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RESEARCH ARTICLE

Competency-Based Hybrid Learning: A Modern Approach to Teaching Programming and Digital Technologies Subjects

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ABSTRACT The COVID-19 pandemic prompted the global education sector to experiment with various forms of online learning as institutions rapidly transitioned to remote formats. This article presents a comprehensive overview of a competency-based hybrid learning methodology, developed and implemented during the pandemic. In addition to detailing the methodology itself, the article also shares the experiences of educators at the authors' institution, who observed significant improvements in educational outcomes, surpassing even pre-pandemic standards. The methodology highlights the limitations of directly replicating traditional in-person instruction in an online format using existing materials and approaches. Instead, it advocates for carefully designed adaptations tailored to the digital environment, leveraging asynchronous components, interactive tools, and newly created e-learning resources to optimize effectiveness. This approach also requires increased interaction between educators and students beyond scheduled classes, ensuring timely support and guidance. Although this methodology may not suit all course types, it has proven particularly effective in advanced information and communication technologies (ICT) and digital technology subjects, such as programming, artificial intelligence, digital or electronic marketing, video editing, 3D engine work, etc. The positive student feedback further underscores the potential of this model to enhance educational quality and outcomes in these domains.

INDEX TERMS Hybrid learning, online learning, blended learning, digital technologies, ICT, modern teaching, training.

I. INTRODUCTION

Higher education is undergoing a transformative shift as modern teaching methods increasingly integrate into traditional practices. Conventional approaches, such as lectures and seminars, remain the cornerstone of university teaching. However, they are now being augmented—or in some cases replaced—by innovative techniques that emphasize interactivity, personalization, and the practical application of knowledge. This shift is driven by the growing accessibility of digital tools, the focus on future-ready skills, and the need to actively engage students in the learning process.

Researchers in engineering education are working to find effective and affordable ways to teach today's millennial learners. Some universities have made progress by introducing digital tools that combine traditional classroom teaching with flexible, on-the-go learning in a hybrid format. However, the use of digital technology in engineering education has often been shallow and less impactful than expected. Studies show that students learn better in environments where they are actively engaged with the material. This has motivated educators to create more interactive lessons and use active

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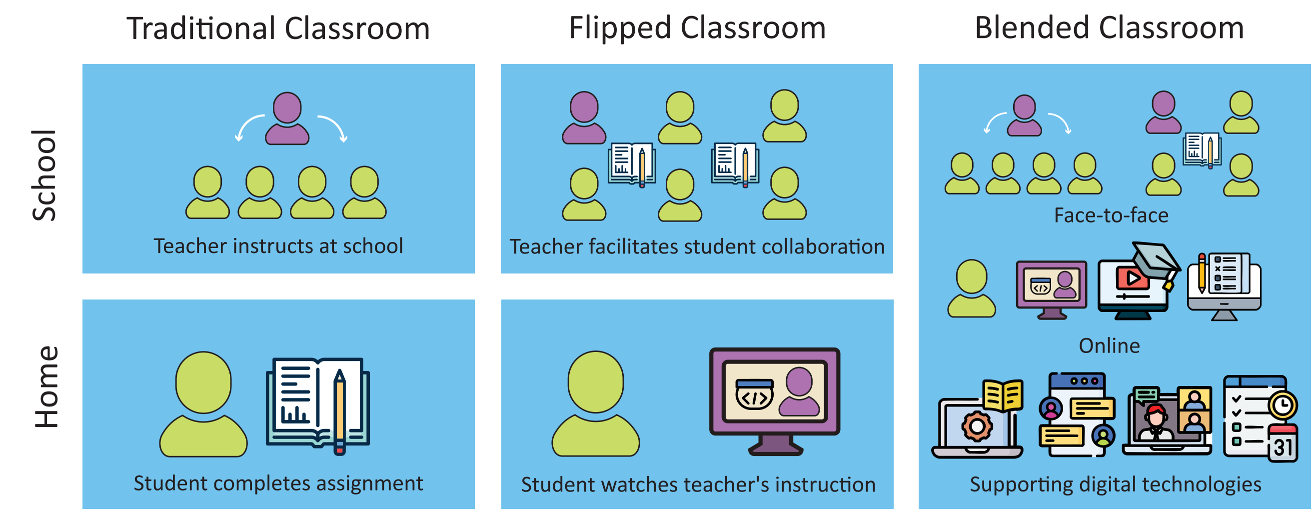


FIGURE 1. Traditional, flipped and blended classroom formats (icons used from [4]).

learning strategies, which have proven to be more effective than traditional lectures [1], [2].

Modern teaching methods are becoming increasingly important as educational institutions strive to meet the diverse needs of contemporary learners. While traditional in-person teaching remains a cornerstone of education, it is clear that integrating new approaches is essential to enhance flexibility, accessibility, and engagement. These approaches span several formats (Fig. 1), each tailored to different learning contexts and objectives, and their thoughtful development is key to their success [3].

Traditional face-to-face teaching fosters direct interaction and immediate feedback, creating a highly engaging learning environment. However, online learning has emerged as a crucial alternative, enabling students to access education remotely. Online methods can be divided into synchronous and asynchronous formats. Synchronous online learning involves live, real-time interactions through virtual classrooms or video conferences, providing opportunities for immediate engagement. Asynchronous learning, by contrast, offers pre-recorded lectures, discussion boards, and assignments that students can complete on their own schedules, maximizing flexibility [5].

Hybrid and blended learning models effectively combine the strengths of in-person and online methods. Hybrid learning allows students to participate in both face-to-face classes and remote activities, providing a balanced approach. Blended learning goes further by integrating digital tools directly into classroom instruction, creating an immersive environment where technology enhances the learning process. These methods reflect the increasing need to make education adaptable, dynamic, and inclusive [6].

In this article we present a competency-based hybrid learning methodology, focusing on integrating traditional in-person instruction with innovative online tools and strategies. It explores the design, implementation, and effectiveness of this approach in teaching programming and digital technologies, emphasizing hands-on learning, student flexibility, and instructor engagement.

II. RELATED WORKS

Blended learning has been extensively studied across various educational contexts, particularly in higher education, programming courses, and teacher training, with significant focus on its effectiveness and challenges. This section reviews related work to provide an overview of existing frameworks, implementation strategies, platforms, courses and outcomes, highlighting key findings and gaps in the literature.

A. PRINCIPLES AND APPROACHES TO BLENDED LEARNING

The study [7] discusses the evolution of education in the context of Industry 4.0, highlighting the role of e-learning, blended learning, MOOCs, and flipped classrooms. It emphasizes that these approaches are crucial for equipping learners with interdisciplinary skills needed for modern industries. MOOCs and flipped classrooms are presented as effective methods for delivering complex technical content, such as robotics, to large audiences while maintaining engagement. Blended learning is showcased as a means to combine online flexibility with practical, hands-on activities to prepare students for real-world applications. The article concludes by stressing the importance of integrating modern educational technologies with traditional methods to ensure sustainable development in engineering education.

The article [6] discusses the ambiguity surrounding the term "blended learning," noting that it has become an umbrella term encompassing various combinations of face-to-face and online education. The author emphasizes the importance for researchers and practitioners to clearly define what they mean by blended learning in their specific contexts. Additionally, the article suggests that more descriptive terms could be used alongside or instead of "blended learning" to enhance clarity in educational discussions.

The author in [8] critiques the current definitions of blended learning for focusing too narrowly on the combination of face-to-face and online instruction, without considering learning theory. It argues that effective blended learning should incorporate pedagogical principles, such as behaviourism and constructivism, to create optimal learning outcomes. The paper introduces a model integrating these learning theories, emphasizing context, methodology, and technology for a comprehensive framework. Ultimately, it proposes a new definition of blended learning as the appropriate use of a mix of theories, methods, and technologies tailored to the learning context.

The article [9] examines the integration of online learning experiences with traditional classroom settings to enhance educational outcomes. It surveys various tools, techniques, frameworks, and models that facilitate blended learning, highlighting their effectiveness in promoting meaningful learning through flexible information and communication technologies. The study emphasizes the benefits of reducing overcrowded classrooms and providing planned teaching and learning experiences. The article finds that blended learning significantly enhances student engagement and learning outcomes by combining the strengths of face-to-face and online instruction. It also highlights that careful planning and the use of appropriate tools and frameworks are crucial for maximizing the effectiveness of blended learning environments.

The study [2] examines the adoption of flipped learning in engineering education, analyzing 62 studies published between 2000 and 2015. The review indicates that flipped learning gained significant traction among engineering educators after 2012, with research primarily focusing on documenting design processes, preliminary findings, and student feedback. However, the study highlights a lack of theoretical frameworks and comprehensive evaluation methods in existing research. The authors suggest that future studies should explore various aspects of flipped learning implementations, grounded in robust theoretical foundations, to better establish its pedagogical efficacy in engineering education.

The article [10] explores institutional approaches to blended learning in higher education, particularly before the COVID-19 pandemic. It highlights the benefits of blended learning, such as flexibility, inclusivity, and enhanced learning outcomes, but notes its limited adoption due to inconsistent institutional strategies. The study identifies three critical elements for successful implementation: clear strategies, robust structures, and comprehensive support. Challenges include the lack of standardized definitions and inconsistent application across institutions. The authors argue that post-pandemic, blended learning must move beyond small-scale implementations to become a normalized practice supported by strong strategic vision and institutional commitment. They emphasize the importance of professional development and technological infrastructure to ensure sustainable adoption and transformative learning experiences.

The article [11] investigates optimal blended learning strategies within engineering curricula, particularly in light of adaptations made during the COVID-19 pandemic. It examines how the shift to digital learning highlighted the importance of well-designed blended strategies, combining face-to-face and online components effectively. Based on focus group discussions with educators from European universities, the study identifies two critical drivers: the social dimension of university life and the complexity of learning outcomes as defined by Bloom's taxonomy. Findings suggest that face-to-face activities are most beneficial in early years to foster social interaction, while advanced years, requiring complex skills, also benefit from increased teacher-student interaction. The study highlights the "bathtub curve" trend, where traditional interactions are highest in the first and last years of study. Post-pandemic, universities demonstrated improved readiness to implement digital learning strategies but faced challenges in re-engaging students for activities that they preferred digitally during the pandemic.

This study [49] examines research on blended, hybrid, and flipped learning models, focusing on how these teaching methods combine online and in-person learning. The authors find that different studies define these terms in different ways, making it difficult to compare their effectiveness. To solve this, they analyze many past studies using a structured system and find that flipped learning often improves student performance, while other blended and hybrid approaches are effective only if carefully planned. The study also shows that giving students feedback during in-class activities is key to better learning, but simply moving lessons online does not automatically improve results. Another important finding is that how a course is designed, including the balance between online and in-person lessons, plays a major role in success. The study suggests that blended and flipped learning can be helpful when properly structured, but teachers need to use technology in a way that truly supports learning. Overall, the research highlights that not all blended models work the same way, and their success depends on instructional design and student engagement.

B. APPLICATIONS OF BLENDED LEARNING IN STEM FIELDS

STEM is an acronym that stands for Science, Technology, Engineering, and Mathematics, encompassing disciplines that focus on critical thinking, problem-solving, and innovation through the application of scientific and mathematical principles in technology and engineering contexts.

The article [12] presents a systematic review of blended learning models applied to introductory programming courses, exploring their effectiveness and outcomes. It identifies five main models: flipped, mixed, flex, supplemental, and online-practicing, categorized based on where content delivery and practical activities occur (face-to-face or online).

The mixed model, combining both modalities, is highlighted as particularly effective, offering flexibility and enhanced learning outcomes. The flipped model emphasizes online delivery of content with in-class active learning, while the flex model allows students to progress online with periodic in-person support. Challenges include student adaptation to online learning and ensuring the integration of online and in-class components. The study also stresses the importance of tailored videos, programming tools, and manageable workloads to enhance learning experiences. It concludes that while all models have potential, thoughtful planning and monitoring are crucial for success, with recommendations for further studies on specific components' impacts on learning outcomes.

Authors in [13] present a bibliometric analysis of the top 10 most-cited articles on blended learning in introductory algorithms and programming courses from 2000 to 2021. It identifies that Norway, Serbia, and Saudi Arabia are leading contributors to the research in this field, with Norway producing the highest number of influential publications. The analysis highlights that blended learning approaches, particularly flipped and mixed models, have shown measurable improvements in student engagement and learning outcomes in programming education. For instance, studies included in the review demonstrated that students in blended learning environments achieved higher scores and exhibited better problem-solving skills compared to those in traditional classrooms.

The article [14] examines the implementation of grounded design as a framework to address challenges in online and blended STEM education, particularly highlighted during and after the COVID-19 pandemic. Grounded design focuses on aligning domain goals with pedagogical beliefs, psychological foundations, and technological tools to create effective, student-centered learning environments. It highlights the use of technologies such as video-based instruction, augmented reality (AR), virtual labs, and simulation tools, which enhance engagement and practical skill development. The study also addresses how gaps in course design, pedagogy, and student engagement exposed during the pandemic can be mitigated through grounded strategies, emphasizing the alignment of technology with validated research evidence to meet specific learning goals. Additionally, the research underscores the importance of inclusive and culturally relevant pedagogy to accommodate diverse student backgrounds, technical infrastructures, and digital literacies. While these approaches show promise, further research is needed to validate and generalize their application across broader educational contexts to support effective, student-centered STEM learning.

The article [15] investigates teachers' perceptions of using blended learning for STEM-related subjects in the context of the Fourth Industrial Revolution. It highlights the potential of blended learning to enhance engagement, collaboration, and adaptability in teaching STEM subjects. However, challenges include a lack of technology-based tools, limited professional development, and infrastructural barriers such as unreliable internet access. The study emphasizes the need for teacher training to effectively integrate technology into pedagogy and suggests that communities of practice can support this transition. Participants noted benefits like virtual consultation hours and increased learner involvement, but emphasized that adequate resources and training are essential for success. Overall, the research underscores blended learning as a transformative approach for modern STEM education while identifying critical areas for improvement.

