Implementation of Steam Technologies for Building Digital Competence of Future Music Art Teachers

Yevheniia Provorova*
Liudmyla Arystova**
Oksana Gorozhankina***
Ruslana Lotsman****
Dmytro Lievit*****

ABSTRACT

The aim of the work is to determine the effectiveness of the implementation of STEAM technologies for building the digital competence of future music art teachers. This aim was achieved through a sociological survey, effectiveness calculations, variation, statistical error. It was established that most students' digital competence level was low (47%) before the study, which affected their level of knowledge. Only 12% of the students had a high level of digital competence. The obtained data contributed to developing approaches to training future music art teachers using STEAM technologies and digital opportunities. It was found that the use of the Vocal Range Vocaberry application has a greater impact on students' digital competence, as the results are related to the detailed study of approaches to voice development. This approach to learning contributed to the acquisition of high-level knowledge by a greater proportion of students (71%). The practical significance of the work is related to the possibility of improving the system of training music art teachers with the use of digital technologies. Further research may focus on establishing the effectiveness of various vocal training programmes for future teachers.

KEYWORDS: creative thinking, digital technology, teaching, music education, pedagogical research.

*Doctor of Pedagogical Sciences, Professor, Vocal Department, Anatolii Avdiievsky Faculty of Arts, Mykhailo Dragomanov State University of Ukraine, Kyiv, Ukraine, ORCID ID: https://orcid.org/0000-0003-2337-0082, E-mail: provorovaye@gmail.com

**PhD of Pedagogical Sciences, Associate Professor, Department of Musical Art, Faculty of Pedagogy, V.O. Sukhomlynskyi National University of Mykolaiv, Mykolaiv, Ukraine, ORCID ID: https://orcid.org/0000-0002-3867-7450, E-mail: laristovaludmila2023@gmail.com

***PhD of Pedagogical Sciences, Associate Professor, Department of Music and Instrumental Training, Faculty of Music and Choreography Education, South Ukrainian National Pedagogical University Named after K.D. Ushynsky, Odesa, Ukraine, ORCID ID: https://orcid.org/0000-0003-1777-2173, E-mail: garmonia8oy.sunpu@gmail.com

****PhD of Pedagogical Sciences, Doctoral Student of Anatolij Avdievskyi faculty of Arts, Mykhailo Dragomanov State University of Ukraine, Kyiv, Ukraine, https://orcid.org/0000-0002-8500-1402, E-mail: rusyalotsman.mdsu@ukr.net

*****PhD in Philosophical Sciences, Associate Professor, Department of Academic and Pop Vocal, Faculty of Musical Art and Choreography, Borys Grinchenko Kyiv University, Kyiv, Ukraine, ORCID ID: https://orcid.org/0000-0003-3237-6427. E-mail: d.lievit.2017@kubg.edu.ua

Implementación de tecnologías STEAM para desarrollar la competencia digital de futuros profesores de Arte Musical

RESUMEN

El objetivo del trabajo es determinar la efectividad de la implementación de tecnologías STEAM para la construcción de la competencia digital de los futuros profesores de arte musical. Este objetivo se logró a través de una encuesta sociológica, cálculos de efectividad, variación, error estadístico. Se estableció que el nivel de competencia digital de la mayoría de los estudiantes era bajo (47%) antes del estudio, lo que afectó su nivel de conocimiento. Solo el 12% de los estudiantes poseía un alto nivel de competencia digital. Los datos obtenidos contribuyeron a desarrollar enfoques para capacitar a futuros profesores de arte musical utilizando tecnologías STEAM y oportunidades digitales. Se encontró que el uso de la aplicación Vocal Range Vocaberry tiene un mayor impacto en la competencia digital de los estudiantes, ya que los resultados están relacionados con el estudio detallado de los enfoques del desarrollo de la voz. Este enfoque de aprendizaje contribuyó a la adquisición de conocimientos de alto nivel por parte de una mayor proporción de estudiantes (71%). El significado práctico del trabajo está relacionado con la posibilidad de mejorar el sistema de formación de profesores de arte musical con el uso de tecnologías digitales. La investigación adicional puede enfocarse en establecer la efectividad de varios programas de entrenamiento vocal para futuros maestros.

