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Use of digital audio workstations in music education to develop creative thinking and increase self-efficacy

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Abstract
Digital audio workstations can be used to develop creative thinking in music students while practicing music production. This research aimed to study the effectiveness of the Pyramix software for the development of creative thinking and musical self-efficacy of Chinese music students. It enrolled 200 students with a mean age of 21.8 years. The effectiveness was determined through the comparison of pre-and post-test results in the experimental and control groups. Self-report measures were employed in the study: the Torrance Test of Creative Thinking (TTCT) for assessing creative thinking and the Musical Performance Self-Efficacy Scale (MPSES) for evaluating musical self-efficacy. In the experimental group, there was an increase in creative thinking in all five subscales during the post-test: originality, elaboration, abstractness, and resistance to premature completion increased by 19.26%, 18.23%, 11.04%, 10.40%, and 15.09%, respectively. The differences were significant and confirmed the effectiveness of using stations to develop creative thinking. However, their use did not have a positive effect on musical self-efficacy in terms of mastery experience, vicarious experience, and verbal/social persuasion. Intergroup differences were not significant; only the physiological state significantly increased by 8.72. This research is significant because it gives information on the effect of digital audio workstations in music education on the development of students' creative-thinking skills through the contribution to existing music knowledge and literature. The findings may be of interest to researchers and educational institution managers, who are interested in enhancing creativity skills.

Keywords Creative thinking · Digital audio workstations · Music education · Music production · Musical self-efficacy

Background

Music is inherently a complex matter with countless variables such as rhythm, melody, harmony, and dynamics, which are intertwined to create a cohesive piece (Zhang, 2022). Music education is distinguished by its effect on cognitive, emotional, and social development (Agnoli et al., 2019). Musical education is distinctive in that it influences the development not only of cognitive skills, such as attention and memory but also contributes to emotional well-being and social integration, unlike other forms of education that may not exert such a comprehensive impact on all these aspects of development. In other words, music can have an impact in ways that go far beyond melodies and musical compositions, from boosting creativity and critical thinking to acquiring musical skills (Tan et al., 2019; Zhang, 2023b). Modern technologies allow music education to improve and progress (Beldean & Constantin, 2022). Traditionally, music education has been focused on acquiring technical skills based on existing musical works; however, with the integration of modern software and technical computer developments, music education can be considered a way to improve creative thinking (Agnoli et al., 2019). In music education, the integration of technology has opened up new opportunities for creativity and research and digital audio workstations (DAWs) are of scientific interest (Bennett, 2018). They include a software application that allows for recording, editing, and playing back digital audio with unprecedented flexibility and accuracy (Bell et al., 2015). Incorporating the DAW as an interactive medium into music education can affect the development of students' creative thinking by creating a platform where their musical ideas

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can be transformed into artistic expression (Gooderson & Henley, 2017; Marrington, 2017).

Creative thinking is a pivotal component of innovation and progress across various domains, from art to science and business, encompassing the ability to transcend traditional ideas, rules, and patterns to generate original and effective solutions. Developing this skill is crucial not only for personal expression and self-realization but also for adapting to the rapidly changing conditions of the modern world, where innovative ideas become a key factor for success. In an educational context, especially in musical education, an emphasis on fostering creative thinking helps students not only enhance their technical performance and compositional skills but also fosters the cultivation of a unique creative voice. This, in turn, supports innovation in the music industry and culture at large, making the promotion of creative thinking a significant undertaking in contemporary education. The development of creative thinking is critical for people, it improves problem-solving ability, promotes adaptation, stimulates innovation and entrepreneurship, promotes self-expression and communication, strengthens critical-thinking skills, and promotes continuous learning, growth, and emotional well-being (Agnoli et al., 2019; Dempsey & Comeau, 2019; Ritter & Ferguson, 2017; Sihombing et al., 2020; Zhang, 2023a).

Thus, the topic of the effect of digital audio workstations on the development of creative thinking and increasing self-efficacy in music education may be of scientific interest (Pendergast, 2021). The current paper describes how a certain DAW can be used to develop students' creativity and be considered as a way to increase their musical self-efficacy. The research hypothesis was that students, who studied with a DAW, showed higher creative thinking and self-efficacy than those who received a classical music education at their institution. The scientific value of this paper lies in its contribution to the discussion about the impact of advanced technologies on creative thinking in music education. This research is practically significant because it answered questions about how educational institutions can use modern digital technologies to develop creative skills.

Literature review

The essence of music lies in the fusion of individual, cultural, and global artistic principles, which represent the collective manifestation of vitality, rhythm, social consciousness, and historical context (Murodova, 2021). Music plays a decisive role in shaping a person's ethical and aesthetic preferences, nurturing emotional sensitivity, and helping to stimulate his/her creative abilities (Zhang, 2023a). In the context of creativity and creative thinking, the musical environment promotes the creation of a piece of music that is original and has practical value (Odena, 2018). However, creativity is a multidimensional concept and educational institutions do not always pay attention to the development of students' creative abilities. They base on knowledge and miss the opportunity to improve the effectiveness of pedagogical practices (Lasky & Yoon, 2020).

The scientific world widely discusses creativity and ways to increase it using technology (Cheng, 2023; Murcia et al., 2020; Ramón & Chacón-López, 2021; Wan, 2023). To broaden the understanding of the terms that are discussed in this context, it is important to consider creativity, creative thinking, and musical creativity, which are related concepts but have different characteristics (Lasky & Yoon, 2020; Odena, 2018). Creativity refers to the ability to generate new ideas, products, and solutions thus creating something new that did not exist before (Rosenhan & Galloway, 2019). Creative thinking is a cognitive process that is directly related to the generation of creative ideas and innovations and also includes divergent and convergent thinking (Zhang et al., 2020a). Musical creativity has a narrower specification and refers to the creation of new and meaningful musical ideas or compositions, including the ability to compose original melodies, harmonies, rhythms, and lyrics, and apply innovation in terms of interpretation, improvisation, and sound production (Gorbunova & Chibirev, 2019).

