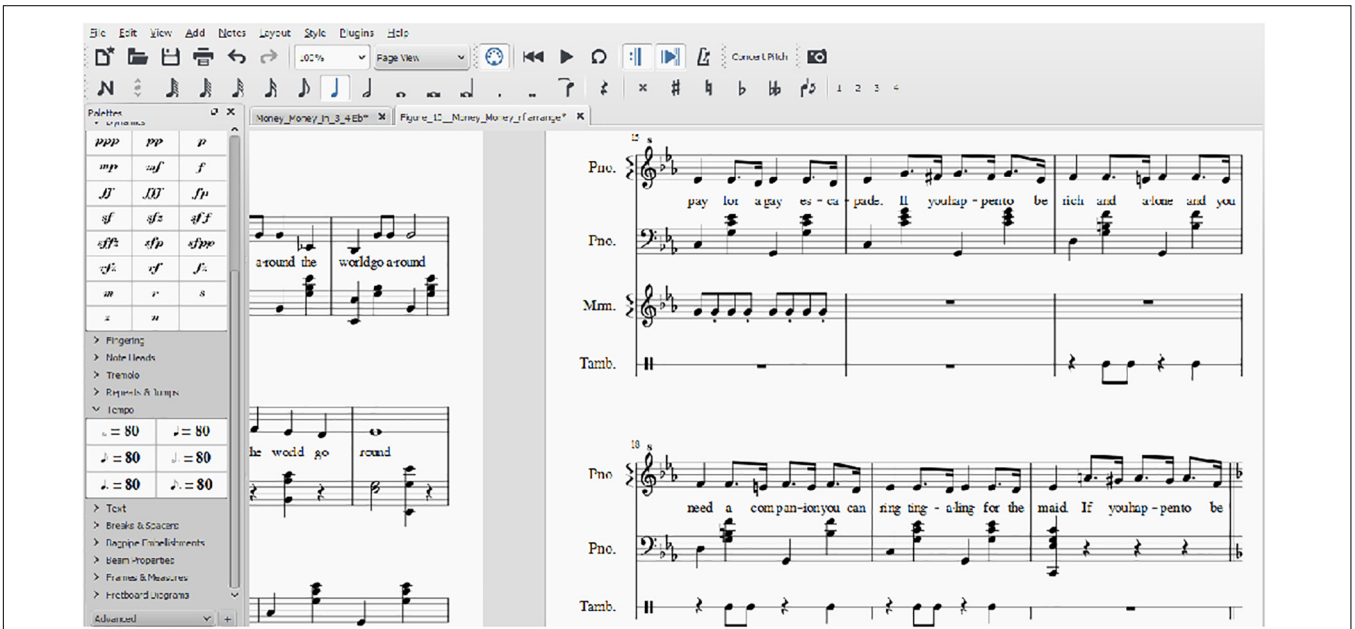
FIGURE 11 | Adding dynamics and tempo from the Palettes (left), and creating lines with ostinato.

instrument lines with selected timbres, although any of the above settings can be changed in the process accordingly. At the beginning of the composition task, students must decide what emotion or mood they wish to express or convey to the audience through their music, and, how they will use musical elements and building blocks to achieve their target, including,