PALABRAS CLAVE: Imaginación creativa, tecnología digital, enseñanza, educación musical, investigación pedagógica.

Introduction

The dynamic digitization processes had an impact on the learning process, which contributes to socialization and the possibility of expanding academic knowledge. Digital technologies affect the perception of information, reveal the potential, develop creative abilities, ensure communication (Kiktenko & Drobotiuk, 2021). Information technologies in music education can also contribute to increasing the effectiveness of education and influence the achievement of the necessary level of musical skills.

Training future music art teachers should involve the development of theoretical and practical knowledge that forms the competence of future teachers. The use of non-standard approaches to learning contributes to the development of creative thinking, which is reflected in the quality of obtaining basic knowledge (Marín-Suelves et al., 2022). One of these approaches is the implementation of STEAM technologies in education. STEAM

technologies represent a process of integrated education that contributes to its modernization, increasing the competitiveness of future specialists in accordance with the needs of society (Watson, 2015). STEAM technologies promote practical implementation of acquired knowledge as a result of orientation to different positions, values that contribute to the application of scientific, mathematical, technical, and engineering knowledge. STEAM technologies contribute to the modernization of education, which is manifested in the delivery of material, the possibility of variation in approaches to the development of practical skills, the development of creativity, cognitive flexibility (Calderón-Garrido et al., 2020).

STEAM technologies imply a primary enhancement of students' motivation, development of research knowledge, in-depth study of the material, and development of professional skills during training. In music education, the use of STEAM technologies contributes to the diversification of knowledge, the ability to provide free access to musical works of different periods (Zhang, 2022). STEAM technologies can be implemented by using digitalization, which contributes to the dynamic combination of knowledge, the development of skills for further successful teaching. Improving musical education contributes not only to the assimilation of musical knowledge, but also to the development of creative potential.

The process of training future music teachers can be implemented with the help of SinophonicOnline, Musiccal4, E-Book Maestro and other technologies (Bannerman & O'Leary, 2021). For example, the Sibelius application facilitates the study of sheet music, enabling the division of a piece of music for easier comprehension. The Sound Forge application is used for the creation of sound remixes, providing the ability to adapt the composition according to the students' capabilities. The SunVox music designer promotes the development of creative skills through the transformation of compositions. Digital technologies are aimed at the constant improvement of basic knowledge, which affects the introduction of new forms of learning and the expansion of musical horizons. This helps to eliminate the limitation of educational resources and affects the process of consistent, thorough, high-quality teaching of the material (García-Gil et al., 2022).

The implementation of STEAM technologies in music education is not wide-spread. The studies analyse on the possibility of improving the educational process with the help of digital technologies only. The aim of the work is to study the peculiarities of the implementation of STEAM technologies in music education for building digital competence

of future teachers.

The aim involved the fulfilment of the following research objectives:

- Determine the initial level of students' digital competence before the study, taking into account the effectiveness of the acquired knowledge before the study;

- Develop approaches to the STEAM-based training of future music teachers, which contributes to the development of students' digital competence;

- Identify the element of STEAM technologies that had the greatest impact on the development of students' digital competence using the coefficient of variation;

- Determine the effectiveness of the developed approaches to learning as a result of the identified levels of acquired knowledge and digital competence.

1. Literature review

STEAM education contributes to the expansion of approaches to the study of subjects through the formation of a universal approach. Digitization of education through the use of STEAM technologies can be aimed at developing skills for learning with musical instruments. This approach facilitates the organization of the educational process, which facilitates the combination of attendance data, homework checks, student assessment (Hödl et al., 2022b). The iMuSciCA Workbench programme is designed to teach music using STEAM technologies. The programme promotes the development of musical knowledge based on technology, science, engineering, art and mathematics, as well as fosters creativity. This approach contributes to a deeper understanding of musical material as a result of the implementation of an innovative musical environment (Kritsis et al., 2020).