Modern digital technologies can help tailor music education to individual needs thus allowing the exploration of genres, techniques, and musical concepts (Wan, 2022), as well as comprehensive assessment in music education (Dai, 2022). Through interactive interfaces and software, students can engage in creative exchanges, where their ideas and musical preferences are dynamically used with modern programs (Zhang et al., 2020b), which can both increase educational productivity and provide additional creative-thinking skills (Cheng, 2023).

Digital audio workstations (DAWs) are applications or software tools for recording, editing, mixing, and creating digital audio (Reuter, 2022). DAW has a wide range of functions that allow for performing a variety of manipulations with sound: cutting, pasting, rearranging fragments, adjusting volume levels, applying effects, and adjusting the sound (Bell, 2015). Moreover, this software also offers virtual instruments and synthesizers that can be played and recorded with MIDI controllers or programmed with sequencers (Bolter, 2019). In addition, there are mixing tools for balancing and enhancing individual tracks, adjusting panning and stereo imaging, and applying various audio effects such as equalizer, compression, reverb, and delay (D'Errico, 2016). They also simplify arranging multiple tracks to create a cohesive piece of music, provide the ability to manage audio files, project files, and session data to

improve navigating and collaborating on music projects, and provide options for exporting finished compositions to a variety of formats including high-quality audio files suitable for distribution or further mastering (Clauhs, 2020).

Practice in music production software has been reported to improve creative-thinking skills (Cheng, 2023) and dedicated music applications are widely used in this context (Ng et al., 2022). The creative processes for producing music involve different brain areas and promote neuronal plasticity, i.e. the brain's ability to reorganize and form new connections (Cavdarbasha & Kurczek, 2017). For example, damage to one part of the brain, the hippocampus, decreases divergent and convergent thinking (Duff et al., 2013; Warren et al., 2016). Music production activates a network of brain regions thus improving neural connections and promoting creative thinking (Greenberg et al., 2021). Working with music involves auditory perception, fine motor skills for playing instruments or singing, and sometimes the visual representation of musical notation, while sensory data integration enhances cognitive flexibility (Brancatisano et al., 2020). Music production involves emotional and expressive aspects that stimulate the limbic system, including the amygdala and hippocampus (Shirsat et al., 2023). Emotions can inspire original ideas, evoke imaginative thinking, and facilitate the exploration of multiple perspectives, and music in particular has a profound effect on emotions (Putkinen et al., 2021), which can influence the generation of ideas. Music production promotes neuroplasticity, i.e. the brain's ability to reorganize and adapt through the formation of new connections, which stimulate the growth of synapses and strengthen the neural pathways associated with cognitive skills (Altenmüller & James, 2020; Papatzikis & Rishony, 2022). Thus, researching whether music production will positively affect creative thinking has a scientific basis and may be of scientific interest.

Along with creative thinking, self-efficacy is also very important in music as it affects musicians' motivation, performance confidence, skill development, creativity, goal achievement, and emotional well-being. Cultivating and nurturing self-efficacy can provide a more fulfilling and successful musical experience (Zelenak, 2020). Social cognitive theory (Bandura, 1997) provides a theoretical explanation of how people use cognitive and behavioral information to shape their lives. Previous research has explored creative thinking, self-efficacy, and modern technology in tandem (Brett, 2019; Chang et al., 2019; Lewis & Hendricks, 2022), which is a promising topic for future research.

The influence of musical education on creative thinking and self-efficacy

Recent research confirms the significance of musical education in shaping and fostering creative thinking, as well as enhancing students' levels of self-efficacy. Empirical evidence suggests that engaging with music improves cognitive functions, which, in turn, impacts creative abilities and self-belief. The literature presents both similarities and differences in findings regarding the influence of musical education. Some studies underscore its universally positive effects, while others highlight the contingencies and the dependency of effects on specific educational methodologies and individual student characteristics. Literature reviews reveal gaps associated with insufficient studies focusing on the influence of musical education on creative thinking and self-efficacy, emphasizing the necessity for further research in this domain. Research questions aim to address inquiries such as how the use of Digital Audio Workstations (DAWs) affects creative thinking and self-efficacy. Can an intervention program, involving a standardized DAW integration protocol, have a statistically significant impact on the constructs under investigation? Based on the literature review and identified gaps, the following hypotheses were formulated for the current study: (1) the use of DAWs will contribute to enhancing students' creative thinking, as evidenced by the analysis of pre-and post-test results; (2) the use of DAWs will increase students' self-efficacy in musical performance, confirmed through test result comparisons; (3) the intervention utilizing DAWs will lead to significant differences in creative thinking and self-efficacy between control and experimental groups.

The motivation behind instrument selection for assessing creative thinking and self-efficacy

The Torrance Test of Creative Thinking (TTCT) and the Musical Performance Self-Efficacy Scale (MPSES) are widely used instruments for measuring creative thinking and self-efficacy, respectively (Alabbasi et al., 2022; Bersh, 2022). The TTCT assesses creative abilities through tasks aimed at eliciting originality, flexibility, elaboration, and so forth (Acar et al., 2023). The use of the TTCT enables the acquisition of quantitative data regarding individuals' creative potential, thereby identifying both strengths and weaknesses in the creative process (Acar et al., 2021). The MPSES measures individuals' confidence levels in their abilities for musical performance, which is significant for musical education and professional practice (Çiftçibaşı, 2021). Both instruments demonstrate high reliability and validity in various studies, affirming their effectiveness in measuring levels of creative thinking and self-efficacy

(Börekci et al., 2023; Cooper, 2021). However, it is important to consider that, like any self-report measures, they may be subject to subjective perception and social desirability, necessitating a careful approach to testing procedures and interpretation of results (Barbot & Said-Metwaly, 2021; Said-Metwaly et al., 2021). In the context of experimental design, the use of TTCT and MPSES may be expedient for assessing the impact of educational interventions, such as the implementation of Digital Audio Workstations (DAW), on creative thinking and self-efficacy. They provide structured and reliable measurement methods that can contribute to a profound understanding of the effects exerted.

