

Innovations in Teaching; the Implementation of ICT in the Teaching of Scientific and Artistic Subjects and their Impact on the Personalization of Learning

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ARTICLE INFO

Keywords:

Information and Communication Technologies, Artistic Subjects, Scientific Subjects, Personalization of Learning

ABSTRACT

In modern education, the information and communication technologies are having an increasing impact on personalized learning. Their implementation responds to the digital transformation in our society and requires the development of digital literacy as a key competence of both teachers and students. In Mathematics, Physics, Music and Art education, individualizing learning is supported by selected tools such as GeoGebra, Corinth 3D, Musescore, Solfy or graphic editors (GIMP, Procreate, Adobe Fresco). They enable adaptive and personalized forms of learning, support visualization, creativity, and self-directed learning. Although artificial intelligence presents challenges related to overreliance, academic integrity, and the development of critical and creative thinking, Information and communication technologies (ICT) and Artificial Intelligence (AI) technologies can enhance education by supporting visualization, collaboration, creativity, differentiated instruction, and personalized learning.

1. Introduction

The dynamic development of digital technologies has brought fundamental changes to our society, economy and ultimately, to education. Schools face the necessity of adapting to modern trends and preparing students for a world in which digital literacy is not only an advantage, but also a condition for successful functioning in the future. Information and communication technologies (ICT) have therefore become an integral part of education, fundamentally influencing not only the content and methods of teaching, but also the role of the teacher and the student's position in the learning process.

Technologies have the potential to increase the variability of education, offer expanded possibilities for visualizing complex phenomena, support collaborative learning, develop creativity and enable differentiation of teaching according to the students' needs (Julien, 2026).

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Cite this article as:

Karásek, R., Vlčeková, A., & Strenáčiková, M. (2026). Innovations in Teaching; the Implementation of ICT in the Teaching of Scientific and Artistic Subjects and their Impact on the Personalization of Learning. *European Journal of Teaching and Education*, 8(3): 78-93. <https://doi.org/10.33422/ejte.v8i3.1925>



In this way, they contribute to the transition from traditional lectures to active learning methods and personalized learning, where the student acts as an active subject of knowledge.

1.1.The Context of Personalized Learning and ICT

The concept of personalized learning arises from the recognition that each student learns at a different pace, prefers different learning styles, has different prior knowledge, experiences and interests. Personalization creates an inclusive learning environment in which individual differences are respected while fostering talent development and strengthening motivation (Petlák, 2023).

The educational context of AI-supported and personalized learning varies and has been explored across various education levels and subject areas. In our study, we focus on higher education and broader secondary-school education, particularly in cross-sector applications in Mathematics, Physics, and Art. In higher education, Azevedo et al. (2022) examined the MathE platform as a case study for mathematics learning and assessment. The study reported generally favourable student perceptions of the platform among 372 higher-education students across eight countries, providing evidence of its applicability across a broad range of university mathematics contexts.

Evidence from higher education is also provided by Luo et al. (2025), whose systematic review of AI-based learning tools focused on applications such as personalized learning, real-time feedback, assessment, and recommendations. It compares different types of AI learning tools and their educational functions, highlighting the potential benefits of AI-supported learning while also indicating variation in outcomes across applications.

At the school level, Al Shloul et al. (2024) investigated activity-based learning and compared it with conventional teaching approaches. They focused on secondary-school students and subjects including science. Their findings indicate that activity-based learning was associated with higher student engagement, motivation, critical-thinking skills, and academic achievement.

At a broader level, Farhood et al. (2025) synthesised 125 studies published between 2015 and June 2025 on AI-based personalized learning. Their review includes studies from K–12 education, higher education, and institutionally supported online learning, compares different AI applications and algorithms and examines their influence on teaching, learning, and assessment.

ICT provides opportunities for adaptive learning, immediate feedback, self-regulation, and individualized approach of the teacher to each student (Golait et al. 2026). Cloud-based platforms allow learning activities to be transferred outside the classroom; thus, learning becomes a continuous process.

The use of ICT has long been associated mainly with Mathematics and Computer Science disciplines. However, the interdisciplinary and creative potential of technologies allows the effective enrichment of artistic subjects as well, mainly Music and Art. Thanks to this, students gain new opportunities for self-expression, discovery and presentation of their own creativity (Petlák, 2023).

The ICT implementation enables:

- simulation of complex phenomena in Physics,
- visualization of abstraction in Mathematics,
- creation and interpretation of Music,
- development of visual literacy and digital creativity in Art.

Recent research indicates that ICT, and specifically AI is transforming both art and music education, particularly in higher education settings. AI tools are increasingly integrated into teaching and learning processes. A systematic review of empirical studies (2019 – 2025) found that AI applications in art education were primarily implemented in university-level courses and were associated with improvements in student engagement, creative thinking, multimodal expression, and learning achievement when supported by structured pedagogical frameworks (Jiang, Fan, & Liu, 2026).

