Transforming Conductor Education through Digital and Virtual Environments: a Focus on Performance and Interpretation Development

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ABSTRACT:

Modern professional conducting education needs to be modernized in response to technological challenges; however, the level of implementation of digital tools remains understudied, especially in the Ukrainian context. The purpose of the research is to analyze the use of digital and virtual environments in conducting and determine their impact on the development of performance and interpretation skills as a component of creative self-realization. The research combined a review of theoretical literature with a survey of students - conductors at music academies in Kyiv. Empirical data revealed a significant gap between students' high interest in modern technologies and low levels of their practical application. Videos of professional conductors and mobile applications remain the most common, while access to virtual reality technologies is extremely limited. The effectiveness of video recording as a method of self-analysis for identifying technical shortcomings and developing reflective skills is confirmed. The need to create digital content in Ukrainian, adapted to the national repertoire, is emphasized. A model of integrating digital tools with traditional education is proposed, focused on the harmonious development of the conductor's personality.

Keywords: conductor training, digital environments, virtual reality, performance and interpretation skills, music education.

1. Introduction

The profession of conductor is one of the most difficult in the musical arts, requiring a synthesis of deep theoretical knowledge, refined gestural technique, sophisticated artistic intuition, and highly developed interpersonal communication skills to lead an ensemble. The formation of a conductor's performance and interpretation skills – the ability to analyze a score, form a unique artistic concept and convey it to the musicians through precise, expressive gestures – traditionally relies on long-term individual mentoring and live practice with an orchestra or choir. As Rastruba (2023) notes, performance interpretation in modern musicology is considered a complex creative process that requires not only technical perfection but also a deep understanding of style, era, and authorial intent. However, traditional teaching methods face significant challenges: limited access to training orchestras and choirs for novice conductors, the high cost of rehearsal time, the subjectivity of pedagogical feedback, and the impossibility of repeatedly repeating complex fragments without tiring the musicians.

International experience demonstrates the rapid development of specialized tools. Thus, Rosiński (2023) in his review outlines the main directions of application of digital technologies in teaching conducting. Japanese researchers Fujiwara et al. (2024) developed a virtual reality (further – VR) training system based on the Saito conducting method, which allows practicing gesture techniques in virtual space.

The psychological and educational implications of virtual reality use are a distinct field of study. Zelenin and Polishchuk (2024) studied the impact of VR environments on the training of creative professionals, noting a decrease in the level of performance anxiety and an expansion of opportunities for creative experimentation. Austermann et al. (2025) studied the phenomenon of "presence" in a virtual environment, which is critical for the effectiveness of learning. Koole and Beaumier (2024) propose to look at the use of VR in education through the prism of post-digital pedagogy, emphasizing the need to integrate technologies into a broader educational context, rather than simply adding them to traditional methods.

The main aim of this research is to analyze and systematize the use of digital and virtual environments in the professional training of conductors and determine their impact on the development of performing and interpretative skills.

2. Materials and Methods

This research is comprehensive in nature and combines a theoretical analysis of the scientific literature with an empirical study of the current state of the use of digital and virtual environments in the professional training of conductors. The first stage of the research involved a systematic review of scientific publications. The methodology included a multi-stage search in the academic databases Scopus, Web of Science, Google Scholar and the V. I. Vernadsky National Library of Ukraine. The search keywords included combinations of the following terms: "conductor training", "virtual reality", "digital technologies", "music education", "performance interpretation", "VR conducting" and their English equivalents.

The empirical part of the research was organized on the basis of the Department of Choral Conducting of the P. I. Tchaikovsky National Music Academy of Ukraine and the Department of Orchestral Conducting of the R. M. Glier Kyiv Municipal Academy of Music. Data collection was carried out during the first semester of the 2025–2026 academic year (December 2025). The research involved 30 students of 1st-4th year conducting specializations (orchestral and choral conducting) aged 17 to 23. All participants were informed about the objectives and procedure of the study and provided voluntary consent to participate.

The main method of collecting empirical data was an anonymous questionnaire. For this purpose, an author's questionnaire was developed, the structure of which was based on the adaptation of international approaches to assessing the use of digital technologies in education. The questionnaire consisted of five content blocks, which allowed for a comprehensive coverage of various aspects of the problem under study (Appendix A).

The first block of the questionnaire recorded demographic data (age, course), the second – the frequency of use of digital technologies in performing and interpreting skills. The third block of the questionnaire contained statements for self-assessment of the impact of digital technologies on the development of performing and interpreting skills. The respondents were asked to rate the following statements on a five-point Likert scale (from 1 – "strongly disagree" to 5 – "strongly agree"): "Using digital technologies helps me better understand my technical errors", "Thanks to video recordings, I can more objectively assess my progress", "Watching master classes of leading conductors online broadens my understanding of interpretation", "Digital tools help me experiment with tempo, dynamics and gestures". The fourth block was devoted to practical aspects of using digital resources for specific educational purposes, in particular, for analyzing scores, comparing different interpretations of the same work, working on gesture techniques with video recording, discussing with fellow students, and receiving remote consultations. The questionnaire ended with a block of open-ended questions that gave the respondents the opportunity to express their own opinions on the most useful digital tools, the shortcomings of existing technologies, and their wishes for their improvement.