Problem statement

This research aimed to investigate the effectiveness of using digital audio workstations (DAWs) on the development of creative thinking and musical self-efficacy in Chinese music students. Specifically, it aimed to evaluate how integrating DAW into music education can impact creative-thinking skills and self-efficacy. At baseline, the authors the following research tasks:

1. To investigate the impact of DAW on creative thinking in groups A (control) and B (experimental) by comparing the results of pre-tests and post-tests.
2. To investigate the effect of DAW on self-efficacy in musical performance in groups A (control) and B (experimental) by comparing the results of pre-tests and post-tests.
3. To determine whether the intervention affected the respondents' creative thinking and musical self-efficacy and to define the significance of these differences.

Based on the specified research objectives, the conceptualization of the procedure and experimental plan entail a comprehensive approach to studying the impact of Digital Audio Workstations (DAW) on creative thinking and self-efficacy in musical performance. The experiment involved two phases: a pre-test phase to assess the initial levels of creative thinking and self-efficacy using TTCT and MPSES, respectively, and a post-test phase after the intervention with DAW. Groups A (control) and B (experimental) will be compared to determine the effects of the intervention. This approach aimed not only to evaluate the direct effects of DAW on the specified aspects but also to align the results with the research aims and objectives, thus ensuring the integrity of the research design and its compliance with contemporary requirements for such experimental studies in the field of musical education.

Materials and methods

To measure creative thinking, the authors used the Chinese version of the figural Torrance Test of Creative Thinking (TTCT) with five subtests: originality, fluency, elaboration, title abstractness, and resistance to premature termination. This test had already been used in previous studies in the Chinese context and was valid (Zhang et al., 2020a). The scores for each subscale were ranked as follows: originality, 40–160; fluency 40–154; elaboration, 40–160; abstractness, 40–160; and resistance to premature termination, 40–160. Standard scores for each of the five standard indicators were averaged to obtain overall creativity (Torrance, 1998).

To measure musical self-efficacy, the authors used the Musical Performance Self-Efficacy Scale (MPSES) (Zelenak, 2011), which had been studied in different cultural contexts (Börekci et al., 2023). The MPSES had not yet been tested in a Chinese context; so, professional translators and a psychologist translated it for this study. The scale contained 24 tasks that reflected four sources of self-efficacy: mastery experience, vicarious experience, verbal/social persuasion, and physiological state. The scale included an agreement with each item, from strong disagreement (0) to strong agreement (100). The researchers tested the translated version with Cronbach's alpha; it had coefficients of internal consistency $\alpha = 0.91$ for mastery experience, $\alpha = 0.92$ for vicarious experience, $\alpha = 0.90$ for verbal/social persuasion, $\alpha = 0.93$ for the physiological state, and $\alpha = 0.92$ for the entire scale.

Participants

A total of 200 third-year students from two Chinese universities participated in the study. There 100 students from university 1 (50 males and 50 females) as well as 100 students from university 2 (50 males and 50 females). Each university provided an equal number of participants to ensure a representative sample. The participants were undergraduate students majoring in music and enrolled in music-related programs.

The respondents were invited to take part in the study by verbal invitation during the lesson. Their age at that time ranged from 20 to 22 years (SD = 21.8). Their participation was voluntary and the students were informed of the possibility to withdraw, if necessary. The participants were randomized into control and experimental groups: $n = 100$ in each with even gender ratios.

Research design

In this study, the Pyramix software was used as an example of a digital audio workstation, which allowed for various

actions to produce music (Merging, 2023). The research took place from September 2022 to May 2023. Pre-test and post-test designs were used to measure changes in creative-thinking abilities and musical self-efficacy before and after DAW exposure using the Pyramix as an example. Participants were assessed for creative thinking and musical self-efficacy at baseline and again after ten months using online testing (Fig. 1).

A standardized DAW integration protocol was developed specifically for this study. It outlined specific activities, tasks, and projects that the experimental group was asked to perform using the DAW. The control group followed the existing music curriculum without DAW. Figure 2 shows an example of the Pyramix software interface. The students worked with audio tracks and produced new musical compositions.

The protocol included tasks for working with audio files as well as producing new melodies, music, and songs. The experimental group had two one-hour sessions per week: eight per month for a total of 80. Especially for this study, the authors involved 10 music teachers from two educational institutions, who had at least one year of experience with DAW and taught these lessons in their mini-groups (10 students per 1 teacher). At the beginning of September, after pre-tests in two groups, students from the experimental group (B) received access to Pyramix and were trained on how to use the software. The experiment lasted until the beginning of May 2023; after that, the researchers conducted post-tests in the control and experimental groups.

Data analysis

Quantitative data collected from the creative thinking and musical self-efficacy scores were analyzed using statistical methods and the non-parametric Mann-Whitney U test in SPSS.

Ethical issues

The university authorities approved this research. The researchers obtained informed consent from all participants. The ethical principles of the study were strictly adhered to throughout the research.

Results

The first research task was to investigate the impact of DAW on the creative thinking in groups A (control) and B (experimental) using Pyramix by comparing pre-test and post-test scores on five subtests: originality, fluency, elaboration, title abstractness, and resistance to premature closure. Table 1 shows the results of creative thinking pre-tests and post-tests using the Torrance Test of Creative Thinking (TTCT) in the two groups.

The results of post-tests demonstrate the increase of indicators in the experimental group and their stagnation in the control group because they have not changed significantly over ten months. On the contrary, in group A, the indicators increased: the highest mean value was for originality and its post-test score was 104.74 thus demonstrating an increase of 19.26% compared to the pre-test. Fluency also increased from 83.42 to 98.63, i.e. by 18.23%. Elaboration and