The authors in [16] presents a strategy to address challenges in teaching programming to large groups, such as grading and remote task execution. The proposed approach utilizes remote labs and automation tools, eliminating the need for students to install software on their devices. This method was implemented in a course with approximately 200 mechanical engineering students during the winter term of 2022/2023. Student feedback indicated overall satisfaction with the system, highlighting its user-friendliness and efficiency, though some technical challenges, such as server load, were noted during implementation.

This paper [17] discusses the implementation of a weekly assessment integrated into a blended learning framework for a Power System Course to enhance student learning outcomes. The course transitioned from traditional two-hour lectures and one-hour tutorials to a blended format, featuring online pre-class activities and in-class sessions. Lecture content was divided into short videos, each focusing on a specific sub-topic, ensuring better attention retention, with classroom time dedicated to connecting theoretical concepts to real-world applications and conducting problem-solving sessions. A significant challenge identified was student reluctance to watch the videos before face-to-face sessions, leading to the incorporation of weekly graded online quizzes as a solution. These quizzes tested students on video content, offered multiple attempts without time limits, and included a balanced mix of theoretical, application-based, and numerical questions. This approach encouraged students to review the videos repeatedly, reinforcing their learning. The paper provides theoretical support for this strategy, along with evidence of its effectiveness, demonstrating improved engagement and comprehension through blended learning.

The study [18] presents a blended learning approach for teaching a Data Structures and Programming in Python (DSPP) course, aiming to enhance student engagement, academic performance, and course satisfaction. This approach integrates online and face-to-face learning experiences, providing flexibility and accommodating diverse learning preferences. Online activities include teaching conducted in an online learning environment, where students engage with materials such as videos, handouts, and textbooks before class. Offline activities consist of face-to-face teaching, where teachers and students interact directly to deepen understanding and solve problems. The results demonstrated a significant improvement in course performance, with students achieving higher grades and demonstrating better conceptual understanding compared to traditional teaching methods. Additionally, students satisfaction was notably higher, as learners appreciated the flexibility and interactive nature of the blended learning model.

The article [19] explores the use of a reflective practice model to teach STEM education in a blended learning environment, combining experiential and transformative learning theories. It highlights the impact of COVID-19 in shifting educational practices, revealing the need for enhanced digital competencies among students and teachers. The study demonstrates that reflective practice fosters critical thinking, creativity, and problem-solving through project-based and inquiry-based approaches, while providing continuous feedback and opportunities for reflection. Teachers emphasized that blended learning increased student engagement and allowed for differentiation, catering to individual needs and interests. The results underline the importance of structured instructional activities and immediate feedback to enhance learning outcomes. The study concludes that implementing reflective practice in STEM education transforms teaching strategies and prepares students for real-world challenges.

Authors in [20] explore the role of digital literacy and its influence on academic performance in blended learning environments for first-year STEM students. It reveals that students with lower perceived digital literacy (LDL) often engaged more frequently with learning management systems (LMS), which positively correlated with improved performance on certain assessments. High-achieving students consistently exhibited higher overall LMS interaction levels, especially around deadlines, compared to low-achieving peers. The study highlights that digital literacy alone does not guarantee academic success, as students' strategies and motivation significantly affect outcomes. It also emphasizes the importance of scaffolding, user-friendly LMS design, and explicit training to help students navigate online resources effectively. The findings advocate for a balanced approach to integrating technology, ensuring both accessibility and academic rigor in STEM education.

The article [21] explores the impact of implementing blended learning in programming courses, focusing on a C programming course at An-Najah National University in Palestine. It highlights the traditional teaching challenges, such as limited practical assignments and delayed feedback, which hinder student performance. The study introduced blended learning using Moodle's Virtual Programming Lab (VPL) plugin, providing students with practical assignments and immediate formative feedback. Results showed a significant improvement in students' overall performance and satisfaction with the course. Students found the online system easy to use, suitable for coding, and practical for submitting assignments. Challenges included occasional feedback inaccuracies and internet connectivity issues, which were mitigated through extended assignment deadlines and improved evaluation criteria. The research concludes that blended learning is a transformative approach, with plans to extend it to advanced programming courses and other disciplines in the future.

The paper [22] presents a blended learning model based on a smart learning environment designed to enhance college students' information literacy. It incorporates four levels: conceptual, intelligence, action, and process, collectively termed CIAP, enabling an integrated approach to learning. Empirical research demonstrated significant improvements in students' information literacy across four dimensions: consciousness and attitude, knowledge and skills, application and innovation, and morality and responsibility. The findings showed that blended learning fosters immersive experiences and effective information literacy training through interactive learning environments and tailored resources. This model was specifically tested on students of engineering technology at Huainan Normal University in China, focusing on integrating digital tools and interactive activities within technical disciplines. Challenges addressed include the necessity for clear learning objectives, timely feedback, and innovative assessment methods to sustain progress. The study underscores the role of smart technologies, such as AI and big data, in creating adaptive and scalable learning systems, with future research aiming to optimize the model for broader applications and integration with diverse learning contexts and technologies.

The article [23] introduces a hybrid approach combining Ant Colony Optimization (ACO) and Genetic Algorithms (GA) to enhance personalized learning in e-learning environments, offering valuable support for blended learning models. By adapting to learner characteristics such as cognitive abilities and emotional states, the algorithm ensures tailored and effective learning experiences.Key innovations include clustering learners using genetic K-means and optimizing their learning paths through ACO and GA. This approach complements blended learning by providing personalized digital pathways that integrate seamlessly with in-person instruction. Experimental results demonstrate that the method improves learning outcomes and engagement, highlighting its potential to support and enhance blended learning frameworks through dynamic and adaptive digital content delivery.

The study [24] investigates the effectiveness of a STEM-based Blended Project-Based Learning (Blended-PjBL-STEM) model in improving students' scientific literacy skills and engagement. Conducted with 105 seventh-grade students in Indonesia, the research revealed significant improvements in scientific literacy, particularly in explaining scientific phenomena and designing scientific investigations, with a medium-level N-gain score of 0.40. The model combines face-to-face and online learning with project-based methods, allowing students to connect theoretical knowledge to real-world problems like environmental pollution. Students responded positively to the model, achieving a high category score of 70.1% on average for scientific literacy. The findings highlight the potential of Blended-PjBL-STEM in promoting active learning and critical thinking while addressing Indonesia's historically low scientific literacy rankings. This innovative approach demonstrates the importance of integrating technology and practical projects to enhance STEM education outcomes.

This study [25] investigates the impact of integrating the Problem-Based Learning (PBL) model with the Flipped Classroom approach on students' mathematical creative thinking abilities. Traditional teaching methods often fail to cultivate creativity, focusing instead on memorization and procedural learning. By combining PBL, which promotes collaborative problem-solving and real-world applications, with Flipped Learning, which allows students to build foundational knowledge before class, this approach fosters higher-order thinking skills and innovative problem-solving. The study uses a Systematic Literature Review (SLR) methodology to analyze previous research on these teaching strategies, confirming their effectiveness in improving students' flexibility, originality, and problem-solving abilities in mathematics. The findings suggest that educators should adopt blended learning approaches to enhance creativity in mathematical education, while future research should explore the long-term impact and scalability of these methods across different educational settings.

The article [26] examines how combining different teaching methods affects students' learning in physical education. The study analyzes 17 peer-reviewed articles to assess the impact of hybrid models on motor skills, cognitive development, emotional engagement, and social learning. It identifies seven types of hybrid models that merge different instructional strategies, such as sports-based education, game-based learning, cooperative learning, and teaching methods focused on personal and social responsibility. The findings show that hybrid models enhance technical skills, decision-making, motivation, independence, and teamwork, making physical education more interactive and effective. However, the study highlights challenges such as limited time for implementation and teachers' unfamiliarity with these methods. The authors emphasize the need for long-term studies and comparative research to determine the effectiveness of hybrid teaching models in various educational contexts.

The article [27] discusses the GRE@T-PIONEeR project, which implements hybrid and flipped learning approaches to enhance nuclear engineering education across multiple European universities. The project, funded by the European Union's Horizon 2020 program, aims to address the declining number of students in nuclear engineering by offering specialized courses in computational and experimental reactor physics. These courses utilize a blended learning model, where students engage with asynchronous online materials before attending interactive in-person or online sessions. The study found high engagement and success rates among students, with onsite participants generally outperforming online learners in interactive sessions. While hybrid and flipped learning effectively improve knowledge retention and practical application, challenges remain in ensuring consistent student participation in asynchronous activities. The research contributes to the ongoing evaluation of blended learning in higher education, emphasizing the need for institutional strategies to support sustainable adoption.

The article [28] explores the implementation of a hybrid learning model based on project work in information technology education. It aims to enhance students' design-thinking skills, which are essential for creating digital innovations. The study involved 80 students from Mandalika University of Education, divided into an experimental group using the hybrid model and a control group following traditional methods. Results showed that the hybrid approach significantly improved design-thinking abilities, including creativity, collaboration, and adaptability. Previous studies have validated the effectiveness of hybrid models, particularly in project-based and flipped learning environments, which share similarities in promoting active student engagement. However, the hybrid model in this study integrates digital tools and project-based learning in a structured way to ensure a dynamic, student-centered experience. The findings suggest that a well-structured hybrid learning environment can better prepare students for real-world challenges in digital innovation, emphasizing the need for curriculum adjustments in IT education.

The article [29] examines how a hybrid learning model based on STEAM education helps improve students' critical thinking skills. It is a meta-analysis of 15 studies published between 2018 and 2023, analyzing the effects of combining online and face-to-face learning activities. The results show that students in hybrid learning environments performed better than those in traditional classrooms, with a strong effect size of 1.052 ($p < 0.01$). The p-value ($p < 0.01$) indicates that the results are statistically significant, meaning there is less than a 1% chance that the observed improvements happened randomly. The effect size measures how much the hybrid learning approach influenced students' critical thinking skills compared to traditional teaching methods. In this study, it was computed using Cohen's d, which calculates the difference between the mean scores of students in hybrid learning and traditional classrooms, divided by the standard deviation. A value of 1.052 suggests a large positive effect, meaning that hybrid learning had a significant impact on student learning. The article also reviews previous research confirming that hybrid learning improves motivation, engagement, and learning outcomes, as nearly all analyzed studies reported better student performance compared to traditional teaching. While the study does not directly compare hybrid learning to project-based learning or flipped classrooms, it highlights that hybrid learning includes aspects of both. Like flipped learning, students first study online materials before class, and like project-based learning, they apply knowledge in practical activities. The article suggests that combining these methods in a structured way leads to better learning results. In conclusion, the study finds that STEAM-based hybrid learning is an effective method for developing critical thinking skills and recommends further research to understand how it can be applied to different subjects and learning environments.

C. APPLICATIONS OF BLENDED LEARNING IN NON-STEM FIELDS

The paper [30] explores the feasibility of implementing a blended learning approach to train graduate students in GenerationPMTO, an evidence-based parenting intervention. The study involved 13 students from five universities enrolled in Psychology, Social Work, and Family Therapy programs, who underwent both in-person and online training over an academic year. Results indicated significant knowledge acquisition, high satisfaction with the blended learning format, and acceptable fidelity scores among instructors. Qualitative feedback supported the acceptability and usability of the blended learning training, suggesting that such an approach can effectively integrate evidence-based practices into university curricula, particularly benefiting low-resource and ethnically diverse settings.

The article [31] explores the integration of blended learning in higher education to accommodate diverse learning preferences and enhance practical skills. The authors developed a Preliminary Model and Implementation framework, comprising stages such as Online Learning, Face-to-Face Instruction, and Practical Application. In the Online Learning Stage, students accessed a variety of digital materials, including videos, readings, and interactive modules, to build foundational knowledge at their own pace. This stage emphasized flexibility, allowing learners to engage with content according to their individual schedules and learning styles. The subsequent Face-to-Face Instruction focused on deepening understanding through discussions, clarifications, and collaborative activities. Finally, the Practical Application stage provided opportunities for students to apply theoretical concepts in real-world scenarios, reinforcing learning outcomes. The study concluded that this structured blended learning approach effectively enhanced student engagement, accommodated diverse learning preferences, and improved the overall teaching and learning experience.

The article [32] explores a hybrid learning model that combines project-based learning with the flipped classroom approach to improve engineering education. The study was conducted in an engineering design course and involved students working on product design and development projects. In this model, students study theoretical content online before class through videos and quizzes, allowing more time for hands-on projects, discussions, and problem-solving during in-person sessions. The study found that students using this hybrid method performed better, developed stronger problem-solving skills, and were more engaged compared to those in traditional project-based courses. The flipped classroom aspect helped reduce lecture time, giving students more independence while still receiving structured guidance. Compared to traditional project-based learning, the hybrid model provided better content organization, increased motivation, and more opportunities for teamwork. The study also references previous research showing that combining online learning with practical activities enhances student understanding and engagement. Overall, the findings suggest that this hybrid approach can improve learning outcomes in engineering courses and should be explored in other fields.

The study [33] compares the effectiveness of blended learning in histology practical courses for medical students, using two different models: flipped physical classrooms and flipped virtual classrooms. The research was conducted at Zhejiang University's medical school with three student groups: one following traditional classroom learning (89 students), another using flipped virtual classrooms (146 students), and a third using flipped physical classrooms (93 students). The study assessed student quiz and final exam scores, as well as satisfaction levels with blended learning. The findings showed that students in blended learning groups performed better on classroom quizzes compared to traditional learning students. However, students in flipped physical classrooms achieved the highest final exam scores, suggesting that in-person interactions helped students better understand and apply knowledge.The study concludes that blended learning enhances student learning outcomes, but physical classroom interactions remain essential for deep understanding in medical education. While online resources help students prepare, they should be complemented by face-to-face sessions for discussion and clarification. The authors suggest that future studies should explore how to optimize blended learning models for different medical subjects.