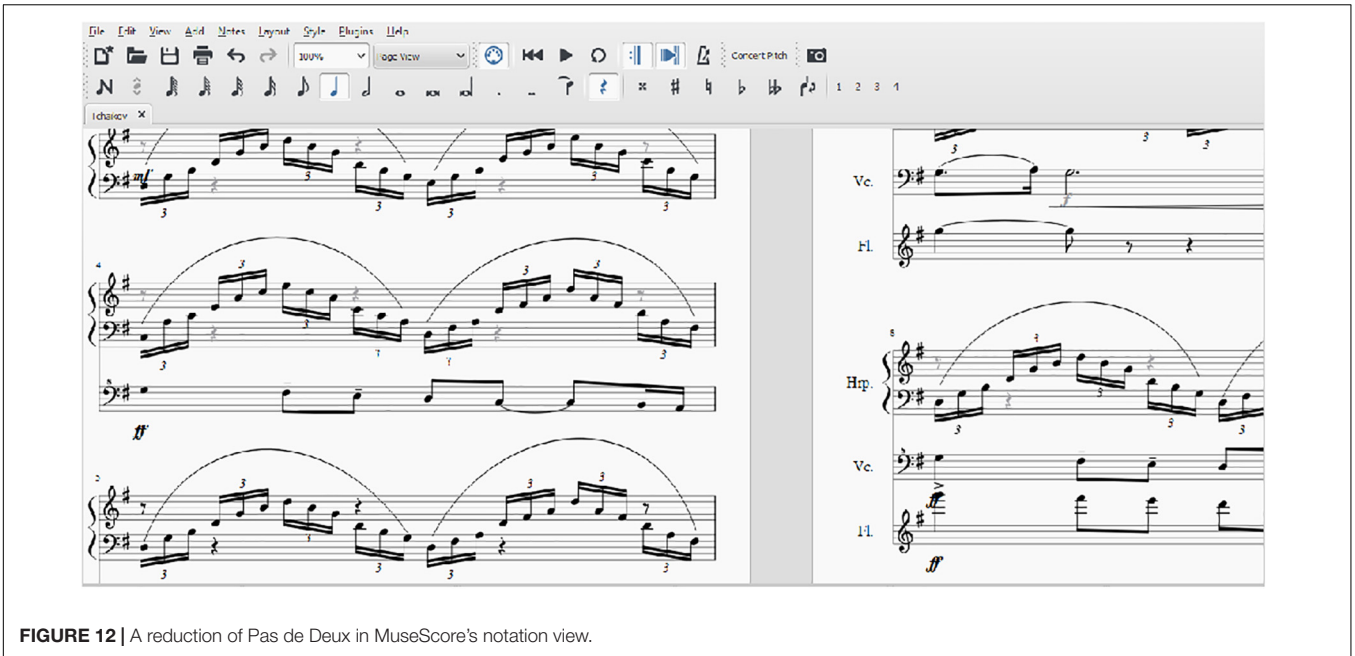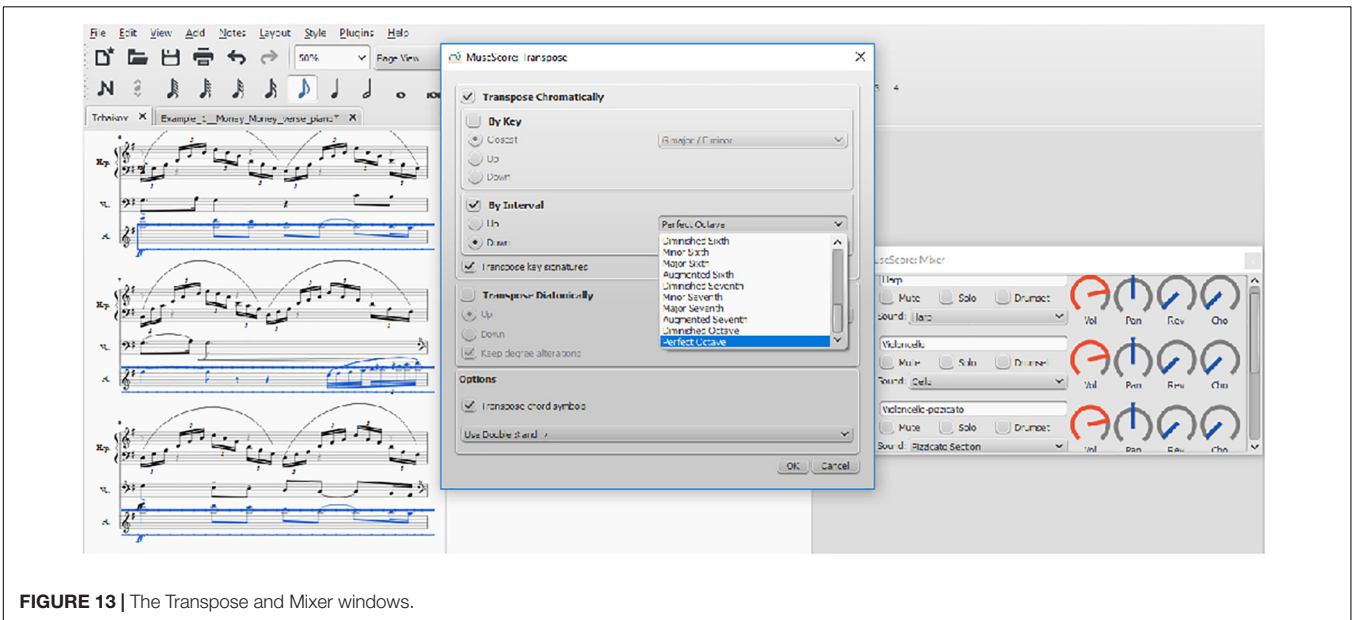**FIGURE 12 |** A reduction of Pas de Deux in MuseScore's notation view.

FIGURE 13 | The Transpose and Mixer windows.

for example major/minor mode, melodic movement, dynamics, tempo, timbre/sounds, motives, ostinato and pedal point.

Even though the approach presented here using MIDI technology has many advantages, teachers must also be aware of some limitations of this technology in order to use it more effectively in teaching. Perhaps the biggest disadvantage of MIDI is that instruments do not sound as realistic as real instruments, because this technology lacks certain natural elements that are present in acoustic instruments, such as strumming a guitar, bowing a violin, or blowing air through a wind instrument. Furthermore, the fact that all instruments play with great precision result in an unnatural feeling that is not met in natural

orchestral settings. Due to these constrains, music played by MIDI instruments sounds less expressive than music performed by humans using real instruments.

Despite the aforementioned weaknesses of MIDI technology, musical concepts and emotions can be expressed and understood using music notation software, and, particularly MuseScore. In order to achieve better results when creating examples or designing activities, apart from using good sound cards and sound fonts, teachers must have in mind some tips and encourage students to follow them. Concerning instrument sounds, good or realistic timbres are percussions and keyboards. Instruments that sound unnatural include solo brass and strings, although

orchestral legato strings may not sound bad in an orchestration with appropriate balance and mixing. In addition, students should be guided to explore synthetic or electronic sounds and experiment with the Palette, the Synthesizer, and Mixer windows, adding dynamics and articulation, adjusting volume, effects (echo, reverb), and tempo to achieve a good sounding and balanced orchestration. Furthermore, changing playback devices may cause instrument timbres to sound very differently, thus, exporting final products to an audio format, such as, mp3s is another option.