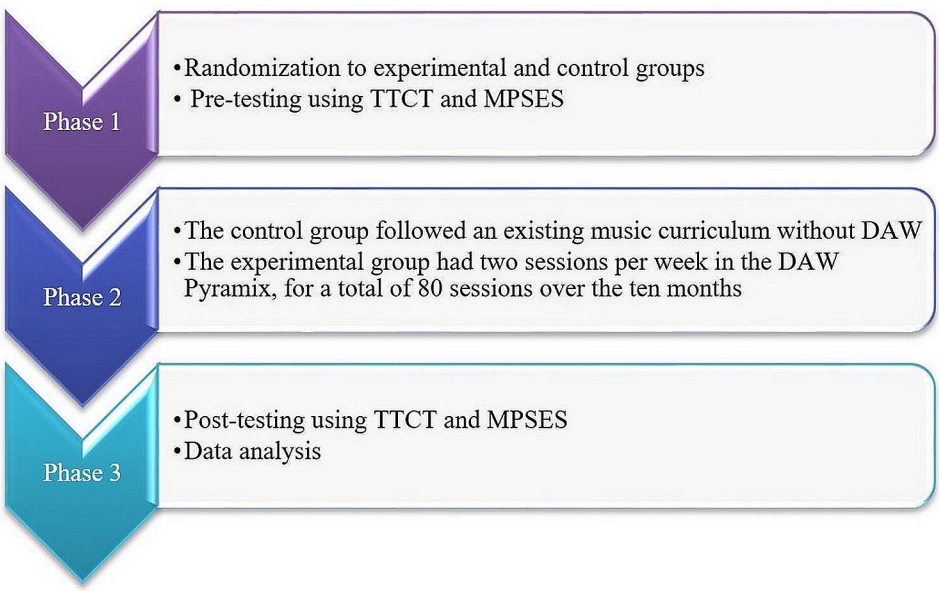


Fig. 1 Graphical research model

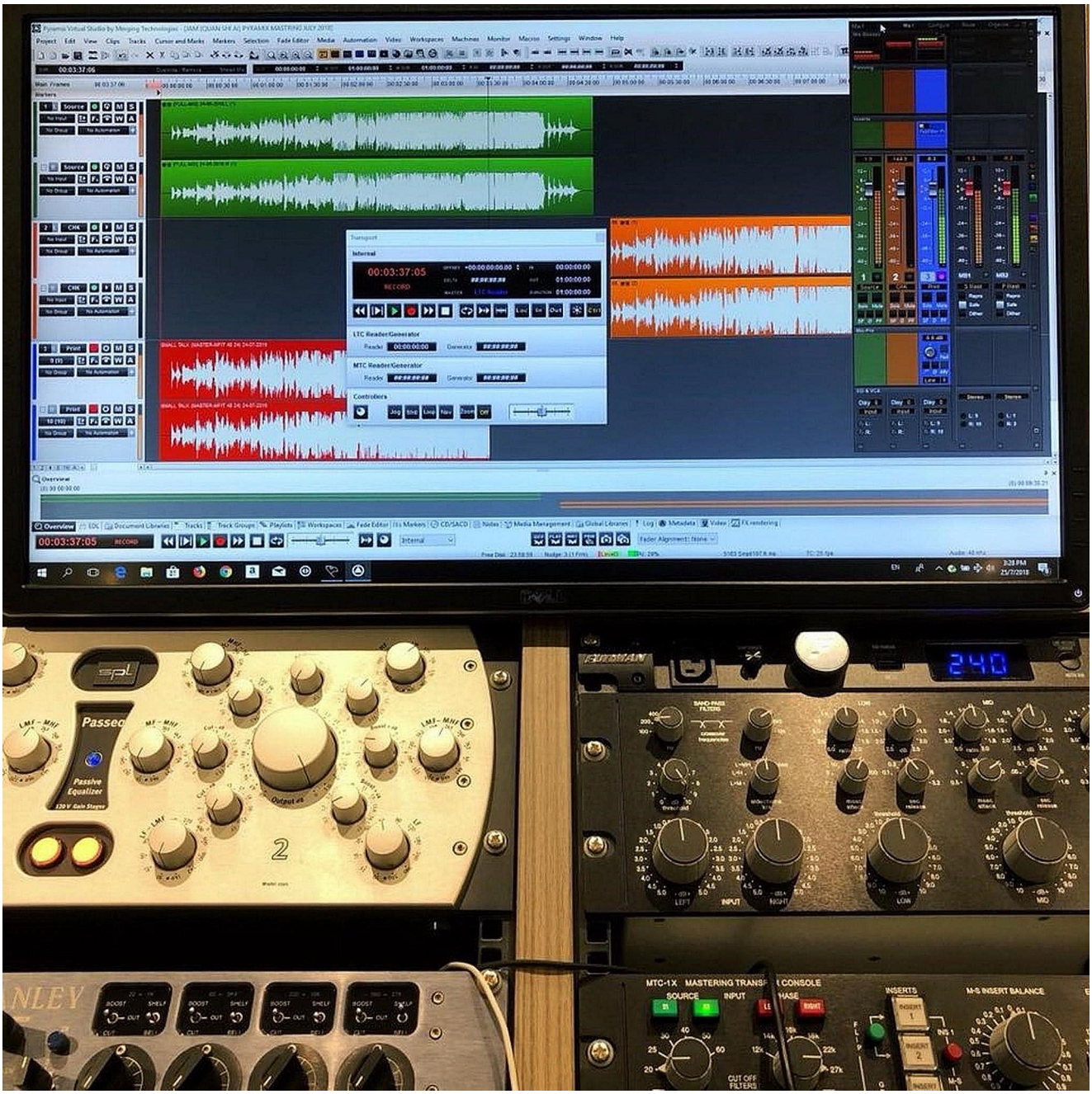


Fig. 2 Example of the Pyramix interface

abstractness increased by 11.04% and 10.40%, respectively. Resistance to premature termination also increased in the experimental group: from 86.33 to 99.36, i.e. by 15.09%.

The second research task was to investigate the effect of DAW on musical self-efficacy in groups A (control) and B (experimental) by comparing pre-test and post-test scores using the Music Performance Self-Efficacy Scale (MPSES) (Table 2).

Post-test results show that musical self-efficacy was not positively affected by digital audio workstations because pre-test and post-test scores did not increase for master experience, vicarious experience, and verbal/social persuasion. At the same time, the physiological state increased from 267.60 to 290.93 (by 8.72%) according to the post-test in the experimental group and did not change significantly in the control group.