In visual arts and design education, comparative and case-based studies show that generative AI tools can support creative exploration, idea generation, and interdisciplinary project work. Students use AI to generate alternative concepts and visualize solutions. At the same time, AI brings challenges related to authorship, assessment practices, academic integrity, and equitable access to technology into arts education (Rong et al., 2025; Fang, 2026)

Similar trends are evident in music education, where AI is increasingly implemented at the secondary and tertiary levels, particularly in nine major areas of application, including intelligent tutoring systems, personalized learning environments, composition support, music theory instruction, ear-training platforms, performance assessment, collaborative music making, virtual and augmented reality environments, and assistive technologies (Sánchez-Jara et al. 2024). AI-supported learning systems have the potential to provide immediate feedback, adaptive practice recommendations, and individualized learning pathways, contributing to more efficient and student-centered music instruction (Zhang, 2026).

Despite many benefits, AI should be viewed as a pedagogical support tool rather than a substitute for artistic or musical expertise. Comparative analyses highlight the continuing importance of teachers in fostering creativity, critical reflection, aesthetic judgment, and human expression. Current research therefore advocates a human-AI collaborative approach in which technology enhances, rather than replaces, artistic and musical learning processes (Mazlan et al., 2026)

Overall, existing evidence suggests that AI can positively influence creativity, engagement, and personalization in various school subjects, including Mathematics, Physics, Arts and Music. In the future, studies should examine measurable learning outcomes, compare ICT-supported and traditional instructions, and explore its impact across diverse educational levels and cultural contexts.

1.2. Methods

Our main aim is to point out the possible use and impact of ICT in teaching Mathematics, Physics, Music and Art on personalized learning/teaching.

Partial aims are to introduce the possibilities of using technology in teaching selected subjects, identify the benefits and limitations of ICT implementation, and explore the possibilities of personalized teaching and learning supported by digital tools.

This study employs a qualitative review methodology to examine the role of information and communication technologies (ICT) in teaching Mathematics, Physics, Music, and Art, with particular attention to their potential to support personalized learning and teaching. The review was guided by the following research questions:

- RQ1: What possibilities does ICT offer for teaching and learning Mathematics, Physics, Music, and Art?
- RQ2: What benefits and limitations are associated with the implementation of ICT in the selected subject areas?

- RQ3: How can digital technologies contribute to personalized teaching and learning?
- RQ4: What pedagogical functions of ICT are most relevant to personalization across the selected disciplines?

The search focused on studies addressing the integration of information and communication technologies (ICT) in teaching Mathematics, Physics, Music, and Art and their contribution to personalized learning. The relevant sources published between 2020 and 2026 were identified through academic databases Scopus, Web of Science, Google Scholar and Eric and scholarly search engines using a combination of keywords ICT in education, digital technologies, personalized learning, technology-enhanced learning, Mathematics education, Physics education, Music education, and Art education.

The selected literature sources were analysed using qualitative content analysis and thematic comparison. The findings were organized according to three main themes: (1) possibilities of ICT implementation, (2) benefits and limitations of digital technologies, and (3) the potential of ICT to support personalized learning and teaching. The analysis also compared the specific uses of ICT across Mathematics, Physics, Music, and Art in order to identify both discipline-specific and common pedagogical possibilities.

The reviewed findings were subsequently interpreted in relation to pedagogical practice. Particular attention was paid to the ways in which digital technologies can support different learning needs, increase learner activity and engagement, facilitate differentiation, and provide opportunities for individualized learning. By synthesizing theoretical and practical findings, the study provides an interdisciplinary perspective on the use of ICT to enhance teaching effectiveness and address diverse learner needs.

2. ICT Innovation in Teaching Scientific and Artistic Subjects

In modern education, which is constantly changing due to technological progress, the implementation of ICT gains increasing importance. In Mathematics, which is often considered a demanding and abstract discipline, the use of digital tools represents an opportunity to make the curriculum more attractive, to increase the level of students' understanding and to support students' individual needs. Many students fail in Mathematics not because of a lack of ability, but because of a lack of motivation, a lack of understanding of abstractions or a fear of mistakes. Technology can alleviate these problems by making learning more accessible, understandable, and personalized.

The integration of Artificial Intelligence (AI) represents the next level of ICT implementation, bringing radical changes to teaching. AI is no longer limited to software and interactivity, but it has adaptive, analytical and generative potential that significantly supports personalization and effectiveness of learning in both scientific and artistic types of subjects (Furze, 2025).