EMPIRICAL EVIDENCE

The derived design methodology was tested and revised in a three-cycle design-based research that aimed at determining the effectiveness of the five proposed music guidelines through the implementation of the five lesson designs in control and experimental secondary education classrooms with 516 participating students (Macrides and Angeli, 2018a,b). The aim of the design-based research was to reach a robust methodology for designing technology-enhanced learning within the context of listening and composition activities in music that would include the affective domain.

The three cycles spanned over a period of one school year while the implementation of the lesson designs and the data collection procedures per cycle were completed in a period of 7 weeks during the regular weekly 40-min music class meeting. Prior to the application of the lesson designs, a pre-test and a questionnaire concerning student demographics and musical background information were administered. The first two lessons focused on listening and analysis of two listening excerpts using animated listening maps. Lessons three and four focused on the teaching of musical materials and constructs using the notation program MuseScore while engaging students in two short composition exercises. Lesson five consisted of a composition task involving the use of musical materials presented in all the previous lessons and was completed in two meetings.

The proposed guidelines and methodology were tested by assessing students' learning gain on musical knowledge through a post-test that was administered at the end of each lesson and a delayed test given a week later. Furthermore, music composition products were collected at the end of the final lesson and evaluated according to the Composition Assessment Form. The results presented herein concern the composition task. This investigation sought to determine if there were any statistically significant differences in the musical quality, coherence, originality and emotional expressivity of student compositions between the experimental and control groups.

Method
Participants
The participants in the study were secondary school students ($N = 516$) who were enrolled in Grade 8 ($N = 114$), Grade 9 ($N = 366$), and Grade 10 ($N = 36$). Students were between 14 and 16 years of age, and were selected from five schools, one private and four public schools from three different towns. In the

first cycle, there were 50 participants all of which were enrolled at School A in Grade 9. In the second cycle, the total number of participants was 148, of which 72 were enrolled at School B in Grade 9 and 76 at School C in Grade 9 ($N = 40$) and Grade 10 ($N = 36$). The total number of participants in the third cycle were 318, including 228 students enrolled at School D in Grades 8 ($N = 90$) and 9 ($N = 138$) and 90 students at School E in Grades 8 ($N = 24$) and 9 ($N = 66$).

Cycle 2 had the highest percentage of students studying music privately (30%) and the highest percentage of students continuing their private music instruction after their fourth year of study (14%). Cycle 3 had the second highest percentage of students studying music outside school (28.5%), however, only 6% continued after the fourth year, while in cycle 1 only 12.5% received private music lessons most of which dropped out before their fourth year.

Students, belonging in intact classes, were randomly divided into two groups to form the control and experimental groups for each cycle. There were 26 intact classes, 11 of which were assigned as control and 16 as experimental. The number of students per class in public schools usually ranged from 22 to 25, whereas in the private school the number of students per class was usually 15. The teaching in the two groups was equivalent in terms of teaching procedures and materials. The difference in the approach between control and experimental groups was the use of technological tools during the implementation of some activities for the experimental group.

Due to the length of the study and the large amount of data that had to be collected and analyzed, the results for 191 students (control group, $N = 86$; experimental group, $N = 105$) or about 40% of the student compositions have been graded and are presented in this paper. Students come from three schools and belonged in nine intact control and experimental classes, three of which were in cycles 2 and six in cycle 3.

Composition Assessment Form
The Composition Assessment Form (CAF), as shown in the **Appendix**, was created by the researchers to assess students' compositional tasks. This scoring form was based on a similar instrument created by MacDonald et al. (2006) in a tertiary education music department in Scotland. The criteria in the Macdonald et al. evaluation form included the use of compositional devises and musical materials (such as motivic/thematic development, pitch/melodic organization, rhythmic development), the technically informed and creative use of sound sources, the clarity of notation and quality of presentation, and the overall conception (musical coherence and musical imagination). The CAF used in this study includes most of the above criteria and some additional musical concepts and materials that were presented in the lesson designs as well as criteria for evaluating the expression or induction of musical emotions or mood.

The CAF consisted of seventeen items, each rated on a scale from 0 to 5. Thus, the maximum score a student composition could receive was 85 marks. The criteria were grouped in five sub-categories, namely, overall conception (OC),

compositional materials (CM), sound resources (SR), notation (N), and emotions evoked (EE).

The OC sub-score derived from the sum of three items, i.e., musical coherence, musical imagination, and emotional expression/conveying mood. The sub-score CM was made of six elements, i.e., motivic/thematic development, pitch organization, rhythmic development, compositional devices (such as ostinato and pedal point), dynamics, and tempo. The score for the SR sub-category was based on two criteria, i.e., technical knowledge and imaginative/skilled use of resources (musical instruments or software), while the sub-score for N was based on just one item, that is, clarity and accuracy of notation. The final sub-score concerned the use of musical materials to evoke emotion (EE) and was formed from the total score on five criteria, i.e., tempo, timbre (sounds, instruments), mode, melody, and dynamics.

Procedures for Lesson Five: Music Composition

Students of both groups were given a composition worksheet which included the requirements of the assignment, a table named "Diagram of composition" and a three-part system. The composition task required creating a melody line and two simple accompanying lines, including a rhythmic and a melodic accompaniment, of eight measures in length, that would convey an emotion or mood. Students were expected to effectively manipulate musical elements or concepts that have been presented in Lessons 1–4 in order to create an expressive musical sentence. These materials and constructs included characteristics of melody, melodic motion, pitch, major/minor mode, dynamics, tempo, motive and motivic development, melodic and rhythmic ostinato, and pedal note.