The third research task was to determine whether the intervention affected the respondents' creative thinking and musical self-efficacy and to define the significance of these

Table 1 Results of creative thinking pre-tests and post-tests by TTCT subtests in control (A) and experimental (B) groups

		Originality, pre-test	Originality, post-test	Fluency, pre-test	Fluency, post-test	Elaboration, pre-test	Elaboration, post-test	Abstractness, pre-test	Abstractness, post-test	Resistance, pre-test	Resistance, post-test
Group A	Mean	86.93	87.34	85.47	85.32	85.91	87.84	88.47	86.50	86.30	85.20
	Standard deviation	10.962	10.071	9.758	11.279	12.793	12.620	11.731	12.121	13.005	12.219
	Standard error of the mean	1.096	1.007	0.976	1.128	1.279	1.262	1.173	1.212	1.301	1.222
	Excess	−1.316	−1.235	−1.161	−1.396	−1.146	−1.145	−1.327	−1.367	−1.280	−1.406
Group B	Mean	87.82	104.74	83.42	98.63	87.06	96.67	88.22	97.39	86.33	99.36
	Standard deviation	10.977	3.243	10.021	6.192	13.011	4.441	10.929	4.264	12.744	5.471
	Standard error of the mean	1.098	0.324	1.002	0.619	1.301	0.444	1.093	0.426	1.274	0.547
	Excess	−1.221	−1.104	−1.256	−1.117	−1.285	−0.962	−0.793	−0.930	−1.245	−1.126

differences. Tables 3 and 4 show the significance of differences between the experimental and control groups.

There were significant intergroup differences in the Torrance Test of Creative Thinking scores across all five subscales ($P = 0.05$). This confirmed that the differences were significant and the Pyramix DAW demonstrated the positive impact of music production on the creativity of music students.

Only the physiological state had a significant difference thus showing that music production in digital audio workstations using the example of Pyramix could not comprehensively increase musical self-efficacy. These results indicate the need for further research.

Discussion

The post-test results in the current research showed a significant increase in the experimental group scores and confirmed the positive impact of digital audio workstations on creative thinking. Some previous studies have also focused on confirming these findings (Cheng, 2023; Murcia et al., 2020). For example, Cheng (2023), investigated how music production software improved creative-thinking skills in music in 300 respondents. The researchers found improvements in four musical dimensions: musical length (ML) improved by 66% and 66.5% and musical flexibility (MF) increased by 41.6% and 36.2%, respectively. Musical originality (MO) improved by 48.3% and 37.9% and musical syntax (MS) increased by 46.7% and 41.3%, respectively. Ramón and Chacón-López (2021), assessed the effect of musical improvisation on the development of children's creative thinking and found that creativity was significantly stimulated through musical improvisation with a significant increase in the four musical factors in both groups with major progress in musical originality and musical syntax, which also was similar to the current findings.

In addition, Ritter and Ferguson (2017), confirmed the connection between music and creative thinking. Also, Murcia et al. (2020), studied digital coding and how it affected the creativity of a focus group and found that the use of the BeeBot iPad application had a positive effect on children's creativity. Also, another research investigated the effect of interactive technologies on the development of creative abilities using the Torrance Test of Creative Thinking and revealed its effectiveness (Xing & Qi, 2023).

As for digital audio workstations (DAWs), according to Pendergast (2021), they can be used for creative projects in the music classroom, and serve as fundamental musical, creative, and technological concepts for music production. Bogunović (2019), reviewed theoretical and empirical research in the cognitive psychology of music, psychology

Table 2 Results of musical self-efficacy pre-tests and post-tests by four MPSES sources in control (A) and experimental (B) groups

		Mastery experience. pre-test	Mastery experience. post-test	Vicarious experience, pre-test	Vicarious experience, post-test	Verbal/social persuasion, pre-test	Verbal/social persuasion, post-test	Physiological state, pre-test	Physiological state, post-test
Group A	Mean	388.36	382.76	287.95	285.49	364.83	363.68	272.10	267.59
	Standard deviation	28.277	27.542	21.036	20.788	32.515	31.348	24.591	23.494
	Standard error of the mean	2.828	2.754	2.104	2.079	3.252	3.135	2.459	2.349
	Excess	−1.058	−1.153	−1.225	−1.396	−1.295	−1.180	−1.178	−1.140
Group B	Mean	390.96	383.94	285.02	286.86	359.53	362.47	267.60	290.93
	Standard deviation	28.303	27.807	20.847	19.394	31.486	31.966	25.014	19.687
	Standard error of the mean	2.830	2.781	2.085	1.939	3.149	3.197	2.501	1.969
	Excess	−1.195	−1.194	−1.184	−1.302	−1.350	−1.344	−1.345	−1.284

of creativity, and interdisciplinary research on creative cognitive processes in composing music, and found the relationship between creative thinking and composing music, which also echoed the current findings. Also, Sabet (2019), described the experience of composing original music using GarageBand for iPad in secondary school, which contributed to the creation of a student-centered learning environment, equal access, and engaged communities, and also demonstrated itself as a constructive way to effectively integrate technology in the classroom. Students demonstrated a tangible understanding of these standards thus confirming the possibility of implementing such software or DAWs. Also, Chang et al. (2019), discussed the impact of 3D computer-aided design on the creative self-efficacy and productivity of design students. The study found that the use of 3D-CAD significantly increased students' creativity and strengthened their creative self-efficacy, especially in counteracting external negative evaluations of their creative products with positive beliefs (Chang et al., 2019). In part, this echoed current findings regarding an increase in the fourth source of self-efficacy, a physiological condition that described how the music made a person feel better, enjoy musical projects, learn to control nervousness during performances, and appreciate positive memories of most or all past musical performances (Zelenak, 2011). This topic is promising for future research to fill existing gaps.

Thus, the current study makes a significant contribution to understanding the influence of Digital Audio Workstations (DAW) on the development of creative thinking and musical self-efficacy among students. Theoretically, it corroborates and extends previous findings regarding the positive impact of music software on creative abilities, providing additional evidence within the context of Chinese musician students. Practically, the research results underscore the potential of integrating DAW into musical education to stimulate the creative process and enhance students' confidence in their musical abilities. The analysis of related findings is limited, as there is a scarcity of materials investigating the relationship between DAW usage and the development of creativity and self-efficacy, indicating the need for further research in this area. Future research directions should encompass the examination of the long-term effects of using DAW on creative thinking and self-efficacy, broadening the demographic and geographic participant base to enhance result generalizability, as well as the development and testing of assessment tools adapted to various cultural contexts.