The STEAM approach in education provides an opportunity to develop teamwork skills. Digitization of learning can be achieved through the use of Scratch Music, earSketch, UPISketch and iMuSciCA programmes. It was established that digital applications used in STEAM education contribute to the development of students' creative skills, improve memorization of information. Effectiveness is related to evoking interest in learning as a result of using non-standard approaches (Özer & Demirbatır, 2023). Music education is associated with the use of artistic and technical elements, which contributes to a more detailed study of the presented material. Artistic approaches are related to the formation and development of emotionality and expressiveness during the interpretation of the melody.

Technical approaches involve the use of a variety of digital elements that enhance practical skills (Ramsey, 2022). The interactive integration of multisensory technologies in the process of music education provides the possibility of detailed study of musical culture. In Taiwan, an advanced approach is the creation of virtual reality technologies through the interaction between the National Taiwan Symphony Orchestra and the Industrial Technology Research Institute. Virtual reality contributes to the development of creative learning methods as a result of combining science, technology, engineering, art, and mathematics (Ho et al., 2023).

In Korea, STEAM technologies are currently a traditional tool for learning music. Students believe that the use of STEAM technologies helps to solve educational problems and promotes competence development. This approach promotes the development of creative musical abilities through the interaction of science, technology and art (Kim & Chae, 2016). Modern technologies in music education promote building professional competencies. This provides diversity, improvement of the educational process, creation of alternative approaches to education. The use of digital technologies contributes to the development of practical skills with the help of specialized programmes, the study of theoretical information through a game. This approach is reflected in the memorization process (Wan, 2022). Music art is aimed at the formation of aesthetic interests, thereby promoting the development of musical talent and cultural qualities. Digital VR multimedia technology is used for the transformation of higher music education, which is connected with the creation of new educational ideas. This technology helps to develop vocal skills as a result of learning lessons of different complexity (Xiao, 2022).

The literature review revealed that STEAM technologies are used for the development of creative skills as a result of combining traditional education and digital technologies.

2. Methods

2.1. Research design

The first stage of the research provided for identifying the level of students' digital competence before the study. The results were obtained directly from the respondents, which also made it possible to identify the level of students' knowledge before the study through calculations. Approaches to learning were implemented in the second stage of the study, which involved studying the features of STEAM technologies and the possibility of

involving digital applications. Modern technologies were chosen for training in terms of the possibility of their use for the development of certain professional skills. The process also affects the possibility of developing students' digital competence. The approach was implemented as a result of studying the features of more than 180 applications designed to develop music knowledge. When choosing computer technologies, their theoretical and practical potential for conducting classes was taken into account. Training in accordance with the developed approaches was conducted in 2022 (October 2022 - December 2022).

The third stage of the research involved the identification of the effectiveness of building digital competence from the proposed elements of STEAM technologies, which became the basis for the development of educational approaches. The results were based on receiving information from students after completing the training. The elements of STEAM technologies were based on the study of musical laws, the development of practical knowledge, and experimental skills. Elements of developing logical thinking and ensuring social relationships were also included. The third stage of the research also provided for identifying students' acquired knowledge according to the gradation of a high, sufficient, medium, and low level. The level of acquired knowledge in musical subjects is checked in order to obtain the effectiveness of training. The possibility of correct use of digital applications, which became the basis of the educational process, was taken into account in the general data. Students were asked to develop a lesson programme according to the chosen topic using digital technologies, which was reflected in the obtained grades.

2.2. Sampling

The study involved 135 students of Sukhomlynskyi National University of Mykolaiv and National Pedagogical Dragomanov University. The limitation regarding the participants in the survey was the selection of first-year students who studied at the Music Department and Vocal Department. Restrictions on the choice of students are related to the possibility of developing scientific knowledge among students who have not had sufficient musical knowledge. This knowledge can be developed during additional classes aimed at developing students' digital competence. All students were in equal conditions, which required a preliminary study of the functions of technologies that were involved in the development of learning approaches.

2.3. Methods

The level of students' digital competence before the study was tested using theoretical and experimental methods. First, a sociological survey (Appendix A) was conducted, which revealed the level of students' digital competence according to their understanding. The level of students' digital competence was checked based on the possibility of listing the technologies used, explaining the possibility of understanding their use in the learning process. Next, the level of students' knowledge of music art was checked, which practically confirmed the obtained data. The effectiveness ratio was used for this purpose:

$$k_r = \frac{\sum p_1 + p_2 + p_3}{p_{gen}}, \qquad (1)$$

p_1, p_2, p_3 – grades for acquired musical knowledge, level of digital competence, level of vocal abilities, respectively;

p_{gen} – probable general assessment of the effectiveness.