After explaining the requirements of the assignment, the teacher encouraged students to follow the "Diagram of composition" as a guide to their creative thinking process. Initially, students were advised to think of an emotion or mood that they would like to express or communicate through their music and to write the emotion in the space provided on the "Diagram of composition." At the same time, they were told that they were free at any point during the process to change their ideas. Additionally, the "Diagram of composition" contained five items relating to musical elements or constructs. Next to each element there were guiding questions and some ideas prompting students to make decisions about how these materials could be manipulated in relation to emotions. Specifically, these musical features included melody and melodic motion (i.e., skips, steps, ascending, descending, and/or combinations, high or low register), mode/scale (i.e., C major or A minor scales were written on the handout and played by the teacher), types of accompaniments (i.e., rhythmic and melodic ostinato, pedal notes) and appropriate instruments/sounds, dynamics (i.e., soft, medium, loud, crescendo, *pp, p, mf, f, ff*), and tempo (i.e., slow, medium, fast).

During the composition activity, students in either group were working in pairs. Students in the experimental group were using the software MuseScore and the template composition file provided on their computers to create, experiment, and save their work. For the purpose of grading, compositions were collected in the form of MuseScore files.

The template was created to save time in getting started with the task, and to define its limits and length. The pre-selected sounds of the three instruments were piano sound for the melody, vibraphone for the melodic accompaniment and claves for the percussion line. These sounds have been chosen for the template file because they are very commonly used instruments in music classrooms, and their Midi sound reproduction is very close to the acoustic sounds. Thus, not only students were familiar with them, but also, both groups were starting off — at least initially — using similar instrument sounds. Finally, the experimental group was given an additional handout containing some technical information about basic functions of the software, necessary for completing the task.

The teacher technically demonstrated some basic functions of the software for the experimental group. These included inputting notes using the N button, selecting note values, creating a pedal note using whole notes, and entering rhythmic patterns using the Palette. Then students were reminded of the techniques shown in L3-4 which involved using the copy/paste and transpose functions in order to create an ostinato by repeating and shifting the pitch of a pattern and the up/down arrows in order to create variations of a melodic pattern.

In the second composition meeting, students were shown the use of Mixer and how to change instrument sounds. Furthermore, the teacher demonstrated how to insert new instrument lines from the Create Menu, how to alter the tempo using the slider, and how to insert dynamics onto their score using the Palette window. For the third cycle only, students had the opportunity to listen to two or three student compositions from cycle 2.

During the lessons, the teacher provided support as needed by showing technical functions of the program or by listening to individual pairs' composition and advising them on their work. At the end of each 40-min session the teacher collected the files of the experimental group. At the beginning of the second meeting in the third cycle, the teacher gave individual suggestions to several groups according to specific needs.

Students in the control group were working mainly with keyboards and Orff pitched and unpitched percussion instruments, and, in some cases, with other acoustic instruments, such as bouzouki and guitars. Students of the control group used the classroom instruments to experiment, invent, and perform their compositions, which were recorded by the researcher on a portable stereo digital recorder in the form of audio files. In addition, participants were required to notate their works on the stave provided on their handouts, or in any other way they could, such as writing the names of the notes.

Students of the control group were prompted to create melodies and then accompaniments using the techniques presented in L3-4. These included developing and shaping melodies using a motive, creating melodic and rhythmic ostinato by repeating a motive, and creating a pedal point by sustaining a note usually below the melody. In cases where students could not invent melodic motifs and develop them into phrases, the teacher played a motif on students' instruments and demonstrated ways of developing a melody by varying the motivic idea.

The compositions of the control group were recorded by the teacher at the end of the first meeting and were available to students at the beginning of the next meeting, if students wished to hear them. Feedback was given to each team as needed according to individual requests and after student compositions were recorded for the first time. The suggestions offered included the expansion of melodies and accompaniments. At the end of the process, final products were recorded again.

Results

The results presented herein include five separate sub-scores, one for each of the five categories (OM, CM, SR, N, and EE), and a total score for each student composition that represents the sum of the five sub-scores. For the purpose of statistical investigation, the scores assigned to each composition were equally allocated to each member of the group that created it.

A 2 (cycle 2, cycle 3) × 2 (control group, experimental group) MANOVA was conducted on the total score of composition and sub-scores of overall conception (OC), compositional materials (CM), sound resources (SR), notation (N), and emotion evoked (EE) in order to examine the performance of the two groups across the two cycles. The results showed that there was a statistically significant main effect of group for the whole score of composition (F (1, 187) = 180.783, $p < 0.000$, $partial\eta^2$ = 0.492) as well as for all the sub-scores (OC: F (1, 187) = 51.390, $p < 0.000$, $partial\eta^2$ = 0.216; CM: F(1, 187) = 143.916, $p < 0.000$, $partial\eta^2$ = 0.435; SR: F(1, 187) = 145.471, $p < 0.000$, $partial\eta^2$ = 0.438; N: F(1, 187) = 1480.507, $p < 0.000$, $partial\eta^2$ = 0.888; EE: F(1, 187) = 121.148, $p < 0.000$, $partial\eta^2$ = 0.393), indicating that the experimental group outperformed the control group in all the sub-categories.