Limitations and future research

Potential limitations include self-reported measures of self-efficacy and the lack of previous tests of the Chinese version of the MPSES, as well as the lack of long-term follow-up

Table 3 Significance of differences in post-test scores of TTCT subscales in groups A and B

	Originality	Fluency	Elaboration	Abstractness	Resistance
Mann-Whitney U	384.000	1782.500	2957.500	2557.000	1742.500
Wilcoxon W	5434.000	6832.500	8007.500	7607.000	6792.500
Z	−11.293	−7.867	−4.995	−5.975	−7.965
p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table 4 Significance of differences in post-test scores of MPSES sources in groups A and B

	Mastery experience	Vicarious experience	Verbal/social persuasion	Physiological state
Mann-Whitney U	4873.000	4740.000	4879.500	2399.500
Wilcoxon W	9923.000	9790.000	9929.500	7449.500
Z	−0.310	−0.635	−0.294	−6.355
p-value	0.756	0.525	0.768	**0.000**

to evaluate the sustainability of creative-thinking increase effects. The generalizability of findings is limited by the specific universities that participated in the study. The study did not focus on identifying specific mediators and moderators that may influence the relationship between the use of music software and the development of creative thinking. Furthermore, extending the research to encompass a broader scope of psychology beyond musical education could significantly enrich the understanding of the impact of musical interventions on creative potential in organizational contexts. Specifically, investigating how the use of Digital Audio Workstations (DAW) may enhance employees' creative abilities represents an exciting avenue for future research.

To address the identified limitations, future research should consider employing objective measures in addition to self-reported assessments for evaluating self-efficacy. Additionally, validating the Chinese version of the Musical Performance Self-Efficacy Scale (MPSES) through rigorous psychometric testing is imperative. Longitudinal studies with extended follow-up periods would offer insights into the sustainability of enhancements in creative thinking attributed to digital audio workstation (DAW) usage. Exploring potential mediators and moderators, such as individual characteristics or contextual factors, could deepen our understanding of the mechanisms underlying the relationship between music software utilization and creative thinking outcomes. Moreover, expanding research beyond the realm of music education to investigate the impact of DAWs on creativity within organizational settings presents a promising avenue for future inquiry, potentially drawing from established theories in organizational psychology (Zelenak, 2011; Zhang et al., 2020a).

Conclusion

In the experimental group, there was an increase in creative thinking in all five subscales in the post-test: originality, fluency, elaboration, abstractness, and resistance to premature completion increased by 19.26%, 18.23%, 11.04%, 10.40%, and 15.09%, respectively. The differences between the control and experimental groups were significant thus confirming the effectiveness of using digital audio workstations to develop creative thinking. The authors also found that digital audio workstations did not have a positive effect on musical self-efficacy in terms of mastery experience, vicarious experience, and verbal/social persuasion; the intergroup differences were not significant. However, the physiological state in the post-test of the experimental group significantly increased by 8.72%. This paper has both scientific and practical value and contributes to the existing body of knowledge by exploring the impact of digital audio workstations on the development of creative thinking and self-efficacy in music education. The practical value is to confirm the need to implement DAW in education to develop creative-thinking skills in music students and help them practice producing music. Future research should focus on ways to increase the self-efficacy of musicians and address the limits of current research.

Author contributions All research processes was conducted by Gai Yanan: conceptualization, methodology, software, validation, formal analysis, investigation, resources, writing—original draft preparation, writing—review and editing, visualization, etc.

Funding The research received no funding

Data availability All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The

study was approved at the meeting of the Ethics Committee of Shanxi Vocational University of Engineering Science and Technology.

Consent to participate Informed consent was signed by participants.

Conflict of interests The research has no conflict of interest.

References

Acar, S., Branch, M. J., Burnett, C., & Cabra, J. F. (2021). Assessing the universality of the zero originality lists of the Torrance Tests of Creative Thinking (TTCT)-Figural: An examination with African American college students. *Gifted Child Quarterly,65*(4), 354–369. https://doi.org/10.1177/00169862211012964

Acar, S., Berthiaume, K., Grajzel, K., Dumas, D., Flemister, C. T., & Organisciak, P. (2023). Applying automated originality scoring to the verbal form of Torrance tests of creative thinking. *Gifted Child Quarterly,67*(1), 3–17. https://doi.org/10.1177/00169862211061874

Agnoli, S., Mastria, S., Kirsch, C., & Corazza, G. E. (2019). Creativity in the advertisement domain: The role of experience on creative achievement. *Frontiers in Psychology*, *10*, 1899. https://doi.org/10.3389/fpsyg.2019.01899

Alabbasi, A. M. A., Paek, S. H., Kim, D., & Cramond, B. (2022). What do educators need to know about the Torrance tests of creative thinking: A comprehensive review. *Frontiers in Psychology*, *13*, 1000385. https://doi.org/10.3389/fpsyg.2022.1000385

Altenmüller, E., & James, C. E. (2020). Chapter 16 - The impact of music interventions on motor rehabilitation following stroke in elderly. In L. L. Cuddy, S. Belleville, A. Moussard (Eds.), *Music and the Aging Brain* (pp. 407–432). Academic. https://doi.org/10.1016/B978-0-12-817422-7.00016-X

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. W. H. Freeman and Co.

Barbot, B., & Said-Metwaly, S. (2021). Is there really a creativity crisis? A critical review and meta-analytic re-appraisal. *The Journal of Creative Behavior*, *55*(3), 696–709. https://doi.org/10.1002/jocb.483

Beldean, L., & Constantin, F. A. (2022). Modes of interaction with the digital environment in music composition; lateral thinking. In M. E. Auer, W. Pachatz, T. Rüütmann (Eds.), *International Conference on Interactive Collaborative Learning* (pp. 1044–1055). Springer International Publishing. https://doi.org/10.1007/978-3-031-26190-9_106

Bell, A. P. (2015). Can we afford these affordances? GarageBand and the doubleedged sword of the digital audio workstation. *Action Criticism & Theory for Music Education*, *14*(1), 43–65. http://act.maydaygroup.org/articles/Bell14_1.pdf

Bell, A., Hein, E., & Ratcliffe, J. (2015). Beyond skeuomorphism: The evolution of music production software user interface metaphors. *Journal on the Art of Record Production*, *9*, 1. https://www.arpjournal.com/asarpwp/beyond-skeuomorphism-the-evolution-of-music-production-software-user-interface-metaphors-2/

Bennett, J. (2018). Songwriting, digital audio workstations, and the internet. In N. Donin (Ed.), *Oxford Handbook of Creative Process in music* (pp. 1–1). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190636197.013.28

Bersh, B. (2022). The relationship between music performance anxiety and self-efficacy in sixth-to eighth-grade instrumental students. *Psychology of Music*, *50*(5), 1477–1493. https://doi.org/10.1177/03057356211050667

Bogunović, B. (2019). Creative cognition in composing music. *New Sound International Journal of Music*, *53*(1), 89–117. http://ojs.newsound.org.rs/index.php/NS/article/view/No.53_89-117

Bolter, J. D. (2019). *The digital plenitude: The decline of elite culture and the rise of new media*. MIT Press.