A high level equals 9-10 points; sufficient level — 7 - 8.9 points; medium level — 5 – 6.9 points; low level — 5 points.

The development of approaches to learning was based on the use of well-known methods, which made it possible to study of the peculiarities of STEAM technologies through the analysis. STEAM technologies were chosen as the basis, as they contribute to providing a comprehensive learning process. Among 180 modern programmes, My Voice Coach, Music Theory Program, Vocal Range Vocaberry, Sound Forge were selected for training. The need to develop approaches to education was caused by the need to ensure uninterrupted learning of future music art teachers. Approaches were also aimed at the development of students' digital competence.

The elements of STEAM technologies, which became the basis of the developed educational approaches, were identified by obtaining information from students through a sociological survey (Appendix B). The obtained results of the sociological survey were used to calculate the coefficient of variance in order to identify learning approaches that contribute to the development of students' digital competence (Faure-Carvallo et al., 2022):

$$k_v = \frac{s \times {}^1/_{2n}}{x}, \qquad (2)$$

s — standard deviation of indicators;

x — a selective indicator for calculations.

n — loyalty coefficient, which ranges from 1 to 5 (1 — favours the lowest value of preference, 5 — the highest value of preference).

The knowledge development coefficient was calculated to identify the effectiveness of digital technologies, which were aimed at obtaining musical knowledge and developing digital competence:

$$C_{k.d.} = \frac{(d_t + d_p) \times n}{d_{gen}} \qquad (3)$$

d_t – obtained results for theoretical knowledge;

d_p – obtained results for practical knowledge;

n – indicator for the level of digital competence (equals 0.3);

d_{gen} – general effectiveness.

A high level of effectiveness is equal to 0.5 - 0.7; sufficient level - 0.35 - 0.49; medium level - 0.25 - 0.34; low level – ‹0.25

2.4. Data analysis

Data analysis provided for the statistical error calculations, which was aimed at checking the calculations made. The statistical error was calculated at the third stage of the study. The calculation was applied to determine the elements of STEAM technologies that have a greater impact on the level of digital competence. Statistical error calculations were used to determine the accuracy of the obtained effectiveness of students during training (Aydin, 2019):

$$\bar{x} - t_a \frac{s}{\sqrt{n}} \le a \ge \bar{x} + t_a \frac{s}{\sqrt{n}}, \qquad (4)$$

X — sample mean,

t_α — Student's t-distribution,

a — the average value for the general population,

s — the sample root mean square deviation,

n — the number of parameters for the study.

If the estimated value of the statistical error exceeds 95%, errors were made in the calculations.

2.5. Data collection

A sociological survey was used to collect data from students. A sociological survey was used to determine the level of students' digital competence before the study in order to identify the approaches that contribute to the development of digital competence. The sociological survey was carried out using electronic mailboxes to collect data from all respondents. Data from students were collected within 10 hours upon receiving the assignment. The mailboxes corresponded to the first and last names of the respondents, which excluded the receipt of incorrect data.

2.6. Ethical criteria

Ethical criteria were complied with during the study to ensure quality research. Ethical norms provided for the transparent conditions of conducting the research, which excluded the involvement of respondents in additional sociological surveys. According to COPE (2021), all respondents were introduced into the stages of the study, which facilitated the distribution of study time.

3. Results

When using digital technologies to teach students, it is necessary to know their level of digital competence. Determining this parameter helps to choose the most effective technologies for training. It also enables determining the need for serious additional training in understanding the tools provided by digital technologies (Table 1).