There was a statistically significant main effect of cycle only for the sub-score of sound resources [SR: F(1, 187) = 4.955, $p < 0.027$, $partial\eta^2$ = 0.026]. Pairwise comparisons between cycles using the Bonferroni test showed that cycle 3 was better than cycle 2 for the sub-score of sound sources (SR).

The cycle × group interaction effect was statistically significant for the whole composition score [F(1, 187) = 4.873, $p < 0.028$, $partial\eta^2$ = 0.025]. Furthermore, an interaction effect was also detected for the sub-scores of overall conception [OC: F(1, 187) = 3.932, $p < 0.049$, $partial\eta^2$ = 0.021], compositional materials [CM: F(1, 187) = 4.107, $p < 0.044$, $partial\eta^2$ = 0.021], and emotion evoked [EE: F(1, 187) = 5.654, $p < 0.018$, $partial\eta^2$ = 0.029]. Although no other statistically significant differences were identified in pairwise comparisons between the total scores of cycles 2 and 3, the interaction effects indicate that there were differences in the performance of the two groups in each cycle. While in cycle 3 the experimental group achieved higher scores than the experimental group in cycle 2, the opposite happened for the control group, which achieved higher scores in cycle 2 than the control group in cycle 3.

DISCUSSION

These findings support that computers helped students to better conceive and work up melodies, countermelodies and accompaniments, develop more complicated and musically coherent orchestrations, and better control dynamics and tempo. Furthermore, the results indicate that the lack of performing skills of the control group students greatly restricted their musical thinking, imagination, expressiveness, and development or expansion of motivic ideas. On the other hand, technology and specifically the software MuseScore enabled musical thinking, effective use of compositional devices, constructs and musical elements, imaginative use of the software and its sound resources, and at the same time supported musical expression and emotion induction.

In addition, based on the findings, students in cycle 3 outperformed students in cycle 2 for the sub-category of sound resources (SR), indicating that students in cycle 3 used more effectively and imaginatively the available resources, and experimented with sounds and materials. This outcome can be explained by the fact that students of the experimental group in cycle 3 were shown some additional technical information about utilizing different sounds. On the other hand, most experimental pairs in cycle 2, generally, did not devote time to explore other instrument sounds, but tried to work out a coherent composition with only the instruments and sounds given and within the guidelines of the task. Only in those cases where students demonstrated interest in changing sounds, adding new instrument lines (such as drums or guitars), and further developing their work, they were shown how to technically to do that. It appears that the predefined three-line instrumentation and the fact that students were not specifically informed about other sound possibilities geared then to use the specified sounds. Thus, in cycle 3 it was deemed appropriate to show these affordances in more detail to all the students, usually at the beginning of the second composition meeting. Particularly, using the Create Menu, students were shown how to add new instrumentation lines and select instruments from various instrument categories. Moreover, from the Mixer Menu, students were shown how to easily change the sounds of their existing lines (for example, change the piano sound to an imaginary electronic sound, such as the sound "music glasses"), how to mute instruments in order to work more effectively on specific lines, and how to adjust the overall volume of a line in order to achieve a better balance for their instrumentations. This was necessary for students in cycle 3 since they were adding more lines than students in cycle 2.

Overall, students in the experimental group in cycle 3 tried out more unique sounds and/or created thicker textures by adding more instrument lines in their orchestrations than the experimental group in cycle 2. Also, some students in cycle 3 experimented by dragging onto their score unfamiliar symbols and materials from the Palette in order to see what their effect would be, including many different note heads, various repeat signs, and other symbols.

While the experimental group utilized the available resources to deliver more sophisticated products in cycle 3 than in cycle

2, the control group in cycle 3 did not take this opportunity to create better musical compositions. It is worth noting that, even though the compositions of the control group have been recorded at the end of the first composition meeting to help students continue from where they left, students did not wish to listen to their recorded works in the second class meeting. According to the students themselves, they did not need to hear what they created either because they remembered their music and/or jotted the note names on their handout or wished to start over a new composition. With very few exceptions, most students did not develop further their work, but instead their products were better during the first rather than the subsequent meetings.

Although students of the control group had at their disposal more electronic keyboards and pianos than students in cycle 2, they used them primarily to find an interesting sound and sometimes to listen to pre-recorded music or rhythms, without eventually employing them in their orchestrations. Students devoted more time pushing buttons and very little effort in developing melodies primarily because most students using keyboards were hardly piano players. Thus, most compositions remained at a very early improvisatory stage without making musical sense. This finding suggests that keyboards do not "speak" to or support students in developing ideas the way computer applications do. However, the use of more sound resources by some control group pairs in cycle 3 inevitably raised somewhat the SR score for the control group in relation to the SR score of its counterpart in cycle 2.

The interaction effect identified for the entire composition score and the sub-scores of OC, CM, and EE, indicate that the proposed guidelines and improvements made in cycle 3 concerning the approach to composition, enabled the experimental group in cycle 3 to score higher than the experimental group in cycle 2. These results were achieved despite the fact that students in cycle 2 were more experienced performers than students in cycle 3. On the other hand, students of the control group in cycle 2 succeeded in scoring higher than their counterparts in cycle 3 due to their prior musical knowledge. These findings support that computers helped musically experienced and non-experienced students to get more engaged with the process of composition, the resources and the musical materials as such than musical instruments.

