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Personalisation of learning through artificial intelligence in higher education in the United Kingdom

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Abstract. Artificial intelligence in higher education allows adapting the content to the individual needs of students, but it is necessary to evaluate the effectiveness, consider the issue of algorithmic bias and provide the appropriate development of staff. The purpose of the study was to investigate the influence of artificial intelligence integration on the personalisation of learning in higher education in terms of academic achievement, motivation and engagement. By comparing the functional possibilities of adaptive platforms, it was found that personalisation through intelligent algorithms allows for an individual approach to learning, dynamic adjustment of tasks and timely feedback, while the traditional model is limited in flexibility and is aimed at a nominal average student with a typical level of prior knowledge, a standard rate of content assimilation and conventional educational needs without regard for individual peculiarities. An analysis of educational platforms showed that learning management systems with integrated artificial intelligence tools (Moodle, Blackboard, Canvas, Brightspace, FutureLearn) make it possible to construct individual learning pathways, predict the risk of academic underperformance, and adapt materials in line with student progress, thereby reducing dropout rates and increasing module completion and system activity. The case study method indicated that the use of generative artificial intelligence at the University of Glasgow, the Open University, and the University of Manchester is regarded as a promising tool for supporting the learning process, developing digital competences, and enhancing the flexibility of interaction between students and academic staff, without detailed specification of particular pedagogical interventions, quantitative effectiveness indicators, or structural changes to curricula. An analysis of the role of the lecturer demonstrated that the integration of artificial intelligence transforms professional functions from those of a traditional lecturer to those of a coordinator and mentor who employs analytics to adapt content, adjust learning pathways, and provide personalised support, thereby creating a hybrid model of pedagogical guidance and enhancing the effectiveness of the educational process. The results show that personalisation of learning through artificial intelligence has a holistic positive impact: academic resilience, student engagement and the general effectiveness of the educational process in higher education in the United Kingdom are enhanced. The results of the study can be of use for lecturers, university managers and developers of educational platforms in the implementation of effective artificial intelligence solutions within the teaching and learning process

Keywords: adaptive learning; motivation; digital literacy; distance learning; information technologies

INTRODUCTION

The rapid growth of digital technologies and the increasing role of artificial intelligence (AI) in higher education open up new opportunities for the individualisation of the educational process. AIpersonalisation of learning allows adapting educational trajectories to the individual needs of students, enhancing motivation, increasing the effectiveness of knowledge assimilation and retaining students in the context of distance and blended learning. However, the introduction of innovative technologies is accompanied by a number of challenges, including ethical issues, the digital literacy of academic staff and students and the risk of algorithmic bias. Therefore, the research into AI-based practices for the personalisation of learning in British universities is of particular relevance

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as it enables evaluating the potential benefits and limitations of these technologies, developing recommendations for their effective implementation and contributing to enhancing the quality of the educational process in modern conditions.

In contemporary British academic discourse, studies devoted to the implementation of artificial intelligence in higher education increasingly focus on issues of learning personalisation and the enhancement of students' academic achievement. Thus, K. Sunmboye *et al.* (2025) carried out a large-scale cross-sectional survey of students of medical faculties in the United Kingdom, which assessed the effect of integrating intelligent systems into the process of personalisation of learning. The authors showed that adaptive learning systems allow constructing individual educational trajectories, taking into account the pace of content assimilation of each student and automatically selecting additional resources to eliminate knowledge gaps. The study notes that this approach enhances student engagement, reduces cognitive load and improves academic performance compared to traditional teaching methods. In response, H. Rahiman & R. Kodikal (2024) further developed the discussion of the practical utility of AI in higher education, this time focusing on the impact of incorporating adaptive systems and generative tools in distance and face-to-face classes. The authors report that the use of machine intelligence not only supports automated individual student care but also opens new avenues for the work of academic staff, namely in the realm of progress tracking and real-time curriculum revision. According to F. Dervishi & A. Vrapi (2022), computer technology for educational use has seen extraordinary growth. The authors stress the significance of the digital competences of lecturers, since the performance of AI-enhanced support systems relies on the degree to which educators appropriately use advice and data for the tasks of teaching and learning.