D. PLATFORMS AND COURSES FOR ONLINE AND BLENDED LEARNING

The course "Blended Learning & Flipped Classroom" is organized by the European School Education Platform [34], [35], aiming to empower educators with innovative teaching strategies. It introduces blended learning approaches, including the flipped classroom model, to help teachers combine face-to-face instruction with online tools for more engaging and personalized education. The program also provides practical solutions to overcome challenges in implementing these methods, fostering interactive and collaborative learning environments. By the end, participants gain valuable skills to effectively integrate Information and Communication Technology (ICT) into their teaching practices.

edX [36] is a leading online learning platform founded by Harvard University and MIT, offering a wide range of courses and programs from top universities and institutions worldwide. Through its partnerships, edX provides high-quality education accessible to learners globally, supporting both individual and institutional educational needs. The edX platform supports blended learning models, combining online coursework with traditional in-person instruction to enhance the educational experience. edX's initiatives in blended learning have been adopted by various universities to improve student engagement and learning outcomes. By integrating digital and on-campus education, edX aims to expand access to education and promote lifelong learning opportunities for all.

Coursera for Campus [37] is an initiative that enables universities to integrate Coursera's extensive online course offerings into their curricula, enhancing both blended and fully online learning experiences. By partnering with Coursera, educational institutions can provide students with access to over 5,900 courses, Specializations, Professional Certificates, and Guided Projects developed by leading universities and industry experts. This collaboration allows universities to supplement their academic programs with high-quality, job-relevant content, preparing students for the evolving demands of the workforce. Additionally, Coursera for Campus supports faculty in authoring and scaling online programs, offering tools for creating private lessons, courses, assessments, and hands-on projects tailored to their students' needs. Through this platform, universities can deliver a comprehensive blended learning experience that combines the flexibility of online education with the engagement of traditional classroom instruction.

Saylor Academy [38] is a nonprofit organization dedicated to providing free and open online courses to learners worldwide. Since its inception in 2008, the academy has developed nearly 100 full-length courses at the college and professional levels, all accessible at no cost and designed for self-paced learning. These courses are crafted by subject matter experts and aim to facilitate skill development, career advancement, and degree completion. Additionally, Saylor Academy collaborates with various educational institutions to offer tuition-free college credit opportunities through a network of partner schools. Among these partners, Florida International University, University of Maryland Global Campus, and Western Governors University are notable for their higher rankings and acceptance of Saylor Academy credits.

The IEEE Blended Learning Program [39] combines modern e-learning techniques with hands-on practice to equip engineers with industry-relevant skills. This flexible and comprehensive learning experience allows participants to study at their own pace through microlearning-based modules accessible anytime, anywhere. The program offers a variety of courses, including topics such as Machine Learning, Internet of Things (IoT), and VLSI design, all designed to bridge the gap between academia and industry. Participants benefit from insightful assessments and performance analytics, enabling them to apply concepts using Electronic Design Automation tools. The program is recognized for its effectiveness in preparing students and professionals for the demands of the engineering industry.

ETH Zürich actively incorporates blended learning methodologies across various courses and programs, seamlessly integrating online and face-to-face instructional elements [40]. For instance, the CAS ETH in Entrepreneurial Leadership in Technology Ventures [41] is among the first continuing education programs at ETH Zurich to consistently implement a blended learning philosophy, which has become the standard method in contemporary executive education. Additionally, the MAS in Applied Technology program employs blended learning and flipped classroom concepts to maximize the value of on-campus time, enabling participants to engage in interactive discussions and exercises.

Furthermore, ETH Zürich offers blended learning courses [42] in collaboration with other universities, providing students with shared online environments and joint activities.

MIT's blended learning initiatives [43], [44] integrate online and on-campus experiences to improve educational outcomes and bridge academic knowledge with practical applications. These programs emphasize interactive learning, where participants engage with real-world problems and collaborate with industry professionals and peers globally. MIT Professional Education's Digital Plus Programs offer live webinars, international workshops, and multimedia-rich content to create a dynamic and flexible learning environment. Facilitators guide participants through comprehensive modules that combine digital tools with hands-on applications, ensuring an effective and collaborative experience. The approach goes beyond traditional online education by fostering deeper engagement and practical skill development. Through these innovations, MIT prepares learners to adapt to and thrive in the rapidly changing demands of modern industries.

Berkeley College's blended learning courses [45] combine face-to-face instruction with online activities, offering students increased flexibility in their schedules. Before class, students engage with designated materials online, such as videos, handouts, and textbooks, to prepare for in-person sessions. This approach encourages active participation and collaboration, both in the classroom and through online discussions and group projects. Successful blended learning students are typically organized, proficient in time management, and comfortable using digital tools like Canvas. They should expect to spend an additional two to three hours online each week, beyond regular coursework, to complete assignments and participate in discussions. Prior to enrolling, students are required to complete the "Road to Success in Online Learning" (RTS) to ensure they are well-prepared for the blended learning environment.

E. SUMMARY OF RELATED WORKS

Blended learning approaches share several common characteristics across studies, including the integration of online and face-to-face methods to enhance flexibility, engagement, and learning outcomes. Models such as flipped and mixed approaches are widely recognized for their ability to foster critical thinking, problem-solving, and self-directed learning, particularly in STEM and programming education. A key feature is the use of technological tools like Moodle, Microsoft Teams (MS Teams), MOOCs, and interactive multimedia to create scalable and adaptive learning environments. Platforms like Coursera, edX, and Saylor Academy have played a crucial role in supporting blended learning by offering a wide range of flexible and customizable course options. These platforms enable institutions to supplement traditional teaching with digital resources, fostering lifelong learning and practical skill development.

Recent studies have further expanded the understanding of hybrid learning models. Research on integrating Problem-Based Learning with the Flipped Classroom approach confirms their effectiveness in improving students' creativity, problem-solving abilities, and engagement, particularly in mathematics education. Similarly, studies in physical education highlight that hybrid models combining different instructional strategies enhance motor skills, cognitive development, and teamwork, though implementation challenges persist.

Specialized courses in nuclear engineering education have demonstrated the effectiveness of hybrid and flipped learning approaches, particularly in computational and experimental reactor physics. These courses, implemented across multiple European universities and supported by the European Union's Horizon 2020 program, utilize a blended learning model where students engage with asynchronous online materials before participating in interactive in-person or online sessions. While this approach has led to high engagement and success rates, with onsite students generally outperforming online learners, challenges remain in ensuring consistent student participation in asynchronous activities.

In information technology education, hybrid models incorporating project-based learning have been shown to improve students' design-thinking skills and prepare them for real-world digital innovation. Additionally, a meta-analysis of STEAM-based hybrid learning indicates a statistically significant improvement in students' critical thinking skills compared to traditional methods, further reinforcing the effectiveness of structured hybrid learning environments.

While hybrid learning continues to evolve, its successful implementation requires strategic curriculum adjustments, alignment of pedagogy with technology, and enhanced institutional support. The growing body of research highlights the potential of hybrid models to improve student outcomes across disciplines, particularly when combining elements of flipped learning, project-based learning, and digital tool integration. However, further research is needed to explore the long-term impact and scalability of these methods across different educational contexts.

However, significant shortcomings remain, including inconsistent definitions and frameworks, which hinder the development of universal standards. Challenges such as insufficient infrastructure, limited professional development, and student engagement issues are prevalent, particularly in post-pandemic settings. The lack of robust theoretical foundations in many studies further limits the generalizability of findings. To maximize its potential, blended learning requires strategic planning, alignment of pedagogy with technology, and enhanced institutional support to overcome these barriers.

III. BASELINE ANALYSIS OF EXISTING TEACHING METHODS

Over time, teaching strategies have changed dramatically in response to student demands, paradigm shifts in education, and technological breakthroughs. Nonetheless, in many educational contexts, especially in higher education, traditional methods continue to serve as the foundation for instruction. With a focus on programming and digital technology courses, this section assesses the widely used teaching strategies, highlighting their advantages and disadvantages. By comprehending these fundamental procedures, we hope to draw attention to areas where innovation and hybrid models can improve educational outcomes and solve current problems.

Courses in programming and digital technologies, where specialized laboratory equipment is not required, can significantly benefit from the integration of online tools and hybrid teaching methods, particularly in fostering practical competencies among students. However, these potential benefits are not always fully realized in practice, as traditional methods often dominate the teaching process. Based on the authors' experiences, as well as insights gathered from surveys and in-depth interviews with current students and alumni, the following section examines commonly employed methods of in-person and online teaching in programming and digital technology courses at the authors' faculty.

It is crucial to understand that practical exercises, which take priority over lectures, form the foundation of programming courses. At the authors' faculty located in Slovakia, a typical exercise session is usually allocated a duration of 1 hour and 40 minutes. The greatest way to learn programming is to play with code, get hands-on experience, and learn from failures. Although theoretical knowledge serves as a basis, individual (independent) work and iterative problem-solving are the hallmarks of actual expertise. An skilled instructor and supervisor who can mentor students, give prompt feedback, and assist them in overcoming obstacles during practice are essential to this process.

The following subsections, based on the authors' experiences and insights from surveys and interviews with students and alumni, presents the fundamental types of teaching methods used in programming and digital technology courses at the authors' faculty.

A. IN-PERSON TEACHING TYPE 1 - PASSIVE EXERCISE WITH AN ASSIGNMENT

At the beginning of this type of exercise, an assignment is introduced in a few minutes. The assignment may be graded, ungraded, or extended over multiple sessions and is sometimes accompanied by a brief explanation of the relevant topic. During the exercise, students work independently, relying solely on lecture slides and internet resources, without the support of video tutorials or detailed written instructions from the instructor. In some cases, the session is used primarily for grading assignments submitted in previous weeks. Based on our experiences and discussions with students, this type of exercise is among the most common approaches used in programming courses at our faculty. The *passive* in the exercise label denotes the fact that the teachers have only limited interaction with the students.

Advantages

- The instructor can provide personal assistance in case of issues – however, this is only effective if the instructor is sufficiently experienced, which can be challenging for advanced courses in higher years due to a high student-to-instructor ratio.
- Such exercises make more sense in the first year of study – they help students adapt to attending school, socialize with peers, and become familiar with the campus and laboratories.

Disadvantages

- Students often do not perceive in-person exercises as sufficiently creative – especially when the exercise lacks advanced support and relies solely on lecture slides and internet resources, without using specialized equipment. For such activities, in-person attendance is unnecessary.
- In higher years of study, this type of exercise adds little value – students can solve assignments independently at home or with peers in dormitories. They can read the assignment instructions without requiring the instructor's presence.
- This format is often chosen due to a lack of personnel capacity – virtually anyone can conduct such exercises.

It is somewhat of an open secret that in higher years, these exercises are sometimes treated as optional, or instructors may unofficially allow students to leave early from the official exercise session to complete their assignments at home. This occurs because instructors, deep down, understand that students often find it more convenient and productive to work on such tasks in their own time and environment, where they can wait for moments of creative focus. However, while this approach might seem practical and it is not officially sanctioned, it reflects a broader need to rethink how exercises are structured and delivered to maximize their value and efficiency for both students and instructors.

B. IN-PERSON TEACHING TYPE 2 - EXERCISE WITH AN ASSIGNMENT AND INSTRUCTIONAL MATERIALS

At the beginning of this exercise, an assignment is introduced within a few minutes. The assignment may be graded, ungraded, or extended to multiple sessions. Unlike the first type of exercise, where students rely solely on lecture slides and internet resources, this approach provides students with more comprehensive instructional materials, including detailed text-based guides or video tutorials prepared by the instructor.

Advantages

- The instructor can provide personal assistance when students encounter problems, and the instructional material also serves as a helpful resource for the instructor.
- Such exercises are particularly beneficial in the first year of study, as they help students adapt to attending school, socialize with peers, and become familiar with the campus and laboratory environment.

Disadvantages

- In higher years of study, students often question the need to attend such exercises in person, as they can complete the assignments independently at home. This sentiment is frequently reflected in evaluations and surveys.
- Many students complete the exercise in advance (if the materials are provided beforehand), leading to boredom during the session.
- Students may not perceive in-person exercises as sufficiently creative. As noted earlier, when provided with instructional materials, students can effectively complete the exercises at home, which reduces the perceived value of attending in person.

C. IN-PERSON TEACHING TYPE 3 - PASSIVE EXERCISE WITH ACTIVE EXPLANATION BY THE INSTRUCTOR

In this type of exercise, the instructor's primary task is to explain a specific topic in detail. During the session, the instructor writes program code live while projecting it onto a screen, demonstrating the process step-by-step and explaining what they are doing, how they are doing it, and the reasoning behind their actions. This approach provides students with a clear and practical understanding of the topic, helping them connect theoretical concepts with their practical application. The *passive* in the exercise label denotes the fact that students are mostly just passively taking in information and not practising the concepts themselves.

Advantages

- Students gain added value from the exercise as they receive a clear explanation of the topic, ensuring their attendance is worthwhile.

Disadvantages

- Students may struggle to maintain focus for the full 1.5-hour session, as it is challenging to adapt this type of exercise to students with varying skill levels.
- For courses with large groups (as is often the case with programming subjects), the instructor's workload is enormous, effectively requiring them to deliver the same content during three or more exercises.
- The quality of the session can be inconsistent – some sessions are delivered better than others due to instructor fatigue or variation in who conducts the exercise.
- If such a session is not recorded, students cannot revisit it for further clarification or review.

- Student activity during the session is limited, effectively turning the exercise into another lecture.

D. IN-PERSON TEACHING TYPE 4 - ACTIVE EXERCISE: STUDENTS PROGRAM SIMULTANEOUSLY WITH THE INSTRUCTOR

During this type of exercise, a complete program is developed collaboratively. The instructor programs live on a projector, while students simultaneously replicate and build the program on their own devices. This method allows students to actively engage with the material, follow the instructor's process step-by-step, and receive immediate feedback or assistance as needed. It emphasizes hands-on learning and ensures that students leave the session with practical experience and a tangible output.

Advantages

- Truly active learning – students not only listen but also actively program, which enhances their learning compared to passive listening.
- Students leave the session feeling that they have gained practical knowledge and skills, making their attendance worthwhile.
- Students can receive relatively quick assistance from the instructor when they encounter problems.