According to Burnard and Younker (2002) the absence of formal instruction in composition does not affect divergent (imaginative) and convergent (factual) thinking. This explains why students without formal musical instruction were able to invent and develop original ideas using computers. On the other hand, students of the control group with no or little prior musical knowledge did not demonstrate the same level of imaginative or factual thinking as the students in the experimental group with similar musical skills. Rather, their compositions were lacking musical coherence remaining at the exploratory level and had incomplete melodies and orchestrations. Thus, it can be concluded that the approach and software used for the experimental group supported students' divergent and convergent thinking.

Compositional Materials: Rhythmic Development, Compositional Devices, Dynamics, and Tempo

Most experimental teams have completed at least three instrumental lines. Apart from the melody, most of the experimental groups were able to create at least one rhythmic ostinato and one simple melodic accompaniment (including a pedal note, one or two whole note chord tone(s) per measure, or a bordun).

Orchestrations ranged from very simple to very imaginative depending on the number of lines and devices used. Many pairs taking advantage of the software created new instrumental lines and developed more sophisticated and thicker orchestrations with more than three lines. Students included devices such as a counter melody, an imitative second melody, a freestyle note-to-note contrapuntal melody, a harmonic accompaniment with block chords, a melodic and a rhythmic ostinato, or a rhythmical line with varied patterns.

Some experimental groups added more than one rhythmic and/or melodic ostinato. For example, some groups created a contrast and a climax between the two phrases (A and B) by developing different ostinato-based accompaniments for each phrase. Other students used imitation between two melodic lines in phrase A and continued by developing a note to note countermelody as in a free style counterpoint in phrase B. It is important to mention here that these devises or techniques were not presented during the interventions. However, it was not difficult for students to explore this aspect simply by copying figures from one line to the next. Copying and pasting musical text was shown in lessons 3—4 as an approach for developing melodies by varying existing motives, and during the introduction of lesson 5 as an approach for creating an ostinato. Once again, the layout of the software and the copy/paste affordance enabled students to think creatively and imaginatively and to explore and experiment with melodic patterns and materials.

Also, the computer enabled students to explore different rhythmic aspects and to create fascinating rhythms, such as figures with septuplets and descending melodic lines with consecutive 64th-note values that created the effect of impressive glissandi. While computers supported students in creating sometimes complicated and often very effective (musically and emotionally) rhythmic and melodic motives and countermelodies, classroom musical instruments could not facilitate this divergent way of thinking, i.e., the experimentation and invention of interesting and complex rhythmic figures. Even students with advanced musical performance skills –who are a small percentage of the student population– could not perform and therefore could not invent such composite rhythmic figures and orchestrations, let alone to direct and support their fellow group members to do so.

Students in the control group in both cycles did not use melodic ostinato, in their accompaniments. Some dyads of the control group played the melody in unison, without using any other form of accompaniment. Pedal note was only used twice by two groups in cycle 3.

Rhythmic development was very weak in most compositions created by the students of the control group. In most cases, students were not able to create a rhythmic pattern other than the melody, but rather used their percussion instruments to play exactly the rhythm of the melody. Rhythmic ostinato was rarely used, and when employed was a very simple pattern, including tapping on every beat, or on the first and/or third beats, or beating at the end of a motif or in-between motifs where the melody had a rest. Furthermore, the rhythmic organization of melodies was very simplistic, involving very easy one bar motives that repeated throughout.

Most control group compositions did not include composition devices, i.e., accompanying lines of the simplest form. Only four groups of students attempted to create a secondary melody of which the three were in the cycle 3. The two groups (one in cycle 2 and the other in cycle 3) were composing on piano, one dyad on metallophone, and the other on a classical guitar accompanied by two percussion instruments. However, the secondary melodies created on the piano by the two groups were ineffective and quite dissonant because they were played in parallel motion with the melody at the lowest register on the piano, at the intervals of a major second or perfect fourth apart, respectively.

Students did not become aware of the mistake until their presentation time probably due to the noise created by all the groups working simultaneously with musical instruments. Although students tried to revise their composition after their first recorded performance, there was very little change in their melodies and pitch organization during the second or third recordings, while the emphasis was placed on synchronization. Had they been working on computers, students would have probably noticed and corrected the dissonance, and would not have had synchronization issues.

The group working on a metallophone managed to create an effective secondary line that included an ostinato on a pedal note in phrase A and a countermelody that used both parallel and contrary motion to the principal melody. This group, however, did not include any percussion in their composition. The fourth group using a guitar, employed a low E pedal note while playing a simple melody that was based on the repetition of three motives. Although the double stroke on the low E string was more effective and interesting rhythmically, the student changed it to a single stroke during the second meeting and altered somewhat the melodic rhythm. Another group in cycle 1 created only one four-bar melodic line played in unison. During the second recording the melody was spitted between a low and a high octave, creating an imitation or an echo effect when one motive was repeated the same an octave higher.

Dynamics and tempo are elements that control group students hardly considered, as their primary concern was to play accurately the melody notes without stopping. Thus, almost all control group presentations suffer from lack of control in dynamics and tempo.

Students often played at a slower than the desired tempo, i.e., the tempo they designated on their composition diagram. Tempo was usually slow to enable students to perform notes accurately or synchronize when playing in unison. In a few cases the beat was so unstable that the tempo could not be established.

Although several control teams stated on their diagram that their composition would be played either loud, soft of medium loud, all groups maintained the same dynamics throughout at an *mp-mf* level, indicating that they had no control of dynamics to influence emotion. Since, there were no contrasts in dynamics, no musical expression was reflected. Control of musical expression greatly depends on fluency and performance level. It is thus very difficult for students to demonstrate expressiveness and evoke emotions in the listeners while performing their under-practiced newly invented compositions, considering that the average performance level in schools is at an introductory stage.