Table 1. Determining the level of students' digital competence before the study

The level of students' digital competence	The percentage ratio of the competence level	The level of knowledge before the study
High	12%	9.2
Medium	41%	6.8
Low	47%	6.2

A sociological survey of future music art teachers established that most of them do not have digital competence. The reason is that most students studied according to the traditional model before the survey, which excluded the possibility of using specialized

programmes. The teachers developed constructive, organizational, communicative skills of students with a low level of digital competence, excluding the possibility of using additional tools. Students with a medium level of digital competence used modern applications in combination with usual methodological knowledge. A high level of digital competence was not widespread enough among students, but it contributed to obtaining the highest level of knowledge. For this category of students, technologies were used which contribute to deeper training of music art teachers and the possibility of simplified study of individual topics. However, the performance of students who had a high level of digital competence was higher than in other students. High performance is associated with the level of theoretical knowledge, as well as an understanding of the technical component of vocal voice development.

The students studying music art who used modern technologies in their studies obtained a high level of knowledge. Therefore, approaches to training, which were based on building digital competence of future teachers through the introduction of STEAM technologies were developed in the work (Figure 1).

Figure 1. Developed STEAM-based approaches to learning for future music art teachers

I. The first approach provided for the study of music laws that contribute to the expansion of theoretical knowledge in accordance with STEAM technologies. Modern digital platforms (Music Theory Programme), as well as the My Voice Coach application were used during the study of music laws. This approach made it possible to study the peculiarities of musical culture of different periods, taking into account the specific compositional approaches to song writing, and the peculiarities of their performance. The

study of theoretical aspects based on the use of digital technologies also contributes to the development of students' digital competence. It provides an understanding of the possibility of using such technologies, and enables identifying their effectiveness for the assimilation of relevant knowledge.

II. The second approach to learning provided for the development of practical knowledge through the use of digital technologies. The Vocal Range Vocaberry application was used to implement practical training. The application promotes the gradual voice development eliminating its strain, as practical skills develop on the basis of voice abilities. The application enables detecting the existing voice range, which helps to perform assignments according to the vocalist's capabilities. This approach also contributes to the development of digital competence of future music art teachers, as it enables studying their functions in the course of practical application;

III. A third approach to learning is based on the development of experimental skills that can be achieved through improvisation. The Sound Forge application is used for editing a musical composition and adapting it to the vocalist's voice. This approach will enable future music teachers to adapt the repertoire to the voice of the vocalists, as well as to conduct additional analysis of the composition. The analysis of a musical piece identifies simple (complex) places for vocal performance, which contributes to the development of mechanisms for their further interpretation by students. The growth of practical skills is connected not only with the development of vocal abilities, but also with the understanding of note combinations, the study of musical scores, breathing, etc.;

IV. The fourth approach is related to the development of logical thinking, the possibility of developing algorithms for learning. The SunVox application was used for this purpose, which enables working with musical compositions, focus on the creation of a particular type of music. The application ensures the creation of a new repertoire that develops students' logical thinking as a result of their active involvement in the educational process. Working on musical fragments activates the acquisition of knowledge, which is reflected in the detailed study of the material and the ability to work with digital technologies;

V. The fifth approach to learning was to provide social relationships between students. For this purpose, students were divided into groups, which helped to ensure communication between them to create a joint project. It was necessary to create lessons to deliver the material. The Presentation Creator application was used for this purpose to

present the material in digital format and to ensure the work of students in groups. The work in the group was also related to the development of training programmes for future students.

Next, it was determined which of the presented elements of STEAM technologies most contribute to the development of digital competence of future music art teachers. The indicators were obtained and further used for the calculation of the coefficient of variance and statistical error (Table 2).

Table 2. Determining the elements of learning approaches that had the greatest impact on the development of students' digital competence

An element of STEAM technologies	Calculated data	Statistical error
study of music laws (aspect of natural sciences)	0.89	$0.2\% \leq a \geq 0.31\%$
development of practical knowledge (aspect of technical sciences)	0.94	$0.47\% \leq a \geq 1.3\%$
development of experimental skills (aspect of engineering sciences)	0.91	$1.1\% \leq a \geq 0.92\%$
development of logical thinking (aspect of mathematical sciences)	0.83	$1.8\% \leq a \geq 1.7\%$
ensuring social relationships (aspect of artistic and human sciences)	0.86	$0.93\% \leq a \geq 1.3\%$

The study established that the aspect of technical sciences, which is interconnected with the development of practical knowledge, contributes the most to the development of students' digital competence. Vocal Range Vocaberry was used for the development of practical knowledge in the learning process, which contributes to the gradual understanding of approaches to the vocal voice training. The application helps future teachers to identify peculiarities that should be taken into account when training students. Working with the editor also contributes to the expansion of technological approaches to their development.