The quantitative data obtained during the survey were processed using descriptive statistics methods. For the purpose of summarizing the results, the arithmetic mean and standard deviation were used. The distribution of responses to individual questions was analyzed in percentage terms.

3. Literature Review

Literature review reveals a rapidly developing field at the intersection of music pedagogy, human-computer interaction, and educational technology.

The theoretical framework of this study is informed by a growing body of interdisciplinary research on digitalization in education. Foundational insights into the impact of virtual reality on learning effectiveness and the sense of presence are drawn from Austermann et al. (2025) and Lind (2024). Practical applications of VR in specialized technical training have been explored by Abbas et al. (2023) and Korkina and Zhebanov (2023), while critical perspectives on the integration of technologies into complex educational ecosystems are provided by Foster et al. (2024) as well as Koole and Beaumier (2024). The latter argue for a shift in perspective – from viewing technology as a mere pedagogical supplement to recognizing it as an embedded component of a post-digital learning environment that demands a fundamental re-evaluation of traditional teaching practices.

The broader context of higher education digitalization and globalization has been addressed by Prokopiv and Stynska (2023) and Wang (2022). Within this landscape, Derevyanko (2021) contributes a focused analysis on the role of emotional artificial intelligence in professional training. In the specific domain of music and conducting education, digital transformation has manifested through multiple initiatives.

Online educational resources and workshops for conductors have been developed by ConductIT (2021), the Royal Northern College of Music (2022), and Johnson (2023), while Rosiński (2023) and Shumska et al. (2022) have examined the application of digital technologies and distance learning modalities in conductor training. Foundational research on the psychomotor aspects of conducting, particularly conductor-musician synchronization, was established by Luck and Toiviainen (2006).

More recently, specialized VR applications for conducting pedagogy have been developed by Fujiwara et al. (2024), and the efficacy of VR in enhancing choral conducting performance has been empirically investigated by Zhang and Xie (2025).

Further pedagogical dimensions are addressed by Rastruba et al. (2025), who examine neuroeducational factors in the development of professional competences among art students; Rastruba (2023), who focuses on the organization of independent learning in music teacher training; and Zelenin and Polishchuk (2024), who explore the interdisciplinary interaction of educational components. Broader socio-cultural and theoretical perspectives underpinning this study

are informed by the work of Blau and Rigney (2022).

Finally, it is worth noting the breadth of the initial literature search, which extended beyond the core focus of music education. Works from disciplines such as epidemiology (Kheifetz et al., 2022), logistics and supply chain management (Nitsche et al., 2024), computer science (Shanavas et al., 2024), and agricultural technology (Zürner et al., 2023), while not directly applicable to the present analysis, underscore the widespread and interdisciplinary scholarly interest in the digital transformation of vocational training across diverse professional domains.

Their study (Zhang & Xie, 2025) convincingly demonstrated that students who received objective data about their gestures corrected technical errors much faster and more effectively than those who relied solely on the subjective, albeit highly qualified, opinion of the teacher.

Table 1. Classification of digital environments and their impact on performance and interpretation skills

Digital instrument category	Key features	Contribution to interpretive skill
VR simulation systems	Immersive practice with a virtual orchestra/choir; real-time gesture tracking; modeling of acoustic conditions and ensemble composition.	Improvement of gesture technique; safe space for creative experiments with tempo and dynamics; development of "inner hearing"; reduction of performance anxiety.
Digital gesture analysis systems	Automated analysis of gesture patterns (accuracy of timing, amplitude, clarity of auftakt); correlation of gestures with musical result.	Objective self-assessment complements instructor feedback; identifies technical shortcomings; documents progress over time.
Online learning platforms	Curated video tutorials and workshops; access to interactive scores; forums for professional communication.	Going beyond the local educational environment; getting to know the interpretive styles of leading masters; immersing oneself in scores through multimedia commentaries; professional dialogue in a global community.
Video conferencing platforms	Remote rehearsals and workshops; collaborative work on scores in real time; recording sessions for later analysis.	On-going mentoring regardless of geography; documenting and analyzing one's own progress; studying scores together; developing adaptability to different communicative conditions.

Source: author's own development

This conclusion is of exceptional importance for the development of interpretive skill, since it is precisely technical shortcomings, unconscious "noise" of gesture, that often become an insurmountable obstacle to the realization of the conductor's deep artistic intention. The conductor may have a brilliant interpretation of the work, but if his gestures are unclear or contradictory, the orchestra simply will not be able to embody this interpretation.

For the purpose of determining the specific impact of digital technologies on the traditional pedagogical process, Table 2 presents a comparative analysis of traditional and digital approaches to key aspects of teaching and learning.