Disadvantages

- This method is highly effective, but extremely demanding on personnel, especially when the course has multiple groups/exercises during one week.
- The instructor often needs to address the problems of students who fall behind. If many students struggle, this can significantly slow down the progress of the session, as some groups cover only half the material compared to others. Assisting struggling students can also be both physically and mentally exhausting for the instructor, as identifying and resolving errors in code requires intense focus and repeated effort (e.g., moving around the classroom and troubleshooting individual issues).
- Inconsistent quality – some sessions may be conducted better than others due to instructor fatigue or variations in who conducts the exercise.
- If such sessions are not recorded, students cannot revisit the explanation of the program code later for further clarification.
- The experience of colleagues has shown that many students struggle to maintain attention during such sessions and end up completing the exercises independently at home without seeking help (often because the session may be scheduled in the afternoon or after other mentally exhausting classes).

E. ONLINE TEACHING TYPE 1 - PASSIVE EXERCISE WITH AN ASSIGNMENT

This method involves a direct one-to-one (1:1) transfer of the first type of in-person teaching (*In-Person Teaching Type 1 – Passive Exercise with an Assignment*) into an online environment. At the beginning of the session, conducted as an online meeting, an assignment is introduced within a few minutes. The assignment may be graded, ungraded, or designed to span multiple sessions. During the exercise, students work independently, relying solely on lecture slides and internet resources, without the support of video tutorials or detailed written instructions provided by the instructor.

Advantages

- If the instructor provides additional details or clarifications beyond the written assignment, this can add value for students (though this does not always happen). The session can be recorded, allowing students to revisit the explanation if needed.
- Almost no benefits, aside from fulfilling formal obligations – the instructor can formally claim to have had direct contact with students through an online meeting.

Disadvantages

- Students have often only formal reasons to join such an exercise – during the session, they are unlikely to work on the assignment and are probably engaged in other activities.

F. ONLINE TEACHING TYPE 2 - PASSIVE EXERCISE WITH ACTIVE EXPLANATION BY THE INSTRUCTOR

This method involves a direct one-to-one (1:1) transfer of the third type of in-person teaching (*In-Person Teaching Type 3 – Passive Exercise with Active Explanation by the Instructor*) into an online environment. During the session, the instructor's main task is to explain a specific topic. The instructor shares their screen, programs live, and explains step-by-step what they are doing, how they are doing it, and why.

This approach raises the question of whether it is necessary to conduct multiple exercise groups for such a session. If a single group suffices, it blurs the line between being an exercise and becoming a second lecture.

Advantages

- Students gain added value from the session as they receive a clear explanation of the topic, ensuring their participation is worthwhile.
- The session can be recorded, allowing students to revisit it later – this compensates for their inability to maintain focus for the full 1.5 hours.

Disadvantages

- For courses with large groups (as is often the case with programming subjects), the instructor's workload is enormous – effectively requiring them to deliver the same content three or more times if multiple exercise groups are created.
- Inconsistent quality – some sessions are conducted better than others due to instructor fatigue or variations in who conducts the session. Ultimately, the best recording will be the one most widely shared among students.

- Student activity during the session is minimal, effectively turning the exercise into another lecture.

G. ONLINE TEACHING TYPE 3 - ACTIVE EXERCISE: STUDENTS PROGRAM SIMULTANEOUSLY WITH THE INSTRUCTOR

This approach involves a direct one-to-one (1:1) transfer of the fourth type of in-person teaching (*In-Person Teaching Type 4 – Active Exercise: Students Program Simultaneously with the Instructor*) into an online environment. During the session, a complete program is developed collaboratively. The instructor shares their screen and programs live, while students simultaneously follow along and build the program on their own devices.

This method encourages active engagement by requiring students to work in real-time with the instructor, fostering a hands-on learning experience.

Advantages

- Students gain added value from the session – they not only receive an explanation of the material but also actively program.
- The session can be recorded, allowing students to revisit it later. This compensates for their potential inability to maintain focus for the full 1.5 hours.

Disadvantages

- The instructor often needs to address issues for students who fall behind. If many students struggle, some groups may cover only half the material compared to others, leading to chaos.
- If problem occurs, it is not possible to directly view the student's monitor during the session. The student must share their screen, which is time-consuming and causes delays while others wait.
- For courses with multiple groups (as is often the case with programming subjects), the instructor's workload is enormous.
- Inconsistent quality – some sessions are conducted better than others due to instructor fatigue or variations in who conducts the session. Ultimately, the best recording will be the one most widely shared among students.

In the Fig. 2 we can see the comparison of all mentioned teaching methods.

IV. PROPOSED METHODOLOGY: COMPETENCY-BASED HYBRID LEARNING

Courses focused on areas such as computer science, programming, computational intelligence, and digital technologies—where specialized laboratory equipment is not required—are increasingly recognized as inefficient when conducted without substantial integration of online tools. Our experience has demonstrated that particularly in advanced years of study, higher student engagement, especially among distance learners, can be achieved when more than 50% of the teaching is delivered through online modalities utilizing modern information and communication technologies (ICT). This hybrid approach, designed to foster competency development, has proven highly effective. Programming courses, in particular, are characterized by a strong emphasis on practical, hands-on activities rather than purely theoretical instruction, aligning closely with the goals of modern hybrid education methodologies.

However, this approach is most suitable for advanced years of study at universities and not for first-year students, who need to be introduced to the school environment, learn to navigate the campus, and develop social connections with peers. Consequently, the methods discussed here are specifically aimed at upper-year students and not freshmen. In the early years of study, more in-person learning is emphasized, providing foundational instruction and hands-on support. As students advance, the methodology shifts toward a greater integration of online learning, allowing for increased flexibility and self-paced skill development, particularly in more specialized areas. Although this methodology may not suit all course types, it has proven particularly effective in advanced information and communication technologies (ICT) and digital technology subjects, such as programming, artificial intelligence, digital or electronic marketing, video editing, 3D engine work, etc. The following subjects are currently taught in this form in the bachelor's study degree, which are part mainly of the study programmes *Applied Informatics* or *Smart Technologies and Automotive Mechatronics*:

- E-Marketing;
- Introduction to Game Design.

The following subjects are currently taught in this form in the master's study degree, which are part mainly of the study programmes *Applied Mechatronics and Electromobility* or *Applied Informatics*:

- Machine Vision and Computational Intelligence;
- Virtual and Mixed Reality;
- Digitization of Manufacturing Processes;
- Multimedia and Telematics for Mobile Platforms.

These subjects are taught at the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Slovakia.

A. ONLINE EXERCISES IN COMPETENCY-BASED HYBRID LEARNING

In the teaching of courses in the field of digital technologies, the focus lies primarily on practical exercises, where students engage in hands-on training and experimentation. These exercises form the core of the learning process, emphasizing the development of practical skills and competencies. In the following section, we describe how this is implemented within the presented framework.

We propose **competency-based learning through proprietary high-quality video courses with active instructor support**.

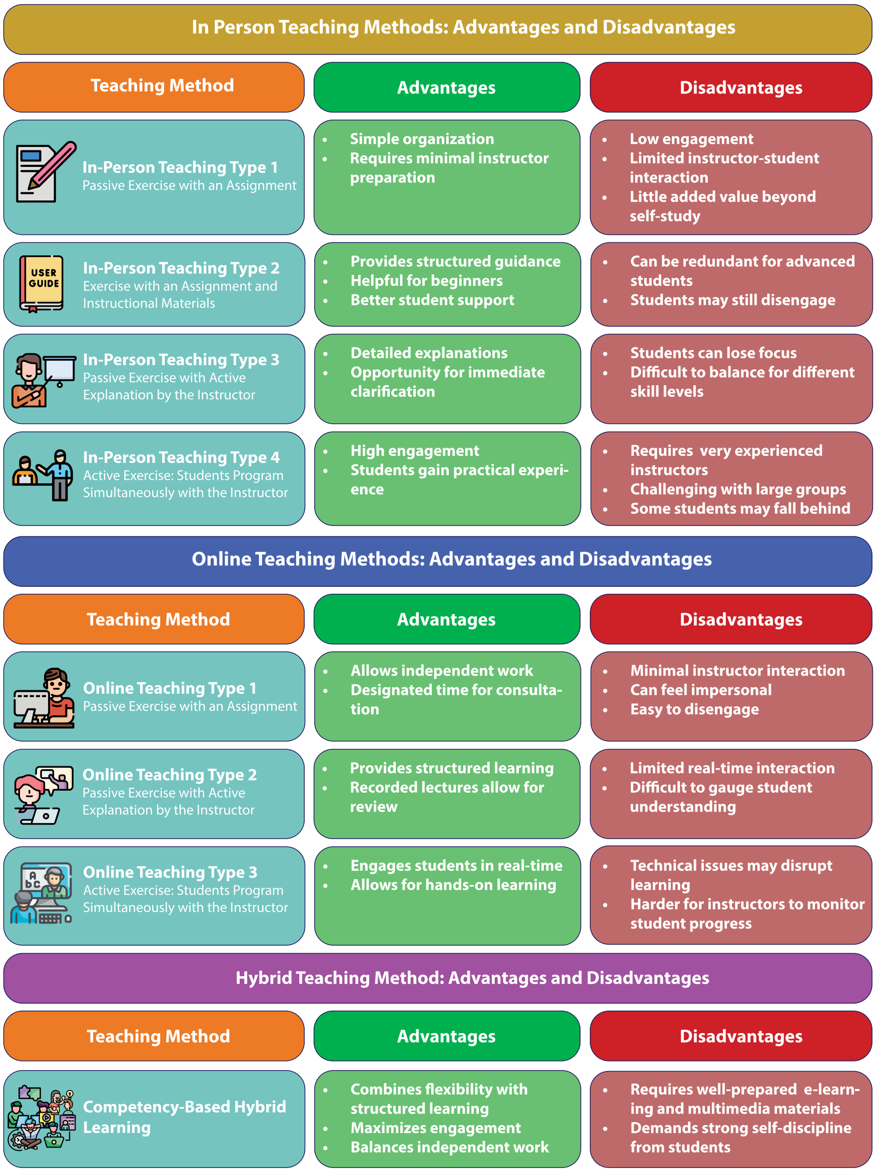


FIGURE 2. **Comparison of teaching methods: advantages and disadvantages (icons used from [4]).**

The exercises in this model are supported by one or, more often, a *combination* of the following types of educational materials:

- Video courses, tutorials, or guides (available in 90% of cases)
- Detailed text-based guides enriched with graphics
- Interactive notebooks (e.g., Jupyter Notebooks, Google Colab notebooks, etc.)

The primary goal of each exercise is for students to complete a specific assignment, such as creating a program with documentation or another comprehensive output. This ensures that each session provides students with *a tangible result* that *can be reviewed and evaluated*. A key advantage of this approach is the *consistency of quality* across individual exercises. By integrating these materials and objectives, the model ensures a structured and efficient way to build practical *skills and competencies* in digital technology courses.

The utilized type of online exercise teaching follows *a weekly cycle*, typically starting on Monday and ending on Sunday at 11:59 PM. Students receive detailed instructions via email (Fig. 3 and Fig. 4) before the start of the next cycle, typically on Sunday evening. These instructions outline how the teaching will proceed, the schedule, and provide access to the materials (e.g. video tutorials, etc.) needed for the exercise. All materials are available at the beginning of the cycle and not just before the exercise, as is sometimes the case with other types of teaching.

Students have the flexibility to organize their time independently and decide when to complete the exercise, as long

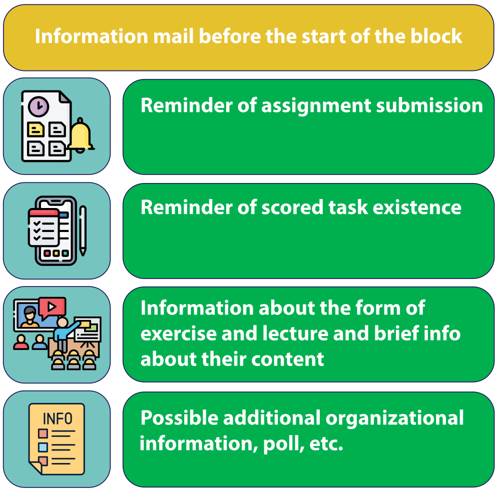


FIGURE 3. Structure of information e-mail sent before the start of the weekly block (icons used from [4]).

Dear Students,

Please remember to submit Exercise No. 6 by midnight today. This serves as confirmation of your completion of the exercise and is therefore mandatory.

We also remind you that the text for Activity No. 2, focused on creating a platformer game, is now available. The submission deadline is March 31st.

This week's Exercise No. 7 and lecture are structured as follows:

Exercise No. 7 will be ONLINE. Instructions for the exercise are available here: https://tinyurl.com/xyz. You can also find the file in the Files section at the top of MS Teams under the General channel or in AIS. Exercise No. 7 is creative and engaging, focusing on creating simple pixel art and animations. The required materials must be uploaded under Assigned Tasks (Assignments) by March 31st, 2024, 11:59 PM. If you have any questions regarding the content of the exercise, please contact Oto Haffner. For communication, please use MS Teams as the primary method. Thank you for your understanding.

This week's lecture will be IN-PERSON, led by professionals from IBM. It will take place on Monday at 1:00 PM in BC300. The topic will be "Generative AI and Design." We hope to see all of you at the lecture, as there are no schedule conflicts. :) We look forward to meeting you.

Thank you for your understanding, and if anything is unclear, feel free to write in the chat or in the General channel, which serves as a forum.

Have a great day,
Erik Kučera

FIGURE 4. Example of information e-mail sent before the start of the weekly block.

as they submit it before the deadline. During the scheduled exercise time as per the timetable, the instructor is available on MS Teams exclusively for the students. This allows for quick consultations via voice calls with screen sharing to address issues or provide rapid responses to questions in the chat.

In practice, however, instructors often respond to students' questions outside of the scheduled exercise times, whenever they have availability, and frequently even over weekends. Email communication is actively discouraged for exercise-related questions, as the MS Teams chat is significantly faster and more efficient for both parties.

In this model of teaching, there is no central online meeting during the designated exercise time in the schedule where students would be required to join collectively. Such a meeting would be an artificial element, offering little to no practical benefit to the learning process. Instead, the focus is on individual engagement and support, tailored to the needs of each student.

Additionally, a central meeting is unnecessary because all the essential information is already provided in the video tutorial. Students can watch and rewatch the video at their own pace, ensuring they fully understand the content. Hosting a meeting would only repeat the information already covered in the tutorial, which would be redundant and inefficient. This approach maximizes the use of resources while allowing students the flexibility to engage with the material in a way that suits their learning style.