In scientific subjects, such as Physics, Chemistry or Mathematics, AI analyses students' answers and procedures in various tasks. Instead of general feedback, it provides more targeted instructions and feedback (Luo et al., 2025) exactly where the student makes errors in logic or calculations. For example, if a student constantly makes mistakes in calculating equations, AI will automatically assign additional exercises and explanatory videos for this particular step. A suitable AI for solving such tasks is MathGPT, which focuses on mathematical calculations and, unlike ChatGPT, makes much fewer errors. In MathGPT, we can use the appropriate command to create a test within seconds that evaluates the answer and also shows the steps that should have led to the correct result.

 Kupujete byt za 150,000 € s 20% akontáciou a financujete zvyšok 30-ročnou hypotekárnou pôžičkou s ročnou úrokovou sadzbou 4%. Aká bude mesačná anuitná splátka (v eurách)?

☐ 500,00 €

☒ 610,50 €
Príliš vysoká; pravdepodobne zaokrúhľovanie sadzby.

☐ 650,00 €

☐ 572,90 €

Figure 1. MathGPT: generated mathematics task with automated feedback and answer evaluation

AI tools help students process and interpret large data sets obtained from virtual or real laboratories. They can identify patterns, anomalies and help fit regression models, allowing students to focus more on understanding, rather than on tedious calculations. AI can also run complex simulations, such as weather forecasting, molecular dynamics and demonstrate how changing input variables will affect the outcome in real time, which supports the understanding of causality and modelling.

In the arts, AI offers generative tools, such as Suno, and AI-powered art generation tools, where students can use generative AI to rapidly prototype ideas. For example, AI can generate a starting visual concept based on a text description (prompt), which the student can then develop manually or digitally. This speeds up experimentation with different styles and themes. AI can visually analyse works, e.g. identify stylistic elements, colour palettes, compositions and compare them with other works from art history, thus offering new analytical insights into creation and interpretation. There are also music AI applications that can listen to a student playing a musical instrument and provide immediate feedback on the accuracy of tone, rhythm and tempo. The system adapts the exercise difficulty to the student's current level, which is a highly effective form of personalized technical training (Mahmoud & Sørensen, 2024).

While the implementation of ICT opens the door to personalization, the integration of generative artificial intelligence such as *ChatGPT*, *Gemini*, etc. brings specific risks to scientific and artistic education subjects that cannot be ignored. Furze (2025) argues that the greatest threat is the potential for automatic generation of solutions and creation, which directly threatens the very purpose of these subjects. In the natural sciences, AI can bypass the process of problem solving and critical analysis of the data, thereby depriving the students' training in logical thinking. In art education, authentic creativity and manual skills are at risk of being neglected, as AI can generate art designs, musical compositions or textual analyses that the student simply takes over, instead of dedicating himself/herself to the long-term creative process and developing his/her own artistic voice. The use of AI in art has many aspects that do not necessarily challenge human creativity as such, but rather support it (Latikka et al., 2023). This may lead to superficial understanding and a false sense of competence, which requires a redefinition of assessment and pedagogical approach, so that AI becomes a tool to support, rather than replace, learning and creation.

2.1. Educational Platforms and Programs in Teaching

2.1.1 Scientific Subjects

Another important group of digital tools in teaching Mathematics and other natural sciences are adaptive learning platforms, which include *GeoGebra*, *Khan Academy*, *Corinth 3D*,

Matika.in or *Umim matiku*. They offer extensive databases of 3D models and interactive tasks differentiated by level of difficulty and are also able to adapt the pace and content of learning to the student's individual needs. They also provide immediate feedback, which is extremely important in Mathematics: the student immediately learns whether (s)he has progressed correctly and can identify and correct an error in real time. The platforms also allow the teacher to monitor the student's progress through analytical functions, thanks to which he can accurately diagnose areas, in which the student needs support. The visualization of abstract mathematical concepts is an area in which ICT plays a fundamental role. Students often cannot understand mathematics as a system of relationships and connections when concepts are presented to them only in text or symbolically. Technologies allow the animation of processes, such as changes in function graphs when modifying coefficients, or modelling probabilistic processes and statistical interpretations. When working with solid geometry, 3D models can help with understanding rotational solids, cross-sections, or volume relationships, which are typically visually challenging. In this way, abstraction is reduced and constructive learning is strengthened.

GeoGebra - Dynamic Geometrical System (DGS) GeoGebra is more than just a set of tools for mathematical calculations. It is a free platform that connects teachers and students from elementary school to professors and university students. GeoGebra offers them a new way to discover and study Mathematics. The program provides the opportunity to work interactively with mathematical objects, change their parameters and observe the subsequent changes. Such manipulation leads students to a deeper understanding of relationships between quantities, and enables discovery learning, which is significantly more effective than passive reception of information.