The development of experimental skills is also of great importance, as it is aimed at working with the repertoire. Working with the repertoire is important for the future learning of students, which contributes to voice training. The use of Sound Forge will

provide an analysis of a musical composition, which provides an understanding of working with modern technologies. The development of logical thinking has a similar approach to working with compositions, which promotes the development of digital competence through the use of SunVox. But this element of STEAM technologies requires additional professional musical knowledge, so it rans the last among all the elements of STEAM technologies that are used.

Studying music laws ranks third in terms of the development of digital competence of future music art teachers. This is related to the possibility of understanding the principles of working with technologies that contribute to the visual display of theoretical material. Ensuring social relationships ranks fourth for the development of digital competence skills, as it requires interaction in a team. The Presentation Creator application was used for team work.

The coefficient of knowledge development was calculated in the research in order to check the effectiveness of the obtained data of students who have been trained as future music teachers. The results are presented in Table 3.

Table 3. The level of acquired knowledge and digital competence of students after the study

Level of acquired knowledge	Percentage ratio of students	Quantified level of acquired knowledge	Statistical error
High	71%	0.67	$1.5\% \leq a \geq 1.2\%$
Sufficient	23%	0.44	$0.38\% \leq a \geq 0.57\%$
Medium	5%	0.31	$1.4\% \leq a \geq 0.98\%$
Low	1%	0.22	$1.23\% \leq a \geq 1.2\%$

The level of acquired knowledge of the majority of students became high, which is connected with the detailed study of educational materials. A detailed study of information became possible with the use of modern technologies, which also contributed to the development of digital competence. More than 20% of students acquired a sufficient level of knowledge, which is related to the understanding of approaches to training future vocalists. These students have learned the functions of applications, thereby expanding opportunities for the preparation of lessons in the future. Students who did not complete

the assigned tasks had a low level of acquired knowledge.

4. Discussion

The level of creative thinking of future music teachers can be developed under the influence of the programmes aimed at activating creative thinking. Creative thinking can be developed under the influence of modern technologies that contribute to the development of both individual and complex skills. This is determined by the fact that modern programmes are aimed at independent comprehension of information, its search, the possibility of application for solving particular problems. The approach promotes the development of additional skills that are related to the development of digital competence. Conducting Torrance's creative thinking test among students of Suzhou University revealed that 52% of students had high creativity level. The results show the effectiveness of the application of digital technologies (Wan, 2023). In accordance with STEAM technologies, music education was combined with physical sciences. This approach made it possible to emphasize the mathematical structure of music, which promotes understandings of musical styles. Physics contributes to the understanding of the interrelationships regarding the peculiarities of sound formation when using musical instruments or the voice. Education consists of conducting regular lectures, laboratory classes, which is connected with the inclusion of non-standard elements of the educational process (Ramsey, 2020). The success of the educational process is related to the enhancement of students' motivation to acquire musical knowledge. The high quality of education is obtained through the application of a non-standard approach to education, which can be implemented with the help of digital technologies. The use of visualizations of these elements during training helps to find new knowledge, which helps to perform assignments of different levels of complexity (Demirbatır, 2020). The aspects of students' motivation were not studied in this work. However, the research is related to studying the possibilities of expanding digitalization skills of future music art teachers.

Smartphones can be used during music lessons. The process can be reflected in the organization of learning and the possibility of using digital programmes. The applications can help to achieve success not only in the development of practical skills, but also in the assimilation of theoretical material. This facilitates easier perception of educational

information, which provides the possibility of simplifying solfeggio lessons. The ultrasonic connection with a smartphone enables detecting the accuracy of task performance (Hödl et al., 2020a). Our study focuses not only on finding music editors, but also on other innovative technologies. Learning of theoretical and practical material, development of experimental skills, and logical thinking were taken into account during their selection.