Experience has shown that students prefer to address their questions and challenges individually rather than in a group setting. Many students feel uncomfortable asking questions in front of their peers and are more confident when given the opportunity to seek assistance privately. This method aligns with the characteristics of today's student demographic, particularly Generation Alpha and students in technical fields, who tend to exhibit more introverted tendencies. The experience is that Generation Alpha is more accustomed to personalized interactions and independent problem-solving due to their extensive exposure to digital tools and environments. These traits make the availability of instructors for one-on-one consultations via chat or video calls during scheduled times especially valuable.

As it was stated before, during the exercise time, instructors are required to be available on MS Teams exclusively to respond promptly to students' inquiries. This includes answering questions in chats or conducting individual calls with screen sharing to address specific problems. The private nature of these interactions encourages student participation and allows them to seek help without the pressure of performing in front of others.

In addition to meeting the special requirements of contemporary students, this teaching style improves the general efficacy and inclusivity of the educational process by accommodating these preferences. With the help of this customized support system, students may study at their own speed while still getting timely, focused instruction from their teachers.

A key question in this teaching model is *how to track attendance*, which is a requirement within the faculty's environment, given that students are not required to join a central online meeting. Traditionally, attendance is recorded by verifying participation in a central online session held during the scheduled exercise time. However, as previously discussed, such meetings do not take place in this system.

Attendance is instead tracked through the submission of assignments. Within the given week, students must complete and submit their task (a complete program, application, or another type of practical output). For more complex assignments, the submission deadline may span two weeks, and attendance is credited for two weeks (or two exercises) upon successful submission. This system firmly aligns with the focus on skill-building and competency development.

Moreover, submitting a completed assignment serves as a far better indicator of a student's engagement and learning than merely attending a meeting. Attendance at an online session can easily be falsified, whereas delivering a practical output provides concrete evidence of the student's effort and understanding. This approach guarantees that the education process stays goal-oriented and closely related to the acquisition of useful skills.

As demonstrated, this teaching approach effectively leverages *asynchronous elements* by allowing students to manage their time independently and complete exercises at their own pace, provided they meet the submission deadlines. With all materials and tutorials available at the start of the week, *students can work whenever they feel most creative and productive*. At the same time, it fulfills the requirements for *synchrony* by ensuring instructors are fully available during scheduled exercise times, providing immediate support and guidance when needed.

Approximately 60–75% of the exercises are conducted online using the described method, while the remaining sessions are held in person. The structure and implementation of the in-person exercises will be detailed in the following subsection.

The video, available at *https://youtu.be/HWjawtET9h8* [46], showcases a selection of highlights from video tutorial and guides. The video is in Slovak, as the course is primarily taught in Slovak, but autogenerated subtitles in other languages (e.g., English) can be enabled on YouTube for accessibility.

B. IN-PERSON EXERCISES IN COMPETENCY-BASED HYBRID LEARNING

As it is a hybrid and not purely online learning, in-person exercises are also implemented. In-person exercises are utilized for the following activities, which students recognize that provide significant added value when they are conducted in-person:

1) **Introduction to the course, surveys, and explanation of the teaching methodology** - conducting these activities in person allows for clearer communication and immediate resolution of initial questions, creating a stronger connection with students.
2) **Beginning of a new teaching block:**
   - *Detailed introduction of the main instructor responsible for the block* - this helps students establish a direct relationship with the instructor and build trust.
   - *Assistance with installing new software* - in-person guidance ensures that students can set up their tools correctly and troubleshoot any issues immediately.
   - *Explanation of graded activities in the block* - clear, face-to-face communication helps students understand the requirements and expectations.
3) **Tests and mid-term evaluations** - in-person testing ensures integrity and provides a controlled environment for fair assessment.
4) **Presentation of assignments (including team projects) to peers** - presenting in person helps students improve their soft skills, such as public speaking and teamwork, which are essential in professional environments.
5) **Presentation of updates and new developments in the course topic by instructors** - face-to-face sessions allow for a more dynamic exchange of ideas and better engagement with students regarding the latest trends and innovations.
6) **Exercises identified as prone to potential issues** - addressing complex topics in person allows for immediate clarification and prevents students from becoming stuck or frustrated.

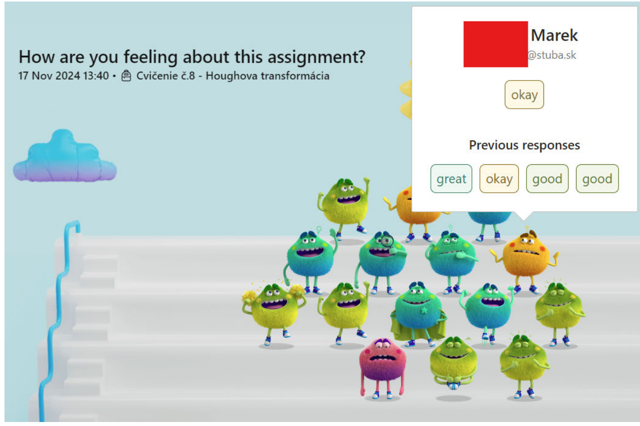


FIGURE 5. Student feedback using Reflect: monitoring engagement and confidence with assignments.

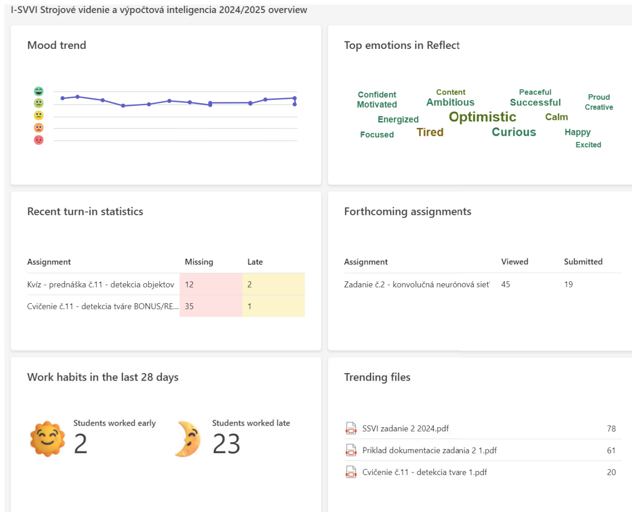


FIGURE 6. Insight dashboard: insights into student mood trends, engagement, and assignment progress for Machine Vision and Computational Intelligence course.

Each in-person exercise also results in a tangible output, with students submitting an assignment upon completion. Additionally, these sessions often include not only the instructors responsible for the exercises but also the lecturers of the course, even though their participation is typically not accounted for in their workload. This combined presence ensures a richer learning experience and allows students to benefit from broader expertise during the sessions.

FIGURE 7. **Reflect and Insight dashboard: monitoring student engagement and emotional states in Machine Vision and Computational Intelligence course.**

The hybrid model offers students flexibility and a greater number of practical and interactive tasks, which they can tackle when they feel ready. The value of attending in-person exercises is enhanced by focusing these sessions on specific activities with high added value, such as discussions about current developments in the field, student presentations of their outputs, or addressing challenges that are difficult to resolve in an online environment. This hybrid approach gives students greater control over their time and learning, as they work on specific, meaningful tasks during exercises and see clear results from their efforts. The exercises become a space where genuine learning occurs, and students receive immediate feedback, which revitalizes their motivation to participate in in-person teaching. By clearly perceiving the benefits to their personal and professional development, students recognize the importance and value of attending in-person sessions as an integral part of their education.

As part of our hybrid teaching approach, we check in with students once a week using the Reflect app and Insight app in Microsoft Teams (Fig. 5-7). With the aid of the program Reflect, instructors can conduct meaningful check-ins, learn more about the wellbeing of their students, and create a more healthy learning environment. These check-ins provide students a chance to express their opinions and comments on the activities, which helps teachers gauge understanding and quickly resolve any issues. The course material and delivery can be continuously improved thanks to this frequent feedback loop, which also creates a positive learning atmosphere.

C. EVALUATION OF TEACHING FROM THE STUDENTS' AND TEACHERS' PERSPECTIVE

Students feedback is regularly collected through surveys, the official evaluation that takes place at the university in every subject, in-depth interviews and also the feedback opportunities offered by Microsoft Teams. This subsection presents the main findings, with more (including graphs from the surveys) to be presented in the report section at the end of the paper.

Main advantages and what students appreciate

- **Improved interaction** with course instructors compared to other subjects - students receive answers when they need them during problem-solving, not just during officially allocated hours, ensuring *interaction occurs when it is most relevant for the student*.
- **Ability to rewind and revisit materials freely**, especially for more challenging sections - misunderstandings in in-person exercises often arise from missing a single sentence, which is not an issue with recorded materials.
- High **clarity and consistency** of video materials - unlike in-person sessions, where quality may vary, video materials are prepared by the instructor who understands the topic best. This eliminates variability often seen in live sessions, where "everything runs smoothly" only during the last term.
- Abundance of **practical outputs** from the courses - this provides a significant advantage when seeking employment, as students can showcase tangible results from their coursework.
- **Flexibility** in time management - students can work on exercises when they feel most creative and productive, rather than being constrained by fixed schedules. This is particularly important for deep, practice-oriented tasks and subjects, such as programming, where learning happens through hands-on experience and active problem-solving. In traditional in-person sessions, many students often waited for the class to end so they could work on the assignments at home, where they felt more comfortable and focused.

Possible disadvantages and student feedback

- Students acknowledge that **these courses are relatively time-intensive** - the focus on producing a large number

of “tangible outputs” reflects the competency-based learning approach but requires a significant time commitment. Nevertheless, the subjects are very well rated as the completed tasks are perceived as meaningful for future careers.
- Students express that while they appreciate the structure of these courses and would welcome more of them, **they do not believe this approach should be applied universally** - they note that certain types of courses may not be suitable for this model.
- **Online teaching is not well-suited for first-year students** - first-year students need time to adjust to the environment, develop regular habits, learn to attend school, and socialize with their peers, making in-person teaching more appropriate during this period.

The following is an evaluation of the teachers that implement this form of teaching.

Advantages for teachers

- **Reduced repetitive work** caused by constantly repeating the same explanations and addressing identical (often minor, e.g., misheard instructions) issues - this allows teachers to focus more on meaningful and unique challenges faced by students.
- **More time to address real problems** raised by students - this creates an opportunity for deeper engagement and more impactful teaching moments.
- **Increased student satisfaction** - Building trust with students leads to attracting high-quality students for bachelor’s and master’s theses, which in turn provides opportunities for quality publications.
- **Improved assignment results** compared to the period before hybrid teaching was introduced - students produce higher-quality outputs under the competency-based approach.
- **Enhanced support** for both talented and weaker students - the hybrid learning model allows each student to progress at their own pace, making the teaching process highly individualized. Talented students can excel without being held back (talent-centric approach), while weaker students receive additional time and instructor support to catch up and succeed.
- **Better distribution of time** dedicated to teaching and preparation throughout the calendar year - teachers are less overwhelmed by repetitive tasks during the semester and can focus on research, project work, and securing grants. However, this comes at the cost of having less free time during summer/winter holidays and exam period. Overall, the main person responsible for the course typically dedicates more time to teaching across the calendar year, rather than less.

Challenges and drawbacks for teachers – what must be considered

- Ensuring student satisfaction **requires teachers to dedicate more time to answering questions** outside of scheduled exercises and lectures - quick responses are expected, and if a teacher is unavailable, a rapid agreement must be made among colleagues to ensure the student’s query is addressed promptly.
- **Greater effort in gathering and acting on student feedback** - teachers may need to adjust materials dynamically if a high volume of similar questions arises.
- **During summer and winter breaks, teachers must review and thoroughly prepare video tutorials** and text-based guides for the upcoming semester - this includes revisiting all materials to ensure their accuracy and relevance.
- **Rapid updates in software versions necessitate frequent material reviews** - video tutorials must be checked before each semester and, if needed, revised (e.g., by adding clarifying subtitles or errata) or occasionally re-recorded entirely. This type of teaching is only sustainable if a video tutorial remains relevant for at least 2–3 years, ensuring the time invested in its preparation pays off given its intellectual, technical, and time-consuming demands.
- **If materials are outdated or unclear, chaos may ensue**, and the teaching structure can collapse like a house of cards - teachers must remain vigilant, monitor recurring questions, and be ready to update materials or publish clarifications in the course communication channels.
- **Teachers must possess skills in video and audio editing**, as well as carefully plan the video’s structure and presentation - well-thought-out dramaturgy is essential to create effective and engaging instructional videos [47], [48].

Despite the aforementioned advantages and high levels of student satisfaction, there remains a tendency among some educators to replicate (mirror) in-person teaching 1:1 through online meetings. While this approach may appear straightforward, it is often inefficient compared to alternative methods. It is important to acknowledge, however, that preparing high-quality e-learning materials for hybrid and asynchronous learning is a demanding and time-intensive task. This trend is also influenced by institutional regulations, which often prioritize verifying that the exercise occurred at the scheduled time rather than focusing on student satisfaction or learning outcomes. Additionally, asynchronous components of teaching, including the time educators dedicate to supporting students outside of formal sessions, often go underappreciated. The quality of educational materials, which plays a critical role in student success, also tends to be insufficiently recognized or evaluated within traditional frameworks.

A similar challenge arises with teaching evaluations (inspections), which are typically conducted by senior faculty members. Asynchronous teaching can sometimes be perceived as lower quality during such evaluations, even though students may feel the opposite. This is because traditional evaluations have often focused exclusively on direct (preferably synchronous) teaching activities, paying little attention to the value and impact of asynchronous elements. To fairly assess this style of teaching, evaluators must adopt a more comprehensive approach that takes into account the full scope of hybrid learning, including the preparation and quality of asynchronous materials as well as the instructor's support outside scheduled sessions. However, not all evaluators are willing or able to adapt to this broader perspective, which can lead to a misrepresentation of the actual teaching quality in hybrid models.