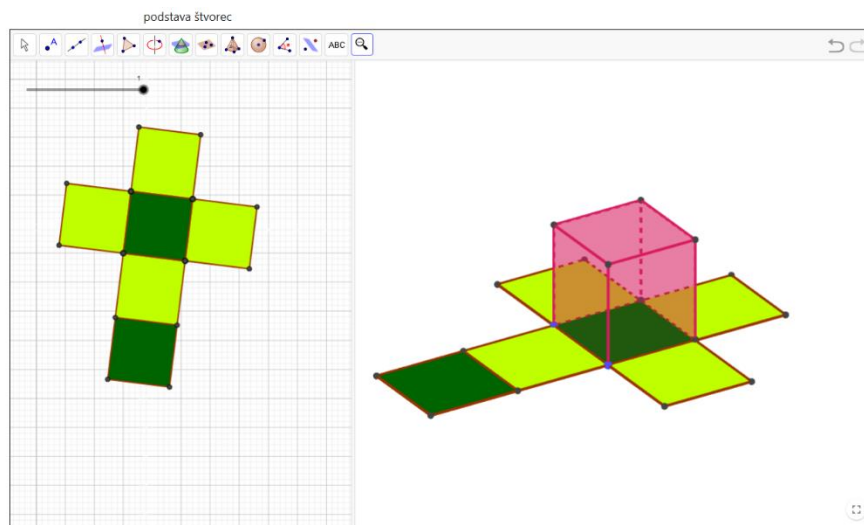


Figure 2. GeoGebra: solids

Digitalization allows for the visual processing of mathematical phenomena that are difficult for students to grasp in traditional presentation. GeoGebra can be used from the first grades in elementary school, where, for example, in geometry it is possible to rotate geometrical shapes in three-dimensional space, visualize projections or explore the relationships between edges and angles, which significantly supports the development of pupils' spatial imagination. In addition to geometry, the program also works great in the field of algebra, where students can solve various types of equations in such a way that the pre-set input values can be changed at will. In this way, they can observe how changes in input values affect outcomes.

ŘEŠ rovnici

$$\frac{y+a}{y+b} - 2 = \frac{y-b}{-y+a}$$

$$\frac{y+3}{y+4} - 2 = \frac{y-4}{-y+3} \quad / \cdot (y+4) \cdot (-y+3)$$

$$(y+3) \cdot (-y+3) - 2 \cdot (y+4) \cdot (-y+3) = (y-4) \cdot (y+4)$$

$$y^2 + 2y - 15 = y^2 - 16$$

Rovnice nemá řešení, jestliže $y \neq -4$ nebo $y \neq 3$

$$y = \frac{-1}{2}$$

a = 3

b = 4

postup řešení = 4

Figure 3. GeoGebra: solving equations

As mentioned, GeoGebra can also be effectively used by professors at universities, where it helps to visualise complex concepts in mathematical analysis such as Riemann sums for understanding a definite integral, graphical display of convergence in Fourier or Taylor series, or to display various functions in 3D space etc.

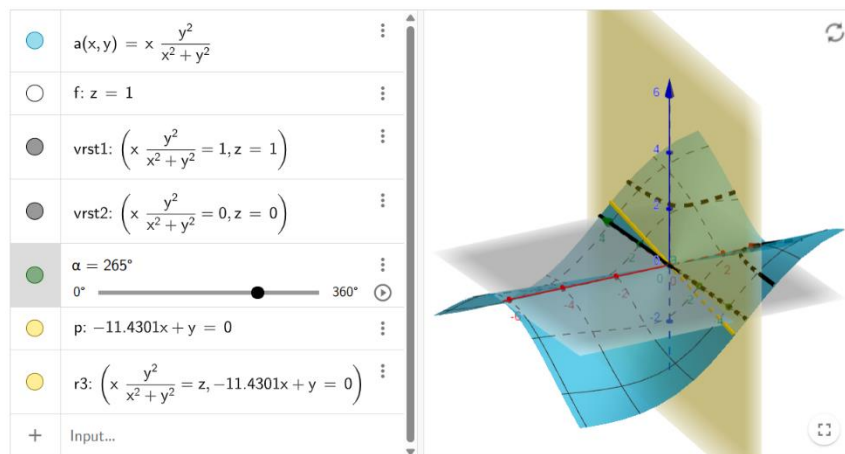


Figure 4. GeoGebra: visualisation of functions

In addition to direct use in the classroom, GeoGebra allows teachers to create their own interactive applets and dynamic worksheets. These materials can be shared online, which supports collaborative learning and provides students with the self-study opportunity.

Working in GeoGebra is intuitive, but in order to be able to use the many tools it offers, it is necessary to learn working with the program. There is a great support from the publisher, e.g. many manuals, videos on the website www.geogebra.com. The developers even organize specialized courses focused on advanced scripting and creating sophisticated tools, for both students and teachers.

Corinth 3D Corinth 3D combines modern technologies with cutting-edge educational content of more than 1,500 interactive models in 3D, augmented reality (AR), and virtual reality (VR). It covers topics from the fields of human, animal, and plant biology, chemistry, mathematics, physics, geology, palaeontology, geometry, astronomy, and culture.