Table 2. Comparative analysis of traditional and digital approaches in conductor training

Aspect of training	Traditional approach	An approach based on digital learning environments
Practice with the ensemble	Limited by rehearsal schedules, musician fatigue, high cost	Unlimited in time, available 24/7, without psychological pressure and financial costs
Feedback	Mostly subjective, depends on the teacher's experience and intuition	Combining the teacher's subjective assessment with objective, quantitative data from analysis systems
Studying scores	Individual work with the musical text, limited opportunities to hear the piece	Use interactive scores, listen to different interpretations, access video commentaries
Access to teachers	Limited geographically and financially, requires physical presence	Global access through online platforms and video conferencing, asynchronous learning options
Error analysis	Relies on student memory and notes, subjective perception	The possibility to view recordings multiple times, quantitative analysis of gestures, tracking progress over time

Source: author's own development

Analysis of digital environments has revealed their fundamental difference from traditional methods: VR systems and gesture analysis not only improve technology but also create conditions under which technical development and artistic research become a single process, eliminating psychological barriers and accelerating professional development. This closes the key cycle for the development of professional skill: "artistic intention → specific gesture → real musical result → deep reflection → conscious correction of intention and/or gesture". In traditional training, this cycle is often broken or greatly stretched in time due to limited rehearsal time, the impossibility of repeating complex fragments multiple times without tiring the orchestra, and the lack of tools for objectively recording the nuances of the gesture. In addition, digital environments create unique conditions for the formation of "interpretative flexibility" – that most important professional quality, which consists in the conductor's ability to quickly and adequately adapt his own interpretation of a work to the most diverse performance conditions: different composition and level of the orchestra, unfamiliar acoustics of the concert hall, specific requirements of the sound engineer during recording, etc. The ability to instantly, with a few clicks, change the parameters of the virtual environment allows the student to gain such diverse experience that in real professional life is accumulated over years of hard work.

It is worth noting that the four separate categories of digital environments – VR simulators, analytical systems, online platforms and video conferencing tools – do not function in isolation but, on the contrary, can organically complement each other in the educational process. At the same time, they organically complement each other, forming a holistic, synergistic educational ecosystem. In such an integrated learning model, a VR simulator can be used for initial practice of complex techniques and bold experiments with interpretation, a gesture analysis system for objective, accurate diagnosis of mistakes and tracking progress, online platforms for deepening theoretical knowledge, familiarization with world experience and finding inspiration, and video conferences for receiving personalized feedback from a mentor and organizing joint projects with remote musicians. It is precisely this complex, systemic integration of various digital and virtual environments into the multi-year process of professional training that creates an unprecedentedly powerful educational ecosystem capable of ensuring a truly harmonious and comprehensive development of the performing and interpretative skills of a 21st century conductor, organically combining filigree technical precision,

depth and sharpness of analytical thinking, limitless creative freedom, and the necessary psychological resilience.

4. Results

This section presents the results of an empirical study obtained during an anonymous survey of students – conductors at the P. I. Tchaikovsky National Academy of Music of Ukraine and the R. M. Glier Kyiv Municipal Academy of Music. The purpose of the survey was to identify the real state of use of digital and virtual environments in the professional training of conductors, as well as to determine the students' subjective assessment of the impact of these technologies on the development of their performing and interpretative skills. The analysis used data from 30 respondents representing all courses of study (1-4) and both specializations (choral and orchestral conducting). The results of the raw data are presented in Appendix B.

Prior to moving on to the analysis of the main indicators, let us consider the composition of the survey participants, which will allow us to assess the representativeness of the data obtained. The distribution of respondents by courses and specializations is presented in Table 3 and in the form of a diagram in Figure 1.

Table 3. Distribution of respondents by course and specialization (n=30)

Course	Choral conducting	Orchestral conducting	Total
1 course	5	3	8
2 course	4	3	7
3 course	5	3	8
4 course	5	2	7
Total	19 (63.3%)	11 (36.7%)	30 (100%)