There is a common misconception among some educators that instructors utilizing hybrid teaching methods have too much free time and, as a result, may not be teaching effectively or are not fully committed to their responsibilities. In reality, hybrid instructors are less burdened by repetitive tasks during the semester, which allows them to focus on research, projects, and securing grants. However, this comes at the cost of reduced free time during summer and winter breaks, as well as during examination periods. Contrary to these assumptions, instructors in hybrid models often dedicate more time to teaching over the course of a calendar year, not less. Many teachers repeat instructions for exercises multiple times a week, often addressing issues caused by students mishearing or misunderstanding. Both of these problems can be effectively resolved with a well-structured video tutorial. However, the repetitive nature of these tasks exhausts teachers, leaving them with less energy to focus on solving real, individual problems. Additionally, while students rate these courses highly, some educators mistakenly attribute this satisfaction to the subjects being "easy." This perception is paradoxical, given the significant workload and tangible outputs required in competency-based learning, which students view as meaningful and beneficial for their future careers.

There are also voices calling for an outright ban on online teaching, citing worse student outcomes. However, these claims are often not supported by thorough analyses. It is important to note that such critiques are frequently well-intentioned, as there are indeed examples of poorly implemented online teaching. These critics often base their opinions on the only online teaching method they are familiar with: the direct replication of in-person sessions via online meetings (1:1 transfer). While this approach is understandably criticized for its inefficiency, these educators often cannot envision alternative online formats that incorporate asynchronous elements effectively.

Furthermore, those advocating for a ban on online teaching are frequently from fields where such methods are less applicable, such as mathematics, physics or laboratory-based subjects with a strong reliance on physical instruments. They may not recognize that other disciplines, such as programming or digital technologies, can significantly benefit from well-structured online and hybrid teaching models. This highlights the need for a nuanced, individualized approach when evaluating and selecting teaching methods. Innovation in teaching should be encouraged, and decisions should be based on the specific requirements of the subject matter and the potential advantages that online and hybrid approaches can offer.

D. LECTURES IN COMPETENCY-BASED HYBRID LEARNING

How should lectures be conducted in a hybrid, competency-based teaching model? How can they be adapted to provide meaningful value within this framework, where students face increased workloads from practical tasks and teachers are heavily engaged in their evaluation and support? These questions are central to ensuring that lectures remain relevant and effective while complementing the hands-on focus of hybrid education.

Four forms of lectures are used:

- **In-person lecture by an university lecturer** - it is streamed and recorded at the same time.
- **In-person lecture by an industry expert** - streamed and recorded at the same time, if company policy allows.
- **Online lecture in the form of an online meeting (e.g. Microsoft Teams) by an industry expert** – used when the expert cannot attend in person.
- **Online lecture by the university lecturer** – pre-recorded with high-quality video and audio.

Knowledge from lectures is assessed through a non-graded quiz conducted in MS Teams. The quiz may also include a survey question to gather student feedback on the course.

As observed, the list does not include synchronous online lectures conducted as live online meetings by the teacher. Why and when is it more effective to deliver online lectures through pre-recorded, high-quality video and audio rather than as live online meetings?

Live online meetings typically suffer from lower-quality audio and video, and instructors are often less focused during these sessions. For lectures in this type of course (programming, digital technologies, etc.), immediate interaction is minimal or non-existent, as students rarely ask questions (unlike in subjects such as mathematics, introductory programming for first-year students, or similar foundational courses). An exception to this is lectures delivered by industry experts, where students benefit from direct access to professionals they otherwise would not encounter.

For this reason, it has proven effective to *pre-record lectures in a suitable environment with proper microphones and carefully video-edit the content*. This includes blending illustrative videos with presentation, removing filler words, correcting mistakes, and improving clarity—tasks that are not possible during live online meetings.

Such pre-recorded lectures are also highly valuable for working students (enrolled in special study method tailored for them) and remain accessible during periods when the instructor is attending conferences or on leave. This approach ensures high-quality, flexible, and consistent delivery of course content (Fig. 8).

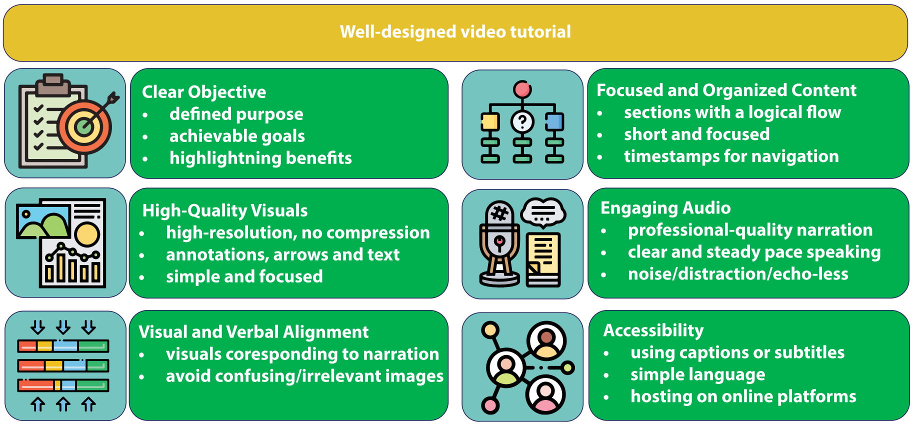


FIGURE 8. Main elements of a well-prepared video tutorial or video lecture (icons used from [4]).

Online lectures (around 50%) are more commonly used in Master's programs, where a significant portion of students are distance learners. In Bachelor's programs, this proportion of online lectures is lower, at approximately 25%.

This type of pre-recorded lecture is particularly suitable for the following cases:

- **Complex lectures with equations** - for example, lectures on computational intelligence or machine vision, which students can rewind and replay for better understanding.
- **Encyclopedic lectures with interesting facts** - these can be listened to during students' free time, similar to a podcast.
- **Lectures whose content is frequently used in exercises and assignments** - providing students with easy access to these materials enhances their application during practical tasks.

Additional Advantages of Online Lectures

- **Precise referencing for assignments or semester projects** - students can refer to exact timestamps in the lecture (a "cheat sheet"), saving time and increasing the likelihood of successfully completing the task.
- **Defined timestamps for quick topic navigation** - when the lecture is hosted on platforms like YouTube or OneDrive (SharePoint), timestamps with descriptions can be added, making it easier for students to locate specific topics and save time during exam preparation.
- **No scheduling conflicts in the timetable** - with online lectures, issues with overlapping lecture times for other courses are eliminated. This is particularly beneficial for subjects with a high number of students from different study programs.
- **Simplified knowledge transfer** - online lectures provide an effective tool for training new instructors, lecturers, or colleagues who need to learn the subject matter, ensuring a smoother onboarding process.

Why is it not better to conduct all lectures in person? Are students sufficiently monitored?

It is important to note that knowledge from online lectures is assessed through mandatory quizzes in MS Teams as well as in-person midterm tests and final exams. The described courses are quite time-intensive (focused on *competency development* and *project-based outputs*), and students are more likely to accept this workload if part of the lectures are available online, allowing them to engage with the material when they feel most creative.

Mostly in other teaching styles there is no such operational verification of knowledge, but attendance at lectures is verified only by presence (while the student may be absent in spirit) or by joining an online meeting (which is easily falsifiable).

Based on several years of experience, live in-person lectures are most suitable for sessions that include organizational information, the start of new teaching blocks, or updates on recent developments in the field. These scenarios are among the few cases where students are eager to engage in discussions, making them ideal for in-person delivery.

Does creating a pre-recorded lecture with high-quality video, audio, and editing make the teacher's job easier? From the perspective of overall workload, the answer is certainly no. One significant advantage for the teacher, however, is the flexibility to prepare the lecture outside of the semester, which supports their publication and project-related activities during semester.

Experience shows that only recording and editing a single high-quality lecture takes approximately 3–4 hours. This effort is worthwhile if the lecture can be reused for at least 2–3 semesters. However, the rapid advancements in the field of digital technologies mean that after this period, the lecture will need to be updated and supplemented to remain relevant.

Since recording and continual re-editing would not save time, in-person lectures are still required for topics that change quickly. This emphasizes how crucial it is to select the right format for every subject according to its unique needs.

What should be kept in mind? Publishing a recorded lecture puts the teacher's work under public scrutiny, requiring more meticulous preparation. Any inaccuracies in the content can

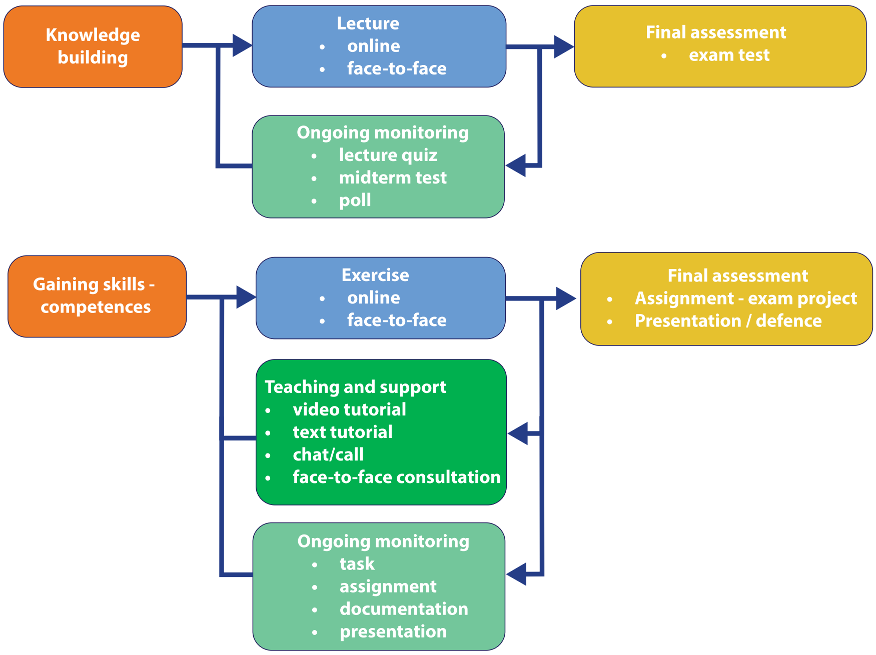


FIGURE 9. Scheme of competency-based hybrid learning.

spread quickly online. This is an aspect many people do not realize, while others are overly aware of it, leading them to avoid streaming or recording their in-person lectures due to a lack of confidence.

Ideally, an online lecture should not exceed one hour. Experience has shown that topics typically covered in a 1.5-hour in-person lecture (standard lecture time at authors' faculty is 1 hour 40 minutes) can be effectively delivered in around one hour in a video format. This is due to the absence of filler content, repeated explanations (as students can replay sections they don't understand), and the lecturer's more focused delivery.

Finally, it is worth acknowledging that many students already rely on video materials to study at home. By preparing comparable, high-quality videos, created by our faculty's staff, the institution can guarantee the accuracy and quality of the content. This approach ensures that the educational material aligns with the faculty's standards and students' needs.

A diagram showing the main elements of the methodology can be found in Fig. 9.

V. EVALUATION AND DISCUSSION

This section contains an evaluation of the teaching method described for selected subjects and also information on what these subjects are about and what their specificities are.

A. MACHINE VISION AND COMPUTATIONAL INTELLIGENCE

This subject is included in the 1st year of the master's degree program in *Applied Mechatronics and Electromobility* as profile and compulsory subject.

The course is designed as a comprehensive introduction to two interconnected domains: Computational Intelligence and Machine Vision, with all practical tasks implemented in Python, reflecting its growing prominence as a standard in these fields.

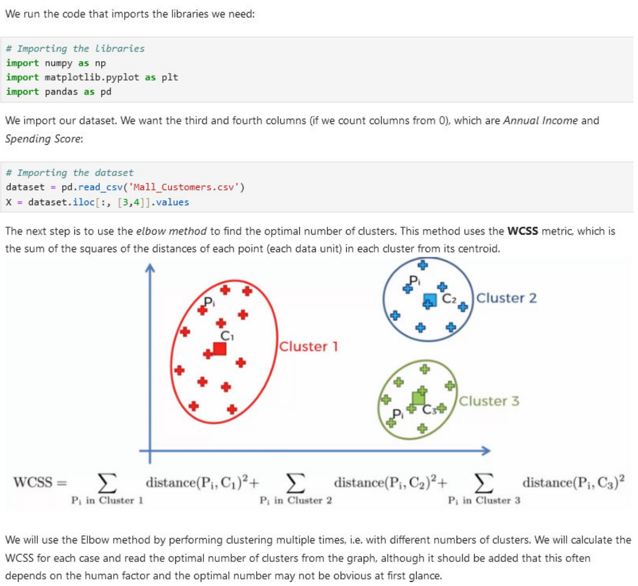
The Computational Intelligence section covers foundational concepts such as object-oriented programming and Python basics, machine learning tasks like classification and regression and artificial neural networks.

The Machine Vision section focuses on image processing techniques, including data structures, image acquisition, histograms, edge detection, thresholding, morphological operations, and Hough transformations. It also delves into optics, camera interfaces, object recognition, face detection, and practical applications of machine vision in real-world scenarios.

In the first half of the course, focusing on Computational Intelligence, students are provided not only with video tutorials and detailed textual guides but also with an interactive Jupyter Notebook (Fig. 10).

This application improves interaction by seamlessly combining executable code, written explanations, graphs, and graphics in a single document. This approach enables students to immediately see the results of their work, play with code, and enhance their comprehension through hands-on experience inside the course materials.

The Jupyter Notebook promotes a seamless transition between theory and practice by allowing students to test theoretical concepts in real time and observe their practical implementations. This dynamic method increases comprehension and engagement, allowing students to better understand the complexities of computational intelligence while experimenting with Python-based solutions.


We run the code that imports the libraries we need:

```
# Importing the libraries
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
```

We import our dataset. We want the third and fourth columns (if we count columns from 0), which are *Annual Income* and *Spending Score*:

```
# Importing the dataset
dataset = pd.read_csv('Mall_Customers.csv')
X = dataset.iloc[:, [3,4]].values
```

The next step is to use the *elbow method* to find the optimal number of clusters. This method uses the **WCSS** metric, which is the sum of the squares of the distances of each point (each data unit) in each cluster from its centroid.

$$\mathrm{WCSS} = \sum_{P_i \text{ in Cluster 1}} \mathrm{distance}(P_i, C_1)^2 + \sum_{P_i \text{ in Cluster 2}} \mathrm{distance}(P_i, C_2)^2 + \sum_{P_i \text{ in Cluster 3}} \mathrm{distance}(P_i, C_3)^2$$

We will use the Elbow method by performing clustering multiple times, i.e. with different numbers of clusters. We will calculate the WCSS for each case and read the optimal number of clusters from the graph, although it should be added that this often depends on the human factor and the optimal number may not be obvious at first glance.