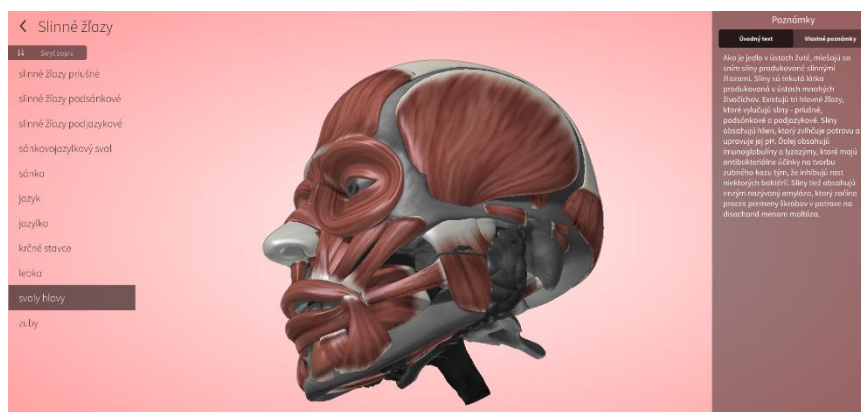


Figure 5. Corinth3D, picture of muscles of the head and face

Each model is perfectly designed, with the possibility to select individual sections. The 3D model can be rotated 360° to show students every detail. A teaching text is prepared for each part.

According to Petlák (2023), an important trend is the gamification of teaching. It uses game mechanisms to increase student motivation and engagement. Studies showed that activity-based learning improves student's level of involvement and ability to think critically (Al Shloul et al., 2024). Applications such as *Kahoot*, *Quizizz* and *Matific* transform traditional mathematical problem-solving into a competitive and fun activity that removes the fear of failure and supports a positive attitude towards mathematics. In addition, the game environment creates a safe space for making mistakes, which is a key to develop mathematical courage, the ability to try, experiment and ask questions (Petlák, 2023).

The digital environment may also contribute to more effective assessment. Automated task corrections save the teacher's time and at the same time, it allows for immediate error diagnosis. This type of assessment is an important element of a formative approach that supports continuous learning, not just summative knowledge assessment at the end of a thematic unit. Thus, students gain a clear overview of what they already can do well and what they need to improve, which is the basis for self-directed learning (Azevedo et al., 2022).

The implementation of ICT in Mathematics has a significant impact on the personalization of learning. Each student has the opportunity to work at his/her own pace, to use different forms of information processing (visual, auditory or kinaesthetic) and to develop his/her strengths. For students who need to repeat the same procedure several times, technology provides time and space without a sense of shame. On the contrary, students with higher mathematical talent can solve more demanding tasks and do projects that help them progress. This supports inclusive education, in which each student can learn to the fullest extent of his/her abilities.

2.1.2 Artistic Subjects

The use of ICT in teaching is already a common part of the educational area Art and Culture. ICT are often implemented in teaching artistic subjects such as Music and Visual Art (Art).

In order to support personalized learning, the implementation of ICT can be oriented either towards the teachers' preparation and work or students' work.

2.1.2.1 Notational Programs

The teachers' preparation requires the use of music programs to write notes or edit already written compositions, and to have several variants available. Musicians are familiar with, for example, the *MuseScore* program, for both its accessibility and its easy, intuitive user-friendly

design. It is designed for simple notation of melodies and compositions. More advanced programs such as *Finale* or *Sibelius* are also well positioned on the market, but is used less frequently in school settings, mostly professionally oriented artistic study fields.