Börekci, A., Dalkiran, E., & Nacakci, Z. (2023). Translation and validation of music performance self-efficacy scale into Turkish. *International Journal of Music Education*, *in press*. https://doi.org/10.1177/02557614231166757

Brancatisano, O., Baird, A., & Thompson, W. F. (2020). Why is music therapeutic for neurological disorders? The therapeutic music capacities model. *Neuroscience & Biobehavioral Reviews*, *112*, 600–615. https://doi.org/10.1016/j.neubiorev.2020.02.008

Brett, T. (2019). Popular music production in laptop studios: Creative workflows as problem-solving within Ableton live. In R. Hepworth-Sawyer, J. Hodgson, M. Marrington (Eds.), *Producing Music* (pp. 179–193). Routledge. https://doi.org/10.4324/9781315212241-11

Cavdarbasha, D., & Kurczek, J. (2017). Connecting the dots: Your brain and creativity. *Frontiers for Young Minds*, *5*, 19. https://doi.org/10.3389/frym.2017.00019

Chang, Y. S., Chen, M. Y. C., Chuang, M. J., & Chou, C. H. (2019). Improving creative self-efficacy and performance through computer-aided design application. *Thinking Skills and Creativity*, *31*, 103–111. https://doi.org/10.1016/j.tsc.2018.11.007

Cheng, Y. (2023). Multimedia programmes: Creating computer music to enhance creative thinking. *Interactive Learning Environments*, *31*(10), 6497–6508. https://doi.org/10.1080/10494820.2022.2039950

Çiftçibaşı, M. C. (2021). Instrument performance self-efficacy perceptions of music education students. *Kıbrıslı Eğitim Bilimleri Dergisi*, *16*(3), 1204–1216. https://doi.org/10.18844/cjes.v16i3.5841

Clauhs, M. (2020). Songwriting with digital audio workstations in an online community. *Journal of Popular Music Education*, *4*(2), 237–252. https://doi.org/10.1386/jpme_00027_1

Cooper, P. K. (2021). *Development and validation of a Scale to Measure Songwriting Self-Efficacy (SSES) with Secondary Music Students.* Doctoral dissertation. University of South Florida.

D'Errico, M. (2016). *Interface Aesthetics: Sound, Software, and the Ecology of Digital Audio Production.* PhD dissertation. UCLA.

Dai, J. (2022). Development of university music education based on neural network and the reform of music education in normal university under the environment of ability education. *Journal of Environmental and Public Health*, *2022*, 7605593. https://doi.org/10.1155/2022/7605593

Dempsey, E., & Comeau, G. (2019). Music performance anxiety and self-efficacy in young musicians: Effects of gender and age. *Music Performance Research*, *9*, 60–79. https://piano.uottawa.ca/wp-content/uploads/2020/10/38.-Dempsey_Comeau_Anxiety-2019.pdf

Duff, M. C., Kurczek, J., Rubin, R., Cohen, N. J., & Tranel, D. (2013). Hippocampal amnesia disrupts creative thinking. *Hippocampus*, *23*(12), 1143–1149. https://doi.org/10.1002/hipo.22208

Gooderson, M., & Henley, J. (2017). Professional songwriting: Creativity, the creative process and tensions between higher education songwriting and industry practice in the UK. In G. D. Smith, Z. Moir, M. Brennan, S. Rambarran, P. Kirkman (Eds.), *The Routledge research companion to popular music education* (pp. 257–271). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781315613444-21/professional-songwriting-matt-gooderson-jennie-henley

Gorbunova, I. B., & Chibirev, S. V. (2019). Modeling the process of musical creativity in musical instrument digital

interface format. *Opción: Revista De Ciencias Humanas Y Sociales*, *22*, 392–409. https://dialnet.unirioja.es/descarga/articulo/8307925.pdf

Greenberg, D. M., Decety, J., & Gordon, I. (2021). The social neuroscience of music: Understanding the social brain through human song. *American Psychologist*, *76*(7), 1172–1185. https://doi.org/10.1037/amp0000819

Lasky, D., & Yoon, S. (2020). A creative classroom for everyone: An introduction to a small 'c'creativity framework. *Thinking Skills and Creativity*, *36*, 100660. https://doi.org/10.1016/j.tsc.2020.100660

Lewis, M. C., & Hendricks, K. S. (2022). It's your body, it's part of who you are! Influences upon collegiate vocalists' performance self-efficacy beliefs. *International Journal of Music Education*, *40*(4), 514–529. https://doi.org/10.1177/02557614221074057

Marrington, M. (2017). Composing with the digital audio workstation. In J. Williams, K. Williams (Eds.), *The Singer Songwriter Handbook* (pp. 77–89). Bloomsbury Academic. https://doi.org/10.5040/9781501396595.ch-006

Merging (2023). *Overview*. https://www.merging.com/products/pyramix

Murcia, K., Pepper, C., Joubert, M., Cross, E., & Wilson, S. (2020). A framework for identifying and developing children's creative thinking while coding with digital technologies. *Issues in Educational Research*, *30*(4), 1395–1417. https://doi.org/10.3316/informit.606316903368280

Murodova, D. (2021). The concept of musical thinking and its stages of development. *Galaxy International Interdisciplinary Research Journal*, *9*(5), 245–250. https://doi.org/10.17605/OSF.IO/ZRQ48

Ng, D. T., Ng, E. H., & Chu, S. K. (2022). Engaging students in creative music making with musical instrument application in an online flipped classroom. *Education and Information Technologies*, *27*(1), 45–64. https://doi.org/10.1007/s10639-021-10568-2

Odena, O. (2018). *Musical creativity revisited: Educational foundations, practices and research*. Routledge.