On the contrary, control or change of tempo was a very easy task for experimental students. Faster tempo was used often as a means to unify musical patterns and shapes in cases where bigger note values or scattered notes were used, and/or for creating a more happy and lively emotional effect. Furthermore, students in experimental teams manipulated dynamics, and shaped musical phrases or controlled the balance between instruments by dragging dynamics markings from the palette on as many notes and lines they needed. Thus, they manually crafted very effective crescendos, built up climax and created fade outs. Some groups also adjusted the overall balance of their instrumentations by changing the overall volume level of each instrument.

Musical Emotions and Technology

In this study, the affordances of technology transformed musical composition into a more practical, understandable, and efficient process. At the same time technology transformed listening-and-analysis into a more targeted, explainable, and pleasant activity by enabling animations, explorations, and experimentations of musical structures and materials. Since empirical research confirms that music expresses emotions (Sloboda and Juslin, 2001; Hargreaves et al., 2012; Juslin, 2013) or carries an "emotional charge" (Paynter, 2002), therefore, any musical undertaking (listening, composing, performing) also involves expression or perception of emotions. Moreover, several studies in the literature of music psychology mapped musical features (such as tempo, mode, harmony, loudness/dynamics, pitch, intonation, intervals, articulation, rhythm, timbre, etc.) to particular emotions (Juslin and Laukka, 2004; Gabrielsson, 2009).

Thus, while students in this study were using or manipulating musical selections, elements, structures, and devices, emotions were also manipulated. When students were shaping melodies or patterns and developing orchestrated musical sentences by changing and adding musical materials, the emotional expression was also formed, sculpted, and varied as well. The emotional effects of musical materials and the affective expressions of compositions created with computers were clearer and stronger because tools guided students' thinking process and played accurately whatever variations or manipulations students made. Furthermore, the emotional understanding of musical features or excerpts was better when the cognitive aspects were better understood. This means that where technology supported the understanding of musical elements it also supported the understanding of emotional expression.

These observations imply that emotions were not only induced, expressed, perceived, or felt, but were also transformed

through the use of tools inasmuch as the musical content was transformed. Musical emotions were transformed as students were isolating and experimenting with musical parameters, instantly experiencing certain emotional effects, and associating musical materials with emotional meanings. More importantly, musical emotions were generated and transformed throughout the creative processes as students were trying out, controlling, and adding new materials and ideas using the available resources. These transformations were only possible because of the affordances of technological tools.

Student composers of the experimental group were able to listen to whatever changes they made, and feel or perceive as audience-listeners the emotional effects of these modifications. Whereas, student composers of the control group were performers, composers, and listeners at the same time, and, to the extent that it was possible, they were experiencing weaker emotions because of their weaker control of materials.

Musical emotions in this study were approached both cognitively and emotionally. Cognitively, because students were understanding emotions in relation to the musical materials that evoked them, and emotionally because through musical experiences (listening and composing) they perceived and felt the emotional impact of the music, or the "feelingfulness" to put it in Swanwick's words.

Although our understanding on how the brain mechanisms process emotion in music is still incomplete (Aljanaki et al., 2016), future advancements in neuroscience will hopefully explain how sound is processed into emotions in our brain. Furthermore, forthcoming developments concerning music emotion recognition (MER) research, and in particular the computational methods and algorithms that explore the musical features and mechanisms underlying music emotional expressiveness (Yang and Chen, 2012), may also support educational endeavors (music applications and lesson designs) in better classifying and explaining the connections between music and emotions.

Conclusion

The empirical findings in this research study sustain that appropriate use of technology can effectively engage and support inexperienced students in understanding musical materials and structures and in using them to create musically meaningful and expressive compositions. In this study the notation program MuseScore has been exploited in two core areas of music education, listening and composition. The empirical findings sustain that technology can be effective only if carefully planned and integrated in the lesson design targeting at curricular objectives and at explaining specific features and procedures of the music. Although many other music technology tools can be used to facilitate learning, their use in the classroom does not automatically ensure effectiveness in learning. For this reason, "promising" and attractive music tools need to be investigated and carefully infused based on the TPCK framework and the proposed music design guidelines that constitute a clarification of the second and third TPCK principles (Angeli and Valanides, 2009). This approach is necessary in order to avoid musical learning that remains on the surface and student products that

lack musical coherence and expressiveness, as is often the case with music technology integration.

Technology integration in this study aimed at enabling students, regardless of prior musical experience, to understand and follow the underlying musical materials and constructs and the emotional meaning of the music, to visualize what is heard and not "seen" and to guide creative musical thinking. Notation programs, and in particular MuseScore, can be used for visualizing concepts through short and reduced musical examples, manipulating or exploring elements, completing creative tasks, and developing musical compositions.

Through exploration and experimentation with the different parameters of individual musical features, the program enables the development of associations between the cognitive and affective aspects of musical materials. While this type of software supports manipulation of individual musical elements or combinations of them, at the same time it reinforces the understanding about the role of each of these features in the structure and emotional expression of the music. It is because of this link between the musical materials and emotions, that students who performed well on the cognitive aspects were also able to better understand their emotional effects.