AI in the studies A. Vrapi *et al*. (2023) focus on the assessment and reassessment of personal skills and achievements, as well as on the conscious monitoring of the results of professional activities and the analysis of real-life situations. Another approach to evaluating the influence of AI on the personalisation of learning is presented in the study by C. Merino-Campos (2025), who carried out a systematic literature review on the use of intelligent systems in higher education. The author demonstrated that adaptive platforms and Learning Analytics tools allow optimising educational trajectories of students, enhancing their cognitive effectiveness and reducing the number of dropouts. The study by R. Sajja *et al.* (2024) describes the application of AI-based intelligent assistants for the personalisation and adaptation of learning in various disciplines. The authors prove that the systems that include modules for prediction, recommendation and adaptation allow monitoring of the students' learning process, provide an individual educational trajectory, and optimise the involvement of students in the educational process. Particular attention is paid to the potential of these platforms to diagnose knowledge gaps of the students and automatically offer the resources to overcome them, thus contributing to the acquisition of knowledge and the development of competence.

Simultaneously, K. Kaswan *et al.* (2024) note in their research that AI in personalised learning is capable of dynamically adjusting the educational trajectory of students by algorithmic prediction of knowledge gaps and recommendation of resources, which, in turn, increases the cognitive efficiency and reduces the lag in learning. The authors highlight that the efficiency of machine learning systems directly depends on their embedding in the overall didactic and methodological design and pedagogical practice, which testifies to the need for a systematic approach to their implementation. In the study of L. Mulaudzi & J. Hamilton (2025), the emphasis is put on the role of the lecturer in the process of AI-supported personalised learning. The researchers prove that the success of AI integration largely depends on the lecturer's active participation in the analytics, interpretation of the system recommendations, and adjustment of the educational process. Alongside this, ethical issues are raised, primarily related to the transparency of algorithms and the security of students' personal data. The authors argue that the lecturer's methodological competence in the field of AI is a key factor in increasing the efficiency of personalised education.

S. Hashim *et al.* (2022) conducted a systematic review of the trends in the application of machine learning technologies in the context of personalised education. The researchers identify the following areas of use of machine learning technologies: adaptive diagnostics, recommendation algorithms, learning behaviour analytics, and intelligent assistants. The integration of these systems is observed in different disciplines and levels of education, from distance courses to face-to-face education, which provides flexibility of educational trajectories and increases students' motivation. In turn, N. Alifah & A. Hidayat (2025) investigate the effectiveness of AI-based Learning Analytics tools in supporting personalised learning. The results of the study show that the use of analytics dashboards and adaptive recommendations makes it possible to effectively predict knowledge gaps in students and offer appropriate educational resources, which contributes to knowledge acquisition and student retention. Referring to the processes and results of the previously discussed studies, S. Pahmi *et al.* (2024) the implementation of virtual reality technology has become an increasingly intriguing topic. However, as noted by the authors, the most efficient way to use these tools would be to combine them with methodological techniques.

Previous studies have primarily focused on assessing the influence of adaptive systems, Learning Analytics, and generative AI assistants on students' academic performance, motivation, and engagement have been mainly investigated. However, the majority of the existing studies have been conducted within the scope of a single subject and distance learning courses, whereas the integral influence of machine learning systems, lecturers, and Learning Management System (LMS) on traditional and blended learning has not been investigated yet. Another research gap is identified in exploring the effect of personalisation on the lecturers' methodological activity, the inclusion of analytics into educational trajectory planning, and methods to minimise algorithmic bias. This study aimed to identify how adaptive systems and learning behaviour analytics influence academic achievement, student motivation, and engagement, as well as to reveal the role of the lecturer in the process of personalisation. The objectives of the study were to analyse research articles and