FIGURE 10. Machine Vision and Computational Intelligence - e-learning material based on Jupyter Notebook.

The assessment in this course is designed to evaluate both theoretical knowledge and practical competencies. The total score is 100 points, divided equally between semester work and the final exam:

- Semester assessment (50 points):
  - Test (10 points) – A written test covering fundamental concepts.
  - Assignments (40 points total):
    - Assignment 1 (20 points): Artificial neural network
    - Assignment 2 (20 points): Deep (convolutional) neural network
- Final examination (50 points):
  - Standard option: a test (50 points) covering theoretical and applied aspects of AI and machine vision.
  - Alternative option: a large-scale project combined with an oral presentation (50 points). The presentation focuses on recent advancements in AI and machine vision, allowing students to explore and discuss state-of-the-art topics.

This assessment structure ensures a balanced evaluation of both theoretical understanding and practical skills, with an emphasis on applied learning in artificial intelligence and machine vision.

The results of the *end-of-course survey* conducted by the instructors after the exam can be seen in Table 1-3 and Fig. 11-13.

From the results of the evaluation in the Academic Information System (students evaluate courses at the end of the semester), the average grade and median grade were also calculated separately for lectures and exercises. Students grade courses the same way they are graded in school. The mean and median scores for the course lectures were 1.14 and 1, respectively (i.e., a grade of A). The mean and median course exercise scores were 1.19 and 1, respectively (i.e., a grade of A).

TABLE 1. Question for students in the winter semester 2024 - "The course was taught in a hybrid method. How satisfied are you with the quality of the teaching of Machine Vision and Computational Intelligence?"

Answer	Count	Percentage
Very satisfied	31	73.81%
Rather satisfied	10	23.81%
Neither satisfied nor dissatisfied	1	2.38%
Rather dissatisfied	0	0.00%
Very dissatisfied	0	0.00%
Do not know	0	0.00%

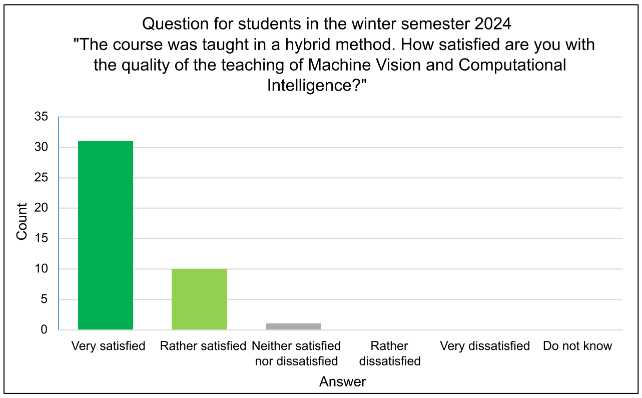


FIGURE 11. Visualization of Table 1 Data.

TABLE 2. Question for students in the winter semester 2024 - "Would the quality of teaching of the Machine Vision and Computational Intelligence course benefit if it were taught more extensively IN-PERSON?"

Answer	Count	Percentage
Yes, it would definitely benefit it and I would learn more	3	7.89%
Yes, it would benefit it	2	5.26%
I don't know	11	28.95%
No, it would not benefit it	15	39.47%
No, it would not benefit it, it is possible that I would even learn less	11	28.95%

It is important to note that from a teaching perspective, Machine Vision and Computational Intelligence is a complex and diverse subject. It encompasses not only programming and documentation of machine learning and vision experiments but also includes numerous lectures on the mathematical foundations of machine vision, featuring a significant amount of equations. This makes it a challenging course in terms of both content and instructional design, far from being a simple or rudimentary subject.

The successful implementation of competency-based hybrid learning within this course underscores the viability and effectiveness of this approach. By integrating diverse teaching methodologies and resources, this model has demonstrated its capacity to tackle the multifaceted nature of the subject while effectively supporting both student engagement and skill development.

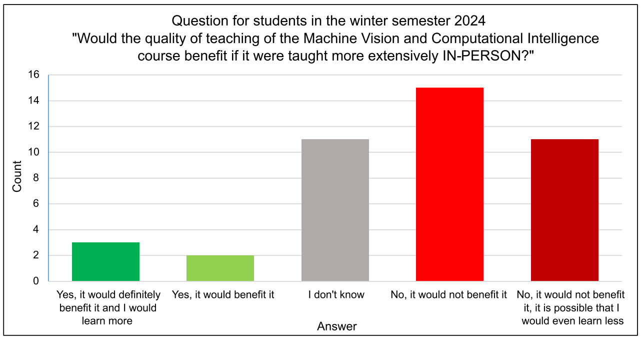


FIGURE 12. Visualization of Table 2 Data.

TABLE 3. Question for students in the winter semester 2024 - "Did you receive answers to your questions in the Machine Vision and Computational Intelligence course quickly enough during online classes if you asked them during the scheduled lab session?"

Answer	Count	Percentage
Yes, in real or almost real-time	16	42.11%
Yes, although it could be faster	1	2.63%
I don't know	2	5.26%
No, I need answers faster	0	0.00%
No, I did not receive any answers at all	0	0.00%
I can't comment, I didn't ask any questions, the tutorials and instructions provided were clear enough	23	60.53%
Other	2	5.26%

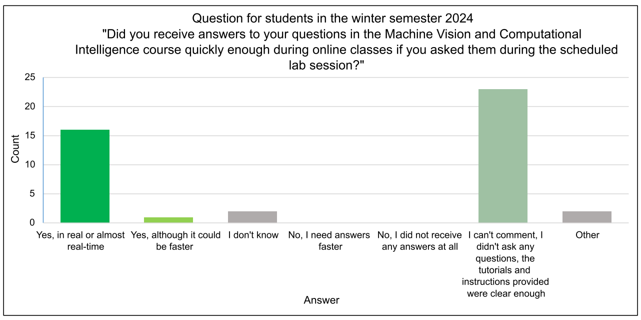


FIGURE 13. Visualization of Table 3 data.

B. VIRTUAL AND MIXED REALITY

This subject is included in the 1st year of the master's degree program in *Applied Mechatronics and Electromobility* as profile and semi-compulsory subject. It is also included in the 2nd year of the master's degree program in *Applied Informatics* as optional subject.

The course Virtual and Mixed Reality introduces students to the innovative fields of virtual, augmented, and mixed reality and their applications in information and communication technologies. It is structured into two distinct parts. The first part focuses on 3D modelling, primarily using Blender, where students learn to create and texture 3D assets. This foundation prepares them to design models suitable for integration into interactive applications.

The second and more comprehensive part centers on 3D engine Unity, where students synthesize various audiovisual components—such as images, sounds, text, videos, 3D models, and animations—to develop complete interactive applications. The scope of this segment extends beyond traditional game development to include practical applications, such as product visualization, virtual showrooms, and marketing presentations.

The course places a strong emphasis on programming in higher-level languages like C#, fostering skills in interactive application development and exploring modern forms of human-machine interaction. By the end of the course, students will be capable of creating complex, interactive 3D applications tailored to a wide range of uses, from edutainment to product marketing.

The assessment in this course is designed to balance theoretical knowledge with practical competencies. The total score is 100 points, divided between semester work and the final exam:

- Semester assessment (40 points):
  - Assignment 1 (10 points): Multimedia 3D model in Blender
  - Assignment 2 (15 points): Interactive game with a ball – development of a simple game involving physics-based interactions
  - Assignment 3 (15 points): Product visualization or augmented/mixed reality application
- Final examination (60 points):
  - Test (30 points) – covers fundamental concepts of extended reality and other digital technologies
  - Major project in Unity (30 points) – A large-scale project incorporating:
    - A functional Unity application with interactive elements
    - A presentation video or 3D model used within the project

Nearly all projects are presented in person, allowing students to demonstrate their work and receive direct feedback. This format encourages the development of soft skills alongside technical competencies.

The results of the *end-of-course survey* conducted by the instructors after the exam can be seen in Table 4-6 and Fig. 14-16.

From the results of the evaluation in the Academic Information System (students evaluate courses at the end of the semester), the average grade and median grade were

TABLE 4. Question for students in the winter semester 2024 - "The course was taught in a hybrid method. How satisfied are you with the quality of the teaching of Virtual and Mixed Reality?"

Answer	Count	Percentage
Very satisfied	34	79.07%
Rather satisfied	8	18.60%
Neither satisfied nor dissatisfied	1	2.33%
Rather dissatisfied	0	0.00%
Very dissatisfied	0	0.00%
Do not know	0	0.00%

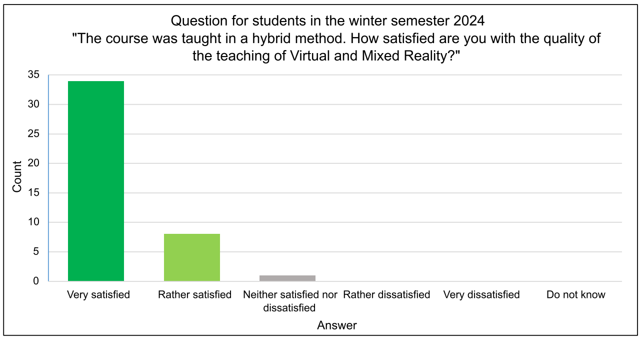


FIGURE 14. Visualization of Table 4 data.

TABLE 5. Question for students in the winter semester 2024 - "Would the quality of teaching of the Virtual and Mixed Reality course benefit if it were taught more extensively IN-PERSON?"

Answer	Count	Percentage
Yes, it would definitely benefit it and I would learn more	1	2.33%
Yes, it would benefit it	4	9.30%
I don't know	5	11.63%
No, it would not benefit it	22	51.16%
No, it would not benefit it, it is possible that I would even learn less	6	18.60%
Other	3	6.98%

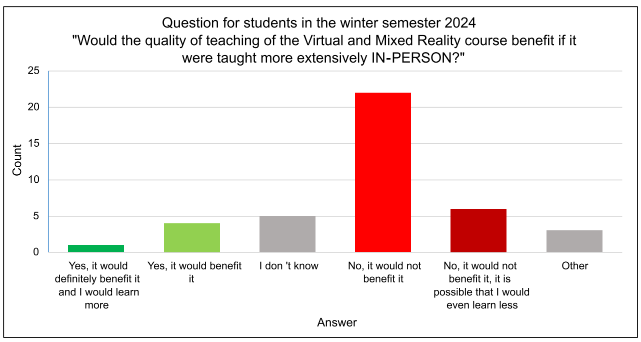


FIGURE 15. Visualization of Table 5 data.

TABLE 6. Question for students in the winter semester 2024 - "Did you receive answers to your questions in the Virtual and Mixed Reality course quickly enough during online classes if you asked them during the scheduled lab session?"

Answer	Count	Percentage
Yes, in real or almost real-time	23	53.49%
Yes, although it could be faster	2	4.65%
I don't know	2	4.65%
No, I need answers faster	0	0.00%
No, I did not receive any answers at all	0	0.00%
I can't comment, I didn't ask any questions, the tutorials and instructions provided were clear enough	16	37.21%

also calculated separately for lectures and exercises. Students grade courses the same way they are graded in school. The mean and median scores for the course lectures were 1.06 and 1, respectively (i.e., a grade of A). The mean and median course exercise scores were 1.03 and 1, respectively (i.e., a grade of A).

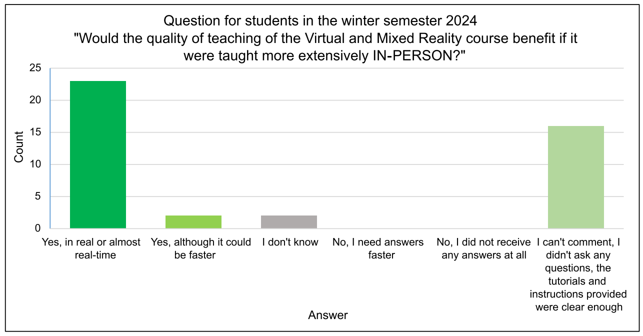


FIGURE 16. Visualization of Table 6 data.

TABLE 7. Question for students in the winter semester 2024 - "The course was taught in a hybrid method. How satisfied are you with the quality of the teaching of Multimedia and Telematics for Mobile Platforms?"

Answer	Count	Percentage
Very satisfied	36	90.00%
Rather satisfied	4	10.00%
Neither satisfied nor dissatisfied	0	0.00%
Rather dissatisfied	0	0.00%
Very dissatisfied	0	0.00%
Do not know	0	0.00%

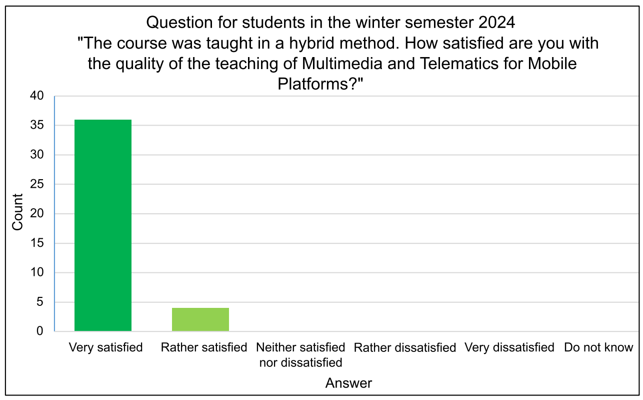


FIGURE 17. Visualization of Table 7 data.

TABLE 8. Question for students in the winter semester 2024 - "Would the quality of teaching of the Multimedia and Telematics for Mobile Platforms course benefit if it were taught more extensively IN-PERSON?"