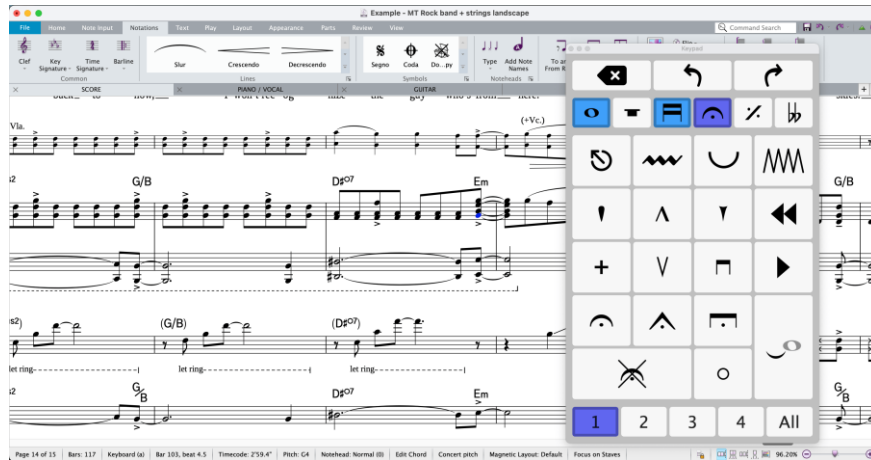


Figure 6. Sibelius, music notation software

The role of music programs is irreplaceable for the teacher. They allow him to choose any piece that the students are interested in and work with it: change the accompaniments, make them two/three-part, transpose to a suitable key, change tempos, easily adapt the pieces to the needs and capabilities of the class, group, or individual. The teacher can create a database of breathing, rhythmic or melodic exercises, share them with the students (if they need more intensive individual education, e.g. to prepare for auditions or exams to artistic secondary schools), edit them flexibly, play them in MIDI format, or place them on websites, as they can be exported to various graphic and musical formats.

2.1.2.2 Platforms for Vocal and Perceptual-cognitive Skills Development

The use of ICT can also stimulate the development of the student's perceptual-cognitive skills. Within musical training, students should improve their ability to consciously perceive the structure of a musical work, and therefore, it is essential that a teacher has the original version of a composition prepared for the class. A real performance is not an option within the teaching process, and therefore, it has to be replaced by online reproduction. The online sources provide various popularization-oriented composition arrangements, which are more engaging for students, and which are often enriched with a visual aspect that helps students follow the development of the melody, the onset of voices, etc. This way, the abstract musical concepts, such as form, polyphony, voicing etc., are more easily accessible and understandable. Classical music compositions are also implemented in many films that are available on-line. The teacher can find them through various applications and directly show students in class that "classical" music is strong and information-dense. By targeting the student's interests directly, the teacher can increase motivation and engagement (Farhood et al., 2025).

ICT technologies also bring the music of other nations closer and help immerse students to different historical periods.

The Internet also offers many educational programs focused on individual learning units.

An interesting way to support vocal activities that also develop auditory-intonation skills and analytical perception, is offered by the program *Solfy*. Originally from Israel, the program focuses on solmization.

"It includes self-exercise, self-assessment, personalized exercise navigation, feedback, and the option to return to previous exercises. Students become aware of their success

or weaknesses, which they can eliminate through perseverance in practice." (Strenáčiková, 2021a)



Figure 7. Solfy: Digital platform for developing solmization, sight-singing, and auditory-perceptual skills

2.1.2.3 Programs for Working with Visual Material

In Art class, teachers can take advantage of students' interest in using social networks. They promote their photos and videos on platforms such as YouTube, Instagram and TikTok on a daily basis. Smartphones already have built-in applications that evaluate and edit images and offer further processing (adding comments, special effects etc.). Students proactively try to make an impression on their peers outside of school with new elements and modifications, and therefore, they often search for innovative elements and functions of various software and applications. Learning based on students' interests and goals is one of the basic principles of personalized learning/teaching.

ICT can be used almost in all classroom activities, starting from the first moments of working with visual material, capturing visualizations with a camera or mobile phone (students look for and create unusual pictures, they use different exposure, vary the angle of view, lighting, colour tuning), through digital processing of the product, to the final creation of a promotional portfolio.

Many students are not satisfied with ordinary adjustments; they want a personal contribution to their compositions. While doing so, they are not limited by the fact that in case of failure, they would ruin the canvas, paper and other art materials. Since each step is reversible and erasable, their courage to experiment is not limited by material issues. At the same time, the ability to save a project in progress, to return to it at any time and complete it, allows them to alternate activities, relax and gain new inspiration. Students can try different colours, textures and compositions in a digital environment, they can immediately see the result. An individual makes decisions based on his/her own observations, opinions, corrections, and profiles, which increases not only his/her artistic abilities and skills, but also his/her artistic taste and style. Such a process supports a deeper understanding of their own artistic language, but also broadens the view of challenges that other students, as well as artists, face in their work.

Classic spreadsheet program such as *Excel* can be used also for artistic expression. It provides space for creating impressionist-style paintings by painting individual windows. Editing photos in *Photoshop*, creating animations, photo collages, timelapses, and storyboards is already a common part of the teaching process. Editors such as *GIMP*, *Procreate*, or *Adobe Fresco* are often used.