The effectiveness of the software lies in the short and manageable length of the excerpts exemplifying musical concepts and the adjustable tempo at which they can be played. Furthermore, the environment of MuseScore scaffolds the inexperienced readers through the piano-roll depiction of the melody, the synchronization of audio and visual information, and the playback cursor which enables students to follow the score without getting lost. The advantage of using MuseScore in learning and understanding music over musical instruments is that the former allows students to focus on the musical transformations and the musical experience itself without the great amount of effort and knowledge needed to perform the musical text.

On the other hand, although performing in-class activities are essential in music education, they do not guide musical understanding and thinking as effectively as technology, partly because musical instruments do not have the affordances of technology and partly owing to the complexity of performing especially for the inexperienced students. Using the same tool for learning, experimenting and creating, helps students, first, to become familiar with the technical functions of the environment, the musical materials and the creative techniques, and second, to apply them effectively in composition tasks.

Knowing that formal performance instruction and prior musical experiences greatly influence compositional approaches and pathways (Burnard and Younker, 2002), it can be concluded that lack of such knowledge restricts musical thinking, expressiveness, development of motivic ideas, and creativity. On the other hand, knowing that the absence of formal instruction in composition does not affect divergent (imaginative) and convergent (factual) thinking (Burnard and Younker, 2002), it means the use of appropriate technology can support students without formal musical instruction to invent and develop really original ideas. Thus, the empirical findings in this study confirm that MuseScore can support students to better conceive and work

up melodies, countermelodies and accompaniments, develop more complicated and musically coherent orchestrations, and effectively use musical materials and constructs, including pitch, rhythm, dynamics, tempo, etc. Furthermore, this technology can enable musical thinking, imaginative use of the software and its sound resources, and at the same time support musical expression and emotion induction. Thus, musically experienced and non-experienced students can get more engaged with the materials and the process of composition a meaningful and feelingful way by using computer applications than by using musical instruments.

FUTURE DIRECTIONS AND CONCLUDING REMARKS

The approach advocated in this research is grounded in the linking of music cognition with the perceived musical emotions and the affordances of technology through the TPCK framework. The advantage of using computer software (irrespective of how "traditional" the musical approaches seem to be) is that they allow of experimentation with musical materials and discovery of their emotional effects, and support students' divergent and convergent thinking in subsequent creative tasks. The proposed set of music design guidelines is an approach that aims to facilitate musical learning and development "in a spiraling, endlessly recursive process" (Bamberger, 2006, p. 73) while incorporating affect in the learning process.

The authors in this study provided examples and empirical findings for student compositions to support the design methodology and instructional principles proposed for guiding technology integration in music education. As the study connects

affect and cognition with the affordances of technology in the design process, it enriches the theory of TPCK with the affective domain and contributes to the conceptualization of TPCK both for practitioners and researchers. It can serve as a reference point for future studies that seek to develop theories and methodologies in instructional design in other domains, including the creative arts, literature and languages, etc., and provide teachers with guidance on learning design. Undoubtedly, including affect in the design process is a complex and mostly unexplored area, and, thus, further investigations toward this direction of research are fully warranted.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Pedagogical Institute of Cyprus. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

The present manuscript is part of the doctoral thesis of EM. CA is the academic advisor of EM. Both authors contributed to the article and approved the submitted version.

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APPENDIX

Composition Assessment Form

| Recording No./ Name |
| Or name of Midi File _____ |
| |
| Class_____ School Name_____ |
| |
| **TOTAL POINTS** _____ |

Please use the following criteria to rate this composition from the recording or midi file.

Overall conception (15 p.)

	5 4 3 2 1 0	
Musically coherent	☐☐☐☐☐☐	Not musically coherent
Highly imaginative	☐☐☐☐☐☐	Lack of imagination
Conveying mood	☐☐☐☐☐☐	Not conveying mood

Compositional materials (30 p.)

Motivic/thematic ideas effectively developed	☐☐☐☐☐☐	Motivic/thematic ideas ineffectively developed
Pitch organization wholly convincing (melodic motion and shape, scale, antecedent, consequent)	☐☐☐☐☐☐	Pitch organization unconvincing
Appropriate use and development of rhythmic features	☐☐☐☐☐☐	Inappropriate rhythmic development
Appropriate use of compositional devices (ostinato, pedal point)	☐☐☐☐☐☐	No or inappropriate use of devices
Appropriate use of Dynamics	☐☐☐☐☐☐	No or inappropriate use of dynamics
Experimented with tempo/steady tempo/appropriate use of tempo	☐☐☐☐☐☐	Inappropriate or unsteady tempo

Sound resources (10 p.)

Technically informed use of resources (software or musical instruments)	☐☐☐☐☐☐	Insufficient knowledge of resources
Highly imaginative use of resources	☐☐☐☐☐☐	Unimaginative and inept (unskilled) use of resources

Notation (5 p.)

Clarity and accuracy of notation, excellent quality of presentation	☐☐☐☐☐☐	Incomplete, messy, inaccurate, or lack of notation, poor quality of presentation

Appropriate use of musical elements to evoke emotion (25 p.)

Tempo	☐☐☐☐☐☐	**No or inappropriate use of elements for eliciting emotion**
Timbre (sounds, instruments, orchestration)	☐☐☐☐☐☐	
Mode (major/minor)	☐☐☐☐☐☐	
Melody/Pitch/Register	☐☐☐☐☐☐	
Dynamics	☐☐☐☐☐☐	