Answer	Count	Percentage
Yes, it would definitely benefit it and I would learn more	0	0.00%
Yes, it would benefit it	2	5.00%
I don't know	8	20.00%
No, it would not benefit it	18	45.00%
No, it would not benefit it, it is possible that I would even learn less	10	25.00%
Other	2	5.00%

This course is highly creative, with loosely defined assignments that allow students to freely express their ideas. These activities are then reviewed and shared to their classmates, creating an atmosphere of collaborative learning and inspiration.

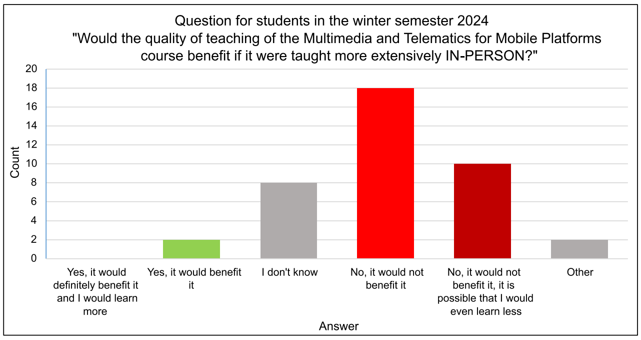


FIGURE 18. Visualization of Table 8 data.

TABLE 9. Question for students in the winter semester 2024 - "Did you receive answers to your questions in the Multimedia and Telematics for Mobile Platforms course quickly enough during online classes if you asked them during the scheduled lab session?"

Answer	Count	Percentage
Yes, in real or almost real-time	29	72.50%
Yes, although it could be faster	0	0%
I don't know	5	12.50%
No, I need answers faster	0	0.00%
No, I did not receive any answers at all	0	0.00%
I can't comment, I didn't ask any questions, the tutorials and instructions provided were clear enough	6	15.00%

Here, the concept of competency-based hybrid learning is demonstrated to be viable and effective. For such creative assignments, students must work at their own pace and when they are most focused and inspired. This flexibility guarantees that the quality of their work is maximized, resulting in the greatest potential outcomes while respecting each student's own workflow and creative process.

C. MULTIMEDIA AND TELEMATICS FOR MOBILE PLATFORMS

This subject is included in the 2nd year of the master's degree program in *Applied Mechatronics and Electromobility* and program *Applied Informatics* as optional subject.

The course Multimedia and Telematics for Mobile Platforms is divided into two distinct parts. The first (Telematics for Mobile Platforms) focuses on telematics, emphasizing the development of network applications, particularly programming Android applications in Android Studio. The second part (Multimedia), which is the subject of focus in this article and taught by the article authors, delves into Unreal Engine, a powerful and advanced tool for creating 3D games and various other types of applications. Unreal Engine provides students with the skills to design complex, interactive 3D environments and applications, demonstrating its versatility beyond game development.

The Telematics for Mobile Platforms part of the course presents a unique challenge. Due to the rapid evolution of the Android ecosystem, maintaining up-to-date multimedia e-learning materials would require yearly re-recording of video tutorials, leading to an unsustainable workload. For this reason, this part of the course primarily relies on traditional in-person teaching or synchronous online sessions via video meetings, rather than the asynchronous hybrid model. This highlights a key limitation of hybrid learning: when a subject undergoes significant changes every year, maintaining pre-recorded materials becomes impractical. In such cases, direct interaction—whether in-person or live online—is the more viable teaching approach.

The Multimedia part of the course is also challenging to prepare for hybrid learning and deliver due to its complexity and the need to accommodate diverse student hardware capabilities. It requires up to four distinct variants of exercises, making it practically impossible to conduct entirely in an in-person format without significant financial investment. For example, the faculty would need to purchase approximately 20 high-performance computers every 3–4 years at an estimated cost of 40,000 EUR (20 computers at 2,000 EUR each) to support the hardware demands.

Why such complexity? The primary tool used in this course is Unreal Engine 4, a highly hardware-intensive platform that constitutes the *first variant of exercises*. Recently, the release of Unreal Engine 5 introduced substantial innovations but with even greater hardware demands. For students with suitable high-performance hardware, a *second variant of exercises* using this updated engine is provided.

However, not all students have access to the required hardware. Those with weaker setups engage in *a third variant of exercises* using the 3D engine Unity, leveraging materials developed for the course Virtual and Mixed Reality. Students who have already completed Virtual and Mixed Reality and are familiar with Unity 3D instead work on *a fourth variant*, which focuses on Unity in 2D.

Despite the varying tools and platforms, *the graded assignments remain identical across all exercise variants*, ensuring fairness and consistent learning outcomes. Students may choose between Unity and Unreal Engine based on their available hardware and experience level.

To further support students with inadequate hardware, the faculty offers the option to borrow university-provided laptops equipped with sufficient specifications. This ensures equitable access to the course, allowing all students to engage with the material and complete the assignments effectively, regardless of their personal resources.

This adaptive approach highlights the flexibility and resourcefulness of the competency-based hybrid model, ensuring inclusivity and maintaining the high standards required for such a demanding and innovative course.

The assessment in this course is designed to evaluate both theoretical knowledge and practical skills, with a total score of 100 points, divided between semester work and the final exam:

- Semester assessment (40 points):
  - Assignment 1 (15 points): Telematics application for Android
  - Assignment 2 (8 points): Game with a ball in Unreal Engine

TABLE 10. Student satisfaction with the course *Multimedia and Telematics for Mobile Platforms* based on the question: "Are you satisfied with your decision to choose this particular subject?"

Year	Yes (#)	Yes (%)	No (#)	No (%)	I do not know (#)	I do not know (%)
2017	49	81.7%	2	3.3%	9	15.0%
2018	38	82.6%	6	13.0%	2	4.3%
2019	29	76.3%	5	13.2%	4	10.5%
2020	38	86.4%	2	4.5%	4	9.1%
2021	20	74.1%	2	7.4%	5	18.5%
2022	40	77.0%	8	15.2%	4	7.7%
2023	31	77.8%	3	11.1%	3	11.1%
2024	38	95.0%	2	5.0%	0	0.0%

TABLE 11. Student recommendations for the course *Multimedia and Telematics for Mobile Platforms* based on the question: "Would you recommend this subject to younger classmates?"

Year	Yes (#)	Yes (%)	No (#)	No (%)	I do not know (#)	I do not know (%)
2017	56	93.3%	0	0.0%	4	6.7%
2018	41	89.1%	1	2.2%	4	8.7%
2019	31	81.6%	4	10.5%	3	7.9%
2020	40	90.9%	1	2.3%	3	6.8%
2021	23	85.2%	0	0.0%	4	14.8%
2022	43	82.7%	3	5.8%	6	11.5%
2023	22	81.5%	1	3.7%	4	14.8%
2024	39	97.5%	1	2.5%	0	0.0%

  - Assignment 3 (7 points): Showroom or knowledge-based game (interactive quiz)
  - Activity in practical sessions (10 points) – assessed through small assignments, which serve both as progress checkpoints and attendance tracking.
- Final Examination (60 points):
  - Test (30 points) – covers theoretical concepts in telematics and Android development
  - Major Project in Unreal Engine (or another suitable 3D engine) (30 points) – A large-scale project incorporating:
    - ∗ A functional application with interactive elements.
    - ∗ A presentation video or 3D model utilized within the project.

All projects are presented in person, allowing students to showcase their work, receive direct feedback, and enhance their soft skills through public presentation.

The results of the *end-of-course survey* conducted by the instructors after the exam can be seen in Table 7-9 and Fig. 17-19.

From the results of the evaluation in the Academic Information System (students evaluate courses at the end of the semester), the average grade and median grade were also calculated separately for lectures and exercises. Students grade courses the same way they are graded in school. The mean and median scores for the course lectures were 1.17 and 1, respectively (i.e., a grade of A). The mean and median course exercise scores were the same, 1.17 and 1, respectively (i.e., a grade of A).

The data on student satisfaction (Tab. 10) and course recommendations (Tab. 11) provide insights into the evolution

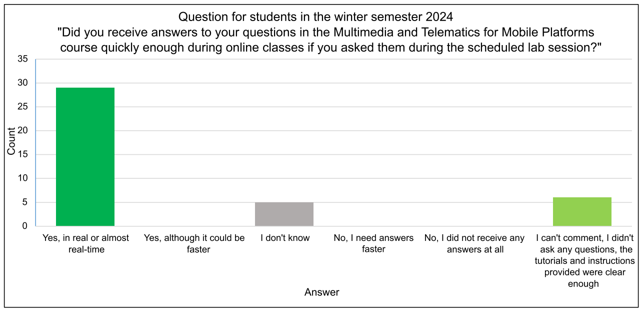


FIGURE 19. Visualization of Table 9 data.

of Multimedia and Telematics for Mobile Platforms and the impact of different teaching approaches over time.

A notable peak in satisfaction and recommendations is observed in 2020, coinciding with the first major shift toward fully online learning due to the COVID-19 pandemic. This transition was driven by necessity, but students responded positively to the flexibility and accessibility of online instruction, as reflected in the increased satisfaction rates.

In subsequent years, as pandemic restrictions eased, various teaching formats were experimented with to determine the best balance between online and in-person instruction. During this transitional period, satisfaction rates fluctuated as efforts were made to reintegrate more in-person teaching while still leveraging digital tools.

By 2024, another significant peak in satisfaction is evident, corresponding to the full implementation of the competency-based hybrid learning approach described in this study. This year marked the introduction of new high-quality multimedia materials, particularly those focused on Unreal Engine 5, further enhancing the course content.

The data strongly suggest that innovation in teaching methods (whether through the initial shift to online learning in 2020 or the structured hybrid model in 2024) leads to increased student satisfaction and engagement.

These findings reinforce the value of continuous pedagogical adaptation and the integration of modern educational technologies, showing that well-designed hybrid learning models can enhance student experience.

VI. CONCLUSION

As educators around the world adjusted to new realities, the COVID-19 pandemic sparked a period of intense experimentation with different teaching approaches. The authors accepted this challenge by introducing a competency-based hybrid learning strategy at their institute at the Slovak University of Technology in Bratislava. This model, thoroughly described and compared with traditional methods in this article, has proven to be a highly effective strategy for fostering practical skills and meaningful learning outcomes. By combining synchronous and asynchronous components, the method takes advantage of both formats' benefits to provide students more flexibility and improve their engagement. This paradigm is especially well-suited for upper-year university students and subjects in digital technologies and programming, where independent learning and project-based outputs are crucial.

The application benefits of the methodology and this article can be summarized in the following points:

- **Enhancing educational engagement through hybrid learning models**
  The integration of competency-based hybrid learning blends asynchronous flexibility with synchronous support, providing an adaptable framework for diverse learner needs. By leveraging both pre-recorded high-quality lectures and interactive real-time sessions, this model facilitates deeper student engagement and cultivates self-reliance in learning.
- **Strengthened practical skill development**
  The focus on project-based and tangible outputs ensures that students acquire competencies directly applicable to professional environments. This hands-on approach bridges theoretical knowledge with real-world application, equipping students with market-relevant skills.
- **Optimized teacher-student interactions**
  The hybrid format reduces repetitive tasks for educators, allowing more time for meaningful student interactions. Individualized feedback and tailored guidance during scheduled online sessions enhance the learning experience, particularly for complex problem-solving tasks. Additionally, the model includes sufficient in-person teaching when it is most impactful, such as for activities requiring hands-on collaboration or immediate feedback.
- **Authentic and student-centered interaction**
  In the hybrid model, interaction happens when students genuinely need it, rather than being forced. Unlike traditional in-person sessions, where students often feel uncomfortable or unprepared to engage, this approach allows them to choose the time and medium for participation. This flexibility stimulates more meaningful exchanges, which students frequently highlight as a major benefit in evaluations and surveys, as it aligns better with their needs and learning preferences.
- **Balanced workload throughout the year for teachers**
  In the academic environment of the authors' workplace and across many Slovak universities, financial compensation for university instructors is often modest. This, combined with institutional and peer expectations, places instructors under significant pressure to adhere to the "Publish or Perish" paradigm, necessitating not only teaching but also active involvement in research projects and publishing to ensure a more sustainable income and professional standing. The hybrid approach alleviates some of the pressure during the semester by reducing repetitive tasks and allowing many teaching materials to be prepared in advance, outside of the semester. This redistribution of workload enables instructors to focus more effectively on their dual responsibilities of teaching and research throughout the year.
- **Streamlining teaching and addressing staffing challenges in IT courses**
  The hybrid model effectively mitigates the issue of limited teaching staff in IT-related subjects, a significant challenge in Slovakia where both the quantity and quality of IT instructors are sometimes problematic. By relying on high-quality pre-recorded materials created by the course leader, this approach provides a consistent foundation for both students and teaching assistants while simplifying the onboarding process for new instructors. Teaching assistants can focus on providing individualized support to students instead of repeatedly explaining the same content, allowing them to manage more students effectively while maintaining consistent teaching quality across the course.
- **Future-proofing education through feedback integration**
  Continuous refinement of teaching materials, driven by student feedback and evolving subject demands, positions the hybrid model as a sustainable solution in modern education. Its ability to adapt to rapid advancements ensures ongoing relevance and alignment with industry standards.

Looking ahead, it is clear that openness to change and a willingness to innovate are crucial for the future of education. Feedback from both students and educators must play a central role in shaping teaching practices, as this dialogue cultivates mutual understanding and continuous improvement. However, it is also vital to address systemic challenges. The growing trend of talent migration from Slovakia to neighboring countries, particularly the Czech Republic, highlights an urgent need for modernization in

Slovak education. Without meaningful change, reversing this outflow of talent will be nearly impossible. Despite the traditionally conservative nature of Slovak academia, embracing innovation and evolving teaching methods are no longer optional but necessary steps to remain competitive and relevant in a rapidly changing global educational landscape.

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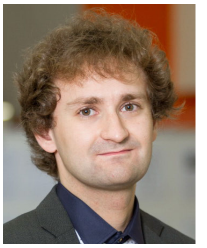

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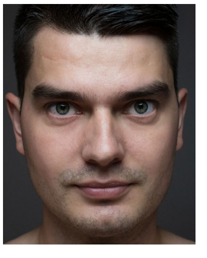

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