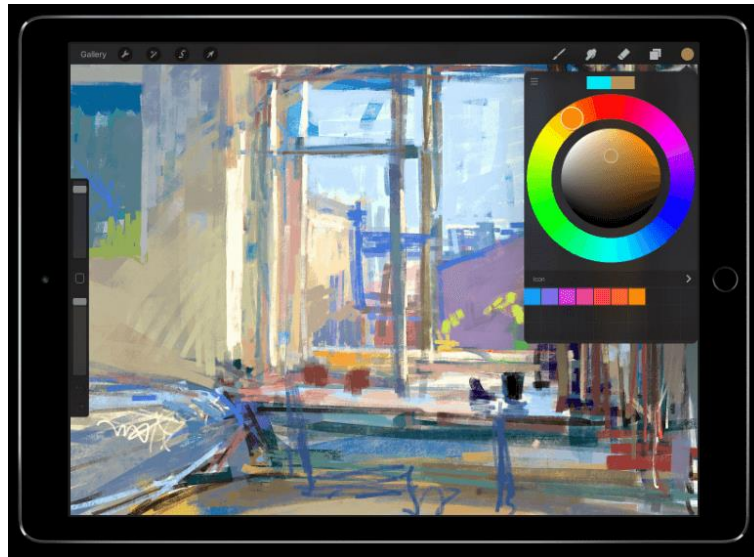


Figure 8. Procreate digital painting environment

These easily accessible computer graphics programs offer an almost complete art studio. They offer both simpler and more complex graphic assets, a wide variety of brushes, pens and pencils. They provide opportunity for students to learn to retouch and artistically manipulate photographs, as well as to incorporate text, to resize it arbitrarily, to layer it on top of each other, and to modify them. Students can change colours, blur, map, change the complexity, adjust the details to the whole, change the motifs, transform, paraphrase the artworks of other authors etc.

Finally, teachers can support the interweaving of visual and musical techniques, for example through the production of student's own synthetic work, i.e. a video, an advertisement or a clip.

However, teachers must help students to get acquainted with issues about ethics, since generative AI raises concerns about authorship, plagiarism, privacy, and transparency (Clark, 2025).

The ICT can enrich also the teaching of both music and visual art history. It provides the database of digital exhibitions and online archives of art from all over the world and from different historical periods. The teachers can choose particular art works and show them to students, which can contribute to understanding art history and to gain a wide range of inspiration from the history.

Art teachers often use ICT while creating materials for the school promotion in both online and printed form (leaflets, posters, brochures, etc.). They often reach to professional *DTP Desktop Publishing programs*, such as *Adobe Frame Maker*, *Adobe PageMaker*, *Adobe InDesign*, *Corel*, *CorelDraw*, *Ventura*, *Microsoft Publisher*, *PageStream*. Since their structure is more complex, they can help with more demanding tasks and perform more complicated assignments requiring a higher level of skill.

3. Results & Discussion

The analysis of relevant sources and own practices indicates that ICT can significantly strengthen personalized learning in Mathematics, Physics, Music, and Art. In selected academic subjects, four interconnected thematic areas emerged, such as feedback and adaptivity, visualization, creativity and active learning, and assessment and monitoring of learning progress. However, the effectiveness of ICT depends on purposeful pedagogical use,

on the teacher's ability to balance technological possibilities with educational and social objectives and very importantly, on the availability of technologies in the classroom.

One of the most significant contributions of ICT to personalized learning is its ability to provide immediate and individualized feedback. In Mathematics, Physics, and other scientific subjects, adaptive platforms provide differentiated tasks and allow students to work at an appropriate level and pace. In Music, ICT facilitates the learning of music notation. Thus, ICT facilitate the personalization by adapting the content, difficulty, pace and also, the feedback to individual needs of every student. Also, it enables students to regulate and take a greater responsibility for their own learning.

The second major contribution of ICT is the visualisation of abstract, complex phenomena. In Mathematics, for example, manipulation with mathematical objects shows consequences of changing various parameters (e. g. in functions), and 3D models support the understanding of spatial relationships. In Physics, interactive 3D models provide representations of concepts, that are difficult to understand, such as the causality based on influencing outcomes by changing input variables.

In Art, digital technologies help learners access the historical concepts and works. Particularly in Music, digital representations enable students to 'see the melody', follow melodic and rhythmic motives, watch the development of individual voices in polyphony etc. In Fine arts, digital tools allow students to experiment with colour, texture, composition, and visual effects and immediately observe the results.

Third, ICT support creativity and active learning by creating conditions for experimentation, discovery, and creative expression. Various gamified application increase engagement by fostering healthy competitiveness and creating safe environment in which students can make mistakes without fear of failure. Moreover, in Art and Music, digital graphic applications enable students to experiment with their work with no material losses, since all changes they make are reversible, and their projects can be saved and revisited. However, the excessive reliance on AI may reduce the creative activity and originality and limit the authentic artistic voice. Therefore, teachers have to make sure that ICT support rather than substitute for student thinking and creative work.

The last generally appreciated advantage of ICT is the formative assessment and continuous monitoring of learning outcomes and progress. Many digital platforms are designed to identify errors and provide teachers with information about students' progress and areas in which they require further support. The assessment becomes an ongoing process through which students learn what they already understand and what they need to improve.