Papatzikis, E., & Rishony, H. (2022). What is music for neuroplasticity? Combined value on infant development and inclusion. In M. Efstratopoulou (Ed.), *Rethinking inclusion and transformation in special education* (pp. 160–177). IGI Global. https://doi.org/10.4018/978-1-6684-4680-5.ch010

Pendergast, S. (2021). Creative music-making with digital audio workstations. *Music Educators Journal*, *108*(2), 44–56. https://doi.org/10.1177/00274321211060310

Putkinen, V., Nazari-Farsani, S., Seppälä, K., Karjalainen, T., Sun, L., Karlsson, H. K., Hudson, M., Heikkilä, T. T., Hirvonen, J., & Nummenmaa, L. (2021). Decoding music-evoked emotions in the auditory and motor cortex. *Cerebral Cortex*, *31*(5), 2549–2560. https://doi.org/10.1101/2020.05.24.101667

Ramón, L. N., & Chacón-López, H. (2021). The impact of musical improvisation on children's creative thinking. *Thinking Skills and Creativity*, *40*, 100839. https://doi.org/10.1016/j.tsc.2021.100839

Reuter, A. (2022). Who let the DAWs out? The digital in a new generation of the digital audio workstation. *Popular Music and Society*, *45*(2), 113–128. https://doi.org/10.1080/03007766.2021.1972701

Ritter, S. M., & Ferguson, S. (2017). Happy creativity: Listening to happy music facilitates divergent thinking. *PLoS One,12*(9), e0182210. https://doi.org/10.1371/journal.pone.0182210

Rosenhan, C., & Galloway, N. (2019). Creativity, self-reflection and subversion: Poetry writing for global englishes awareness raising. *System*, *84*, 1–13. https://doi.org/10.1016/j.system.2019.04.005

Sabet, S. E. (2019). *Study in mobile music technology: High school students composing with GarageBand for iPad.* Doctoral dissertation. New Brunswick: Rutgers University-Mason Gross School of the Arts.

Said-Metwaly, S., Van den Noortgate, W., & Barbot, B. (2021). Torrance test of creative thinking-verbal, arabic version: Measurement invariance and latent mean differences across gender, year of study, and academic major. *Thinking Skills and Creativity*, *39*, 100768. https://doi.org/10.1016/j.tsc.2020.100768

Shirsat, A., Jha, R. K., & Verma, P. (2023). Music therapy in the treatment of dementia: A review article. *Cureus*, *15*(3), e36954. https://doi.org/10.7759/cureus.36954

Sihombing, E. J., Mursid, R., & Tanjung, S. (2020). The effect of cooperative learning models and the ability of creative thinking on the outcomes of learning music art. In B. Sinaga, R. Husein, J. Rajagukguk (Eds.), *The 5th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2020)* (pp. 492–497). Atlantis Press. https://doi.org/10.2991/assehr.k.201124.100

Tan, A. G., Tsubonou, Y., Oie, M., & Mito, H. (2019). Creativity and music education: A state of art reflection. In Y. Tsubonou, A. G. Tan, M. Oie (Eds.), *Creativity in Music Education. Creativity in the Twenty First Century* (pp. 3–16). Springer. https://doi.org/10.1007/978-981-13-2749-0_1

Torrance, E. P. (1998). *The Torrance tests of creative thinking norms—technical manual figural (streamlined) forms A & B*. Scholastic Testing Service, Inc.

Wan, W. (2022). Tecnologias digitais na educação musical: O caso dos estudantes chineses. *Música Hodie*, *22*, e70752. https://doi.org/10.5216/mh.v22.70752

Wan, W. (2023). The importance of developing creative thinking in the preparation of music education professionals in universities. *Interactive Learning Environments*, in press. https://doi.org/10.1080/10494820.2023.2188400

Warren, D. E., Kurczek, J., & Duff, M. C. (2016). What relates newspaper, definite, and clothing? An article describing deficits in convergent problem solving and creativity following hippocampal damage. *Hippocampus*, *26*(7), 835–840. https://doi.org/10.1002/hipo.22591

Xing, Z., & Qi, Y. (2023). Development of creativity in physical education teachers using interactive technologies: Involvement and collaboration. *Education and Information Technologies*, *28*, 5763–5777. https://doi.org/10.1007/s10639-022-11422-9

Zelenak, M. S. (2011). *Self-Efficacy in Music Performance: Measuring the Sources among Secondary School Music Students* USF Tampa Graduate Theses and Dissertations. https://digitalcommons.usf.edu/etd/3419

Zelenak, M. S. (2020). Developing self-efficacy to improve music achievement. *Music Educators Journal*, *107*(2), 42–50. https://doi.org/10.1177/0027432120950812

Zhang, L. (2022). Exploring the independent learning of music students in higher teacher training colleges in a pluralistic network environment. *Journal of Environmental and Public Health, 2022*, 5024006. https://doi.org/10.1155/2022/5024006

Zhang, L. (2023a). Creativity assessment in music education: interpretation of western music by students from the People's Republic of China. *Current Psychology*, in press. https://doi.org/10.1007/s12144-023-04713-y

Zhang, S. (2023b). Interactive environment for music education: Developing certain thinking skills in a mobile or static interactive environment. *Interactive Learning Environments*, *31*(10), 6856–6868. https://doi.org/10.1080/10494820.2022.2049826

Zhang, W., Ren, P., & Deng, L. (2020a). Gender differences in the creativity–academic achievement relationship: A study from China. *The Journal of Creative Behavior*, *54*(3), 725–732. https://doi.org/10.1002/jocb.387

Zhang, W., Sjoerds, Z., & Hommel, B. (2020b). Metacontrol of human creativity: The neurocognitive mechanisms of convergent

and divergent thinking. *Neuroimage*, *210*, 116572. https://doi.org/10.1016/j.neuroimage.2020.116572

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