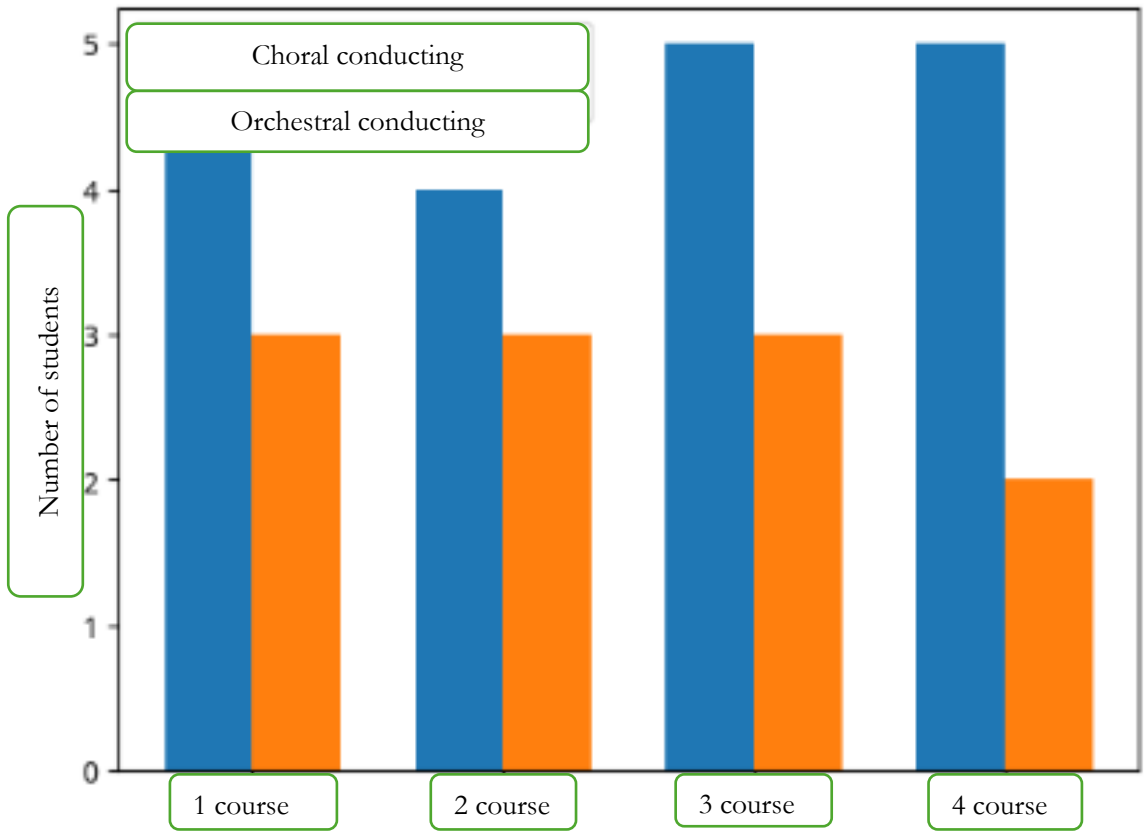

Figure 1. Distribution of respondents by course and specialization (n=30)

As can be seen from the table, the sample is balanced by courses of study (from 7 to 8 students from each course) and covers both specializations, although choir students are represented in a slightly larger number (63.3%), which generally reflects the real ratio of specializations in domestic music educational institutions.

One of the key questions of the research was to identify the real level of student involvement in working with virtual reality as a modern educational tool. The results of the distribution of answers to this question are presented in Table 4 and in the form of a diagram in Figure 2.

Table 4. Experience with VR for educational purposes

Experience level	Number of students	Percentage
No experience	22	73.3%
Tried 1–2 times	6	20.0%
I use it regularly	2	6.7%
Total	30	100%

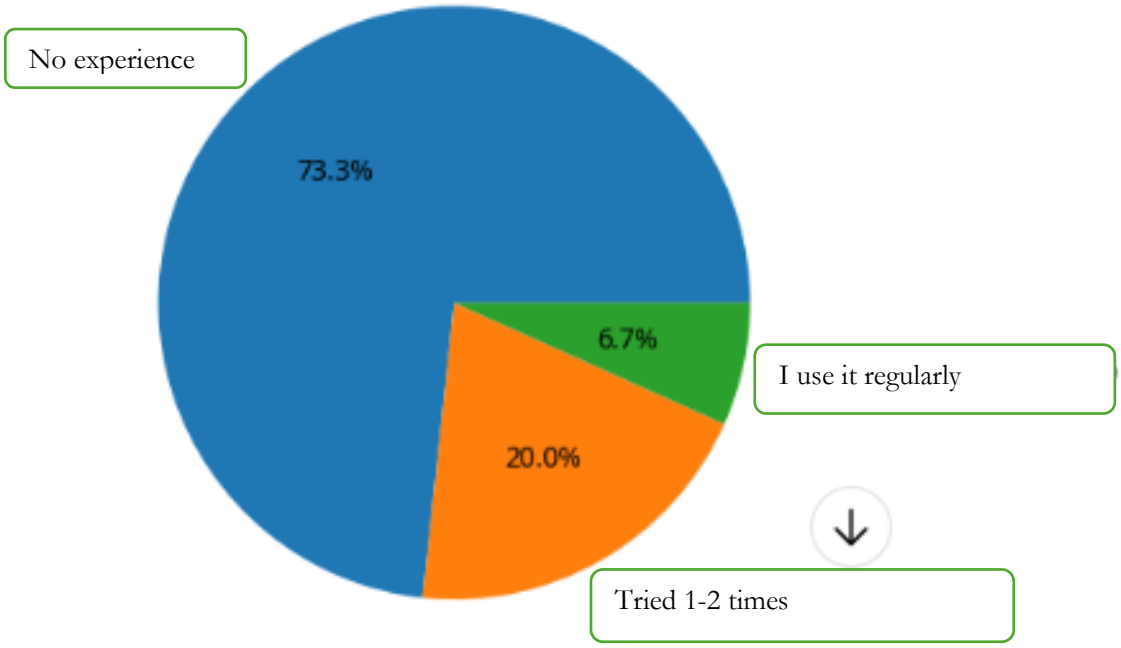

Figure 2. Experience with VR for educational purposes

The data obtained indicate an extremely low level of implementation of VR technologies in the educational process of conductor training. The vast majority of respondents (73.3%) have no experience at all with virtual reality for educational purposes. Only 6.7% of respondents (2 people) use VR regularly. This result contrasts sharply with the high level of interest of students in such technologies, which will be demonstrated in the following sections of the analysis, and indicates a significant gap in the material and technical support of educational institutions.