3.1. Limitations

This study has several limitations. It relies on the interpretation of existing literature rather than on quantitative analyses of learning outcomes. The studies included in the review were conducted in different educational contexts and disciplines, which limits the comparability of their findings. The discussion is supported by the authors' teaching experience and by our experiences with using selected educational technologies. Moreover, our observations arise from the Slovak educational environment, where access to digital tools and implementation practices may differ from those elsewhere. Future research should focus on empirical evaluation of ICT- and AI-supported personalized learning across different educational contexts and learner populations.

3.2. Practical Implications for Teachers

Based on the findings and our own experience, we formulated some suggestions for successful implementation of ICT and AI-supported technologies into the classroom instruction.

- Use ICT as a means to achieve educational objectives rather than becoming an objective in itself. Align the use of ICT with clearly defined learning outcomes: select digital tools according to the specific competencies you plan to develop; for example, GeoGebra and Corinth 3D may support conceptual understanding and visualization in Mathematics and Physics, or Solfy, MuseScore, and graphic-editing applications may foster creativity, interpretation, and technical skill development in Music and Art.
- Use ICT to Differentiate Learning. Allow students to progress at their own pace and according to their individual learning needs, have them track their own progress and skills, give them opportunities to engage in differentiated tasks, levels of difficulty.
- Use ICT to do informed assessment. Since AI tools can generate solutions, texts, images, and musical compositions, assessment should focus more strongly on learning processes, critical reflection, creativity, problem-solving strategies, and the student's ability to justify decisions. Besides the use of technologies, use portfolio assessment, project-based learning, process documentation, reflective journals, and oral presentations, which will provide more valid evidence of learning than products alone. In artistic disciplines in particular, include in assessment criteria which would distinguish AI-supported ideation and the student's original contribution.
- Use ICT to provide immediate formative feedback. Give students personalized feedback through ICT so that they can identify misconceptions, correct errors, fill in gaps in their knowledge and skills, take responsibility for their own learning, and make smart choices. This would help students monitor their own progress, set goals, reflect on their learning, and take greater responsibility for outcomes. Offer them ICT targeted support to improve their achievement and self-regulation. Formative feedback would support both students who require additional assistance and those who need more advanced challenges.
- Use ICT to enhance understanding of complex concepts through visualization and reduce cognitive barriers, to promote active and experiential learning and to support creativity and individual expression. Try to incorporate simulations, dynamic models, and visualization tools to make abstract concepts more comprehensible, increase engagement and motivation while supporting deeper learning (use gamified applications), provide students with opportunities to experiment with different artistic/academic approaches.
- Use ICT as supportive, rather than substitutive tool. In your lessons, design learning activities that require critical thinking, explanation, reflection, and creativity to make sure that AI complements rather than replaces the learning process. Allow students to collaborate and prepare various projects so as to nurture the social and personal interactions among students. Keep the balance between technological innovation and the development of students' critical thinking, creativity, autonomy, and authentic learning experiences.
- Use ICT in your continuous professional development. Set up a plan for ongoing training in the pedagogically meaningful use of ICT and AI tools, participate in professional development focusing not only on technical skills but also on instructional design, assessment strategies, personalization methodologies, pedagogical and ethical competencies etc.
- Promote responsible and ethical use of ICT and AI. Give students explicit guidance regarding acceptable and unacceptable uses of ICT/AI, transparency in reporting AI assistance, copyright and authorship considerations, and the ethical use of generated content. Encourage students to critically evaluate AI outputs, verify information, and use

AI as a tool for exploration and feedback, not as a pure substitute for independent thinking and creativity.

Individual work with programs, whether in a Mathematics, Physics, Music or Art class, respects the students' potential, their abilities, skills, experience, level of creativity, pace, and also, it reflects their opinions. This naturally stimulates their engagement in the learning process. Digitalization changes the way they learn.

However, technologies must not replace human contact, or the value of education. A significant factor in successful transformation remains high-quality teacher training and teachers' professional development.

ICT does not reduce the importance of the teacher, but rather changes his/her role. The teacher becomes a guide and mentor who plans, analyses, motivates, communicates and supports students' reflection. His task is to create a meaningful balance between technology and human interactions.

Overall, the implementation of ICT in education brings many benefits for both students and teachers. It enriches the learning process itself, provides greater clarity, variety of tasks, understandable feedback, supports creativity. It can significantly strengthen personalized learning when it is used intentionally to differentiate tasks, provide timely feedback, visualize content, support creative activity, and monitor individual progress.

In the future, it will be essential to further develop teachers' digital literacy and ensure equitable access to technology for all students, so that personalized learning is not just an ideal, but a reality at every school. At the same time, teachers must ensure that learning with digital technologies remains a meaningful, socially engaging, and collaborative process.

Future implementation of ICT and AI in education should therefore focus not only on technological innovation but also on pedagogically meaningful integration, ethical use, assessment redesign, teacher preparedness, and equitable access to learning opportunities.

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