Information technologies are a common element for the training of music teachers in higher educational institutions of Ukraine. The process involves the use of digital applications that can facilitate independent study of the material or application during distance learning. Information technology can facilitate the development of skills and abilities, as well as the assessment of the performance level (Frytsiuk et al., 2022).

The study of the specifics of information in the published articles revealed that students' digital competence can be developed through the use of digital technologies. Aspects of independent study of the material are also taken into account. In our research, emphasis is placed on the possibility of using STEAM technologies to ensure the training of future music art teachers. The development of teaching approaches was based on the use of digital technologies (Music Theory Programme, My Voice Coach, Vocal Range Vocaberry, Sound Forge, SunVox). The choice of technologies was connected with the possibility of developing particular skills, which further contributes to teaching. The study also established the effectiveness of the developed approaches to learning, which included the level of musical training and the level digital competence.

Conclusions

The aim of the study was achieved, as the effectiveness of the developed approaches to training of future music art teachers and the development of digital competence was confirmed.

It was established that 47% of students had a low level of digital competence and only 12% of students had a high level at the beginning of the study. These results revealed that those students who had digital skills had the highest (9.2) knowledge level. The results are related to the possibility of providing independent learning and development of relevant musical skills.

The presented indicators contributed to the development of approaches for training

future teachers taking into account the possibilities of developing digital competencies. The authors used the Music Theory Programme and My Voice Coach for studying musical laws and theoretical material. Expanding practical knowledge became possible through the use of the Vocal Range Vocaberry application, ensuring social relationships — through Presentation. The Sound Forge programme was aimed at the development of experimental data due to the expanded possibilities of editing musical compositions. The SunVox application made it possible to develop logical thinking, which was reflected in the creation of music.

The authors found that the development of practical knowledge had the greatest impact on the development of digital competence using educational STEAM technologies among students. This element reflects the technical sciences aspect associated with the use of Vocal Range Vocaberry application and promotes voice development. The work established the effectiveness of the acquired knowledge on the basis of the introduced approaches to education, which contribute to the development of digital competence. It was found that 71% of students achieved a high level of knowledge, as they expanded practical and theoretical knowledge, as well as improved the level of digital competence.

The practical significance is the possibility of improving the learning process through the use of technologies that contribute to acquiring musical knowledge. The prospects for further research are related to the comparison of the effectiveness of the used digital technologies as a result of combining STEAM technologies for training of future teachers and students. This approach will reveal the level of digital competence of future teachers and students as a result of the application of self-study techniques.

References

Aydin, B. (2019). An examination of high school students' social skill levels according to participation in musical activities1. *Cypriot Journal of Educational Sciences*, *14*(4), 618-629. https://doi.org/10.18844/cjes.v11i4.4446

Bannerman, J. K., & O'Leary, E. J. (2021). Digital natives unplugged: Challenging assumptions of preservice music educators' technological skills. *Journal of Music Teacher Education*, *30*(2), 10-23. https://doi.org/10.1177/1057083720951462

Calderón-Garrido, D., Gustems-Carnicer, J., & Carrera, X. (2020). Digital technologies in music subjects on primary teacher training degrees in spain: Teachers' habits and profiles.

International Journal of Music Education, 38(4), 613-624. https://doi.org/10.1177/0255761420954303

COPE. (2021). About COPE. https://publicationethics.org/about/our-organisation

Demirbatır, R. E. (2020). Comparison of burnout, vigor and education satisfaction of music and art majors in department of fine arts education. *International Journal of Evaluation and Research in Education,* 9(3), 478-485. https://doi.org/10.11591/ijere.v9i3.20548

Faure-Carvallo, A., Gustems-Carnicer, J., & Guaus Termens, E. (2022). Music education in the digital age: Challenges associated with sound homogenization in music aimed at adolescents. *International Journal of Music Education,* 40(4), 598-612. https://doi.org/10.1177/02557614221084315

Frytsiuk, V. A., Brylin, B. A., Zanalnyuk, A. F., Frytsiuk, V. M., & Mykhaylyshen, A. V. (2022). Implementation of information technology into the education of music teachers. *Journal of Higher Education Theory and Practice,* 22(6), 35-43. https://doi.org/10.33423/jhetp.v22i6.5226