The central part of the questionnaire was aimed at identifying students' subjective opinions on how digital technologies influence various aspects of their professional skills. Respondents rated six statements on a five-point Likert scale, where 1 meant "completely disagree" and 5 meant "completely agree". The summarized results are presented in Table 5.

Table 5. Self-assessment of the impact of digital technologies on skill development (on a scale of 1–5)

No	Statement	Mean (M)	Standard deviation (SD)
5.1	Using digital technology helps me better understand my technical errors	3.90	0.84
5.2	Thanks to the videos, I can assess my progress more objectively.	3.60	1.10
5.3	Watching master classes from leading conductors online broadens my understanding of interpretation	3.70	0.79
5.4	I feel that digital tools help me experiment with tempo, dynamics, gestures.	3.27	1.05
5.5	I lack access to modern VR technologies at my educational institution	4.43	0.73
5.6	Traditional training with a teacher is sufficient, digital technologies are not necessary	3.13	1.22

Analysis of the data makes it possible to draw several important conclusions. The highest level of agreement was demonstrated by respondents with the statement 5.5 "I lack access to modern VR technologies" (M=4.43, SD=0.73). This result is extremely indicative: students are aware of the potential of modern technologies and feel the need for their implementation, but educational institutions are not yet able to satisfy this request. The low standard deviation (0.73) indicates a high consistency of respondents' opinions on this issue.

The second most important statement is 5.1 about the help of digital technologies in understanding technical errors (M=3.90). This confirms the theoretical proposition that the objectification of feedback is one of the key advantages of digital tools. Students recognize that video recordings and specialized programs allow them to see what remains invisible during direct conducting.

Slightly lower, but still quite high, scores were given to statements about expanding the understanding of interpretation through watching master classes (5.3, M=3.70) and about the objectivity of assessing progress through video recordings (5.2, M=3.60). These results indicate that students actively use the digital resources available to them (primarily video hosting) for professional development.

The lowest score among statements describing the positive impact of technology was item 5.4, which described assistance in experiments with tempo and dynamics (M=3.27). This may be due to the fact that this type of creative experimentation requires more sophisticated tools (e.g., VR simulators or sound modeling programs) that are not readily available to most students.

Statement 5.6 "Traditional training with a teacher is sufficient, digital technologies are not necessary" deserves special attention. Its mean value (M=3.13) is the lowest among all, and the standard deviation (1.22) is the highest. This indicates the lack of a single opinion among students on this issue and the presence of polarization of views. Some respondents (those who rated this statement 4–5) adhere to conservative views and consider traditional methods to be quite sufficient. The other part (those who rated it 1–2), on the contrary, is convinced of the need to integrate digital tools into the educational process.

For the purpose of obtaining an objective picture of the actual use of digital technologies, the respondents were asked to rate the frequency of use of six types of tools on a scale from 0 ("never") to 3 ("daily"). The results are presented in Table 6.

Table 6. Frequency of use of digital tools in the learning process (on a scale of 0–3)

No	Tool / Resource	Mean (M)	Standard deviation (SD)
4.1	Videos of one's own conducting for introspection	1.70	1.09
4.2	Video recordings of performances by professional conductors	2.30	0.70
4.3	Specialized online platforms for conductors	0.83	1.09
4.4	Programs for working with scores	1.70	1.09
4.5	VR conducting simulators	0.43	0.90
4.6	Mobile apps (metronome, recording, settings)	1.90	0.80

The data obtained demonstrate a clear hierarchy of popularity of different types of digital tools. Most often, students use video recordings of performances by professional conductors (M=2.30, SD=0.70). This indicator is close to the mark of "1–2 times a week", which indicates the systematic use of this resource as a source of professional development. The low standard deviation indicates that this practice is widespread among the majority of students.

The second position is occupied by mobile applications (M=1.90, SD=0.80), which students use for practical purposes – metronome, recording rehearsals, tuning, etc. This result is quite expected, given the widespread use of smartphones and the availability of appropriate software.

Videos of self-conducting (4.1) and programs for working with scores (4.4) received the same average score (M=1.70). This indicates that students use these tools episodically (on average 1-2 times a month), but not on a regular basis. The higher standard deviation (1.09) in both cases indicates significant variability in individual practices: some students use these tools often, others never.

The lowest frequency of use was recorded for specialized online platforms (4.3, M=0.83) and VR simulators (4.5, M=0.43). These results correlate with previous data on the lack of access to modern technologies. The low use of specialized platforms (ConductIT, RNCM) may be associated with both the language barrier and the lack of awareness of students about the existence of such resources.

A separate block of questions was devoted to the practical purposes for which students use digital technologies. The results are presented in Table 7.

Table 7. Frequency of use of digital resources for various learning purposes

No	Purpose of use	Mean (0-4)	Usage level
6.1	Score analysis using audio/video recordings	2.8	Often
6.2	Comparing different interpretations of the same work	3.1	Often-Constantly
6.3	Working on gesture techniques with video recording	2.1	Sometimes
6.4	Discussing interpretation with fellow students online	1.8	Rarely-Sometimes
6.5	Receiving remote consultations from a teacher	1.4	Rarely

The highest level of use was recorded for the purpose of comparing different interpretations of the same work (3.1), which practically corresponds to the level of "constantly". This indicates that students actively use digital resources (primarily audio and video recordings) to form their own interpretive experience, analyzing and comparing the approaches of different conductors to the same work.

Slightly lower scores were obtained for work on gesture technique with video recording (2.1). Although students recognize the usefulness of this method (which is confirmed by the high score of statement 5.1), in practice, they use it only

occasionally. This may be due to psychological discomfort from viewing their own recordings, as well as the lack of systematic introspection skills.

The lowest scores were recorded for digital communication: online conversations with other students (1.8) and remote consultations with teachers (1.4), confirming the dominance of face-to-face interaction in the educational process. The data indicate an insufficient use of digital platform resources to facilitate collaborative learning and remote communication. The summarized results are presented in Table 8.

The analysis of open-ended responses confirms and deepens the results of the quantitative analysis. Students most often mention YouTube and videos as a primary source of professional development, which correlates with the highest frequency of use of this resource.

Table 8. Thematic analysis of responses to open-ended questions

Category	Typical answers (quotes)	Frequency of mentions
The most useful tools		
YouTube/video	"Recordings of great conductors are the main source of inspiration", "One can observe different interpretations of the same work"	18
Audio recordings	"I listen to recordings to understand the form of the work", "It helps me learn the score"	8
Programs for musical scores	"It's convenient to follow the score while listening"	6
Own video recordings	"I film myself on my phone, then analyze my mistakes – it's very useful"	5
Disadvantages and wishes		
Lack of access to VR	"I would really like to try VR conducting, but we don't have it", "If we had access to such equipment, it would be a breakthrough"	15
The need for Ukrainian-language content	"There are few materials in Ukrainian", "We want more master classes from our conductors"	7
Recording quality	"Many recordings with poor sound or picture quality"	4
Systematicity	"There is a lack of a systematic approach to keep it all from being chaotic"	3

At the same time, the theme of access to VR technologies dominates the wishes, which is confirmed by the high indicator for statement 5.5. For the purpose of identifying the relationships between different indicators, a correlation analysis was conducted, the results of which are presented in Table 9. The correlation analysis showed that the practice of creating one's own films ($r = +0.61$) opens the way for students to deeper professional reflection: meeting oneself on the screen allows them to perceive technical shortcomings through the eyes of an outside observer and to realize them without the usual psychological defenses.

Table 9. Correlations between key indicators

Correlation	Value (r)	Interpretation
VR Experience → Need for Access (5.5)	–0.52	Moderate negative: Those with VR experience are less likely to feel a lack of access
Using video (4.2) → Understanding interpretation (5.3)	+0.48	Moderate positive: more frequent video viewing is associated with better understanding of interpretation
Own videos (4.1) → Understanding mistakes (5.1)	+0.61	Strong positive: Those who frequently record themselves are better able to understand their technical errors
Training course → Using special platforms (4.3)	+0.43	Moderate positive: seniors more often use specialized resources

On the other hand, watching recordings of outstanding conductors (r = +0.48) has a different effect – by watching masters, students receive a variety of interpretive solutions, imperceptibly expanding their own artistic worldview.

The negative correlation between virtual reality experience and a feeling of lack of access (r = –0.52) is intriguing; it seems that students who have already had the chance to experience virtual reality would feel less deprived of it.

The empirical study makes it possible to draw a number of generalized conclusions regarding the current state of the use of digital technologies in the training of conductors. First of all, a significant gap was revealed between the technological demand of students and the real level of provision of the educational process: the vast majority of respondents (73.3%) do not have any experience working with VR technologies for educational purposes, which sharply contrasts with the highest demand for access to modern VR technologies (M=4.43). The most popular digital resources in the real practice of students remain video recordings of professional conductors (M=2.30) and mobile applications (M=1.90), which are used systematically and play an important role in professional development. Particularly revealing is the strong correlation (r=+0.61) between the frequency of own video recordings and understanding of technical mistakes, which confirms the effectiveness of video recording as a method of introspection. At the same time, the attitude towards digital technologies turned out to be heterogeneous: along with a high demand for innovations, there is a group of students who consider traditional learning to be quite sufficient, which indicates the need for a differentiated approach to the implementation of technologies. Separately, an urgent need for Ukrainian-language content and specialized resources adapted to the domestic repertoire was recorded, which requires attention from the developers of educational programs and teachers.

5. Discussion

The empirical study revealed not only a technical gap – the lack of necessary equipment and software – but also a human one: interested students who want to acquire a profession using modern methods are forced to study in the same way as they did decades ago. Creating a favorable environment for professional development means, above all, the ability to listen and respond to this demand. The disparity between students' tremendous interest in contemporary digital tools and their incredibly low actual use was the most significant finding.