García-Gil, D., Cuervo, L., & Bonastre, C. (2022). A critical reflection on virtual music education in a changing world. *International Journal of Humanities Education,* 20(2), 43-61. https://doi.org/10.18848/2327-0063/CGP/v20i02/43-61

Ho, C., Lin, T., & Chang, C. (2023). Interactive multi-sensory and volumetric content integration for music education applications. *Multimedia Tools and Applications,* 82(4), 4847-4862. https://doi.org/10.1007/s11042-022-12314-3

Hödl, O., Bartmann, C., Kayali, F., Löw, C., & Purgathofer, P. (2020a). Large-scale audience participation in live music using smartphones. *Journal of New Music Research,* 49(2), 192-207. https://doi.org/10.1080/09298215.2020.1722181

Hödl, O., Rafetseder, A., Hu, P., & Kayali, F. (2022b). STEAM for non-novice STEM students with digital musical instruments. Paper presented at the *ACM International Conference Proceeding Series,* 179-186. https://doi.org/10.1145/3561212.3561235

Kiktenko, V., & Drobotiuk, O. (2021). Scientific and educational cooperation between ukraine and china in the period 2016-2020. *Shidnij Svit,* 2021(4), 33-35. https://doi.org/10.15407/orientw2021.04.033

Kim, H., & Chae, D. (2016). The development and application of a STEAM programbased on traditional korean culture. *Eurasia Journal of Mathematics, Science and Technology Education,* 12(7), 1925-1936. https://doi.org/10.12973/eurasia.2016.1539a

Kritsis, K., Garoufis, C., Zlatintsi, A., Bouillon, M., Acosta, C., Martín-Albo, D., Piechaud, R., Maragos, P., & Katsouros, V. (2020). iMuSciCA workbench: Web-based music activities for science education. *AES: Journal of the Audio Engineering Society,* 68(10), 738-746. https://doi.org/10.17743/jaes.2020.0021

Marín-Suelves, D., Méndez, V. G., & Monzonís, N. C. (2022). Music education and technology: Trends in research. *Revista Electronica Complutense De Investigacion En Educacion Musical, 19*, 275-286. https://doi.org/10.5209/reciem.74693

Özer, Z., & Demirbatır, R. E. (2023). Examination of STEAM-based digital learning applications in music education. *European Journal of STEM Education, 8*(1), 02. https://doi.org/10.20897/ejsteme/12959

Ramsey, G. (2020). Techniques that can be used in a musical acoustics course. Paper presented at the *Proceedings of Meetings on Acoustics, 42*(1), 035007. https://doi.org/10.1121/2.0001411

Ramsey, G. P. (2022). Integrating science, technology, engineering, and math (STEM) and music: Putting the arts in science, technology, engineering, arts, and math (STEAM) through acoustics. *Journal of the Acoustical Society of America, 152*(2), 1106-1111. https://doi.org/10.1121/10.0013571

Wan, W. (2022). Digital technologies in music education: The case of chinese students. *Musica Hodie, 22*(2), 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*, https://doi.org/10.1080/10494820.2023.2188400

Watson, A. D. (2015). Design thinking for life. *Art Education, 68*(3), 12-18. https://doi.org/10.1080/00043125.2015.11519317

Xiao, H. (2022). Innovation of digital multimedia VR technology in music education curriculum in colleges and universities. *Scientific Programming, 2022*, 6566144. https://doi.org/10.1155/2022/6566144

Zhang, Z. (2022). Innovative construction of reinforcement learning model for information fusion in music education. *Security and Communication Networks, 2022*, 7367418. https://doi.org/10.1155/2022/7367418

Appendix A

Sociological survey on determining the initial level of students' digital competence

Answer options	Student's answer
I have a high level of digital competence	
I have a medium level of digital competence	
I have a low level of digital competence	

Appendix B

Students' determination of STEAM-based approaches to learning that had the greatest impact on the level of digital competence

Answer options	Student's answer
Study of music laws (aspect of natural sciences)	
Practical knowledge development (aspect of technical sciences)	
Development of experimental skills (aspect of engineering sciences)	
Development of logical thinking (aspect of mathematical sciences)	
Ensuring social relationships between students (aspect of artistic and human sciences)	