The statement about the lack of access to VR technologies received the highest average score (M=4.43), indicating a perceived need for students to technologically update the educational process; however, only 6.7% of respondents have regular experience with virtual reality. This gap is especially significant against the background of the benefits that, according to a theoretical review, VR technologies offer for the development of performing and interpretive skills: Fujiwara et al. (2024) demonstrate that VR simulators provide objective feedback on the trajectory of movements,

which is impossible to achieve in traditional teaching.

However, this powerful potential remains unrealized in domestic educational practice, which can be explained by both the high cost of equipment and the lack of methodological developments adapted to the Ukrainian context. The observation of Koole and Beaumier (2024) that the presence of technologies in itself does not guarantee their effective use seems correct – systemic pedagogical integration is necessary, which takes into account the specifics of educational content, teacher training, and student readiness.

Video recording, although inferior to specialized analysis systems in measurement accuracy, remains the most accessible tool for objectifying feedback, because every modern smartphone allows students to see themselves from the outside. At the same time, a slightly lower frequency of using their own video recordings compared to watching professionals may indicate a certain psychological barrier: as Zelenin and Polishchuk (2024) note, watching one's own performance often causes discomfort, especially at the initial stages of learning.

Overcoming this barrier is an important pedagogical task since it is regular video recording, as demonstrated by correlation analysis, that is the key to a deeper awareness of one's own shortcomings. The data also shed light on how digital technologies influence the formation of interpretive skills: the highest indicator among the practical goals of using technologies was the comparison of different interpretations of the same work, which practically corresponds to the level of "constantly". This result has a deep theoretical basis, because, as Rastruba (2023) notes, performing interpretation is a complex creative process that requires a deep understanding of style, era, and the author's intention.

The need for Ukrainian-language content identified during the analysis of open-ended questions deserves special attention: students expressed a desire to have more materials in Ukrainian, master classes by domestic conductors, and resources adapted to the Ukrainian repertoire. The language barrier limits access to international platforms such as ConductIT (2021), and the lack of domestic digital resources preserves the orientation towards Western repertoire, making it difficult to study Ukrainian music.

6. Conclusions

The research confirmed that digital and virtual environments have a significant, but still untapped, potential for learning. Theoretical analysis allowed us to identify four categories of such environments, each of which in its own way expands the horizons of the professional development of student conductors. Virtual reality systems create an atmosphere of creative freedom in which young artists can focus on their artistic endeavors without experiencing the psychological burden inherent in working with a live orchestra. Digital gesture analysis systems offer objective feedback that does not contradict but harmoniously combines with a sensitive pedagogical vision, revealing to students what remains invisible in the maelstrom of direct conducting. Online platforms break down the walls of the classroom, offering the opportunity to join master classes with outstanding conductors from around the world and, through interactive scores, to deeply feel the breath of the composer's thoughts. Each of these tools not only develops technical skills but also nourishes the inner world of the young artist, helping him find his unique voice in the boundless universe of musical interpretation.

Videoconferencing tools ensure continuity of mentoring regardless of geographical location, creating conditions for joint analysis of scores in real time and supporting live professional communication. Each of the digital tools described above makes a unique contribution to the development of professional competence: helping to improve gesture technique, promoting interpretive flexibility and gradually reducing stage fright. This combination of technical sophistication and creative freedom is where true mastery is born.

Thus, the empirical part of the research, conducted on the example of Kyiv music academies, revealed a disturbing dissonance: despite the high demand of students for modern technologies, their implementation remains extremely low. The most

pressing problem was the lack of access to VR technologies, which the vast majority of respondents had never had the opportunity to use. These data are not just a statement of technological inadequacy, but evidence of a growing gap between the expectations of young people who want to study in a modern way and the real conditions offered to them by the education system.

At the same time, the most popular were videos with the participation of professional conductors and mobile applications, and the strong correlation between the practice of one's own videos and understanding of technical mistakes confirmed the effectiveness of video recording as a method of self-analysis. A clear need was identified for the creation of digital content in the Ukrainian language, adapted to the national repertoire. The optimal development model is the organic integration of digital and traditional methods into a comprehensive pedagogical system, where technologies serve technical development, objective diagnostics and broadening of horizons, while live communication with teachers and work with a live orchestra remain the culmination of artistic education.

References

Abbas, Y., Martinetti, A., Nizamis, K., Spoolder, S., & van Dongen, L. A. M. (2023). Ready, trainer … one*! discovering the entanglement of adaptive learning with virtual reality in industrial training: a case study. *Interactive Learning Environments, 31*(6), 3698–3727. https://doi.org/10.1080/10494820.2021.1940215

Austermann, C., von Blanckenburg, F., von Blanckenburg, K., & Utesch, T. (2025). Exploring the impact of virtual reality on presence: findings from a classroom experiment. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1560626

Blau, A., & Rigney, D. (Eds.). (2022). *The Oxford Handbook of Karl Marx*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190056285.001.0001

ConductIT. (2021). *ConductIT: Online resources for conductors*. ERASMUS+ Strategic Partnership project. http://www.conductit.eu

Derevyanko, S. P. (2021). Emotional artificial intelligence in professional training of future psychologists. *Information Technologies and Learning Tools, 81*(1), 192–209. https://doi.org/10.33407/itlt.v81i1.3281

Foster, S., Barth, L., & Chaudhry, Z. (2024). Virtual Gathering Platforms in Academic Teaching: Potential and Applications. *Electronic Journal of e-Learning*, *22*(3), 17. https://doi.org/10.34190/ejel.22.3.3263

Fujiwara, K., Sano, F., & Mitobe, K. (2024). Development of a VR Training System for Saito's Music Conducting Method. *IEEJ Transactions on Electrical & Electronic Engineering*, *19*(2), 187–192. https://doi.org/10.1002/tee.23947

Johnson, C. (2023). *Virtual Conducting Workshops: A New And More Equitable Approach To Professional Development For Conductors* (Doctoral dissertation, Arizona State University). https://keep.lib.asu.edu/items/171950

Kheifetz, Y., Kirsten, H., & Scholz, M. (2022). On the Parametrization of Epidemiologic Models—Lessons from Modelling COVID-19 Epidemic. *Viruses*, *14*(7), 1468. https://doi.org/10.3390/v14071468

Koole, M., & Beaumier, A. (2024). Tipping the canoe: What can be learned from a postdigital analysis of augmented and virtual reality in networked learning? *Proceedings of the International Conference on Networked Learning*, *13*. https://doi.org/10.54337/nlc.v13.8553

Korkina, S. V., & Zhebanov, A. V. (2023). Use of digital technologies to improve the quality of training for railway transport specialists. *AIP Conference Proceedings*, *2624*(1), 020024. https://doi.org/10.1063/5.0133409

Lind, J. (2024). Understanding Students' Learning of Technology through Interaction Supported by Virtual Reality. *Design and Technology Education*, *29*(2), 336–358. https://eric.ed.gov/?id=EJ1449719

Luck, G., & Toiviainen, P. (2006). Ensemble musicians' synchronization with conductors' gestures: An automated feature-extraction analysis. *Music Perception, 24*(2), 189–199. https://doi.org/10.1525/mp.2006.24.2.189

Nitsche, A. M., Franczyk, B., Schumann, C. A., & Reuther, K. (2024). A Decade of Artificial Intelligence for Supply Chain Collaboration: Past, Present, and Future Research Agenda. *Logistics Research, 17*(1), Article 5. https://doi.org/10.23773/2024_5

Prokopiv, L., & Stynska, V. (2023). Higher Education Digitalization in the Context of Globalization Changes. *Annales Universitatis Mariae Curie-Skłodowska. Sectio J, Paedagogia-Psychologia*, *36*(3), 7–18. https://doi.org/10.17951/j.2023.36.3.7-18

Rastruba, T. (2023). Organization of independent work in the training of future teachers of musical art: modern challenges and realities. *Professional Art Education,* *4*(1), 41–51. https://doi.org/10.34142/27091805.2023.4.01.05

Rastruba, T., Huseinova, L., Koval, O., Pavlenko, O., Liashenko, T., & Dvornyk, Y. (2025). Examining an Interdisciplinary Interaction of Educational Components as a Prerequisite for Developing Professional Competences in Art Students: Neuroeducational Factors. BRAIN. *Broad Research In Artificial Intelligence And Neuroscience, 16*(1 Sup1), 16–26. http://dx.doi.org/10.70594/brain/16.S1/2

Rosiński, A. (2023). Digital technologies in teaching conducting. *PUPIL: International Journal of Teaching, Education and Learning*, *6*(3), 57–67. https://doi.org/10.20319/pijtel.2023.63.5767

Royal Northern College of Music. (2022). *RNCM launches free digital resources for aspiring conductors*. https://www.rncm.ac.uk/news/rncm-launches-free-digital-resources-for-aspiring-conductors/

Shanavas, V. A., Changat, M., Hellmuth, M., & Stadler, P. F. (2024). Clusters and Unique Least Common Ancestors in Directed Acyclic Graphs. *Research Square Platform LLC*. https://doi.org/10.21203/rs.3.rs-3997739/v1

Shumska, L., Shumskyi, M., Savchuk, G., Puchko-Kolesnyk, Y., Velychko, N., & Chincheva, L. (2022). Features of the applying the information and communication technologies in the conditions of distance master's training of choir and orchestra conductors. *Revista Eduweb*, *16*(3), 205–217. https://doi.org/10.46502/issn.1856-7576/2022.16.03.15

Wang, J. (2022). The application of computer music technology in the cultivation of music education professionals. *Mathematical Problems in Engineering*, *2022*, Article ID 9632920. https://doi.org/10.1177/02557614221084315

Zhang, L., & Xie, D. (2025). Using virtual reality to enhance students' chorus conducting performance. *Interactive Learning Environments*, *33*(3), 2085–2098. https://doi.org/10.1080/10494820.2024.2390545

Zürner, S., Deutschländer, P., Schieck, M., & Franczyk, B. (2023). Sustainable Development of AI applications in Agriculture: A Review. *Procedia Computer Science*, *225*, 3546–3555. https://doi.org/10.1016/j.procs.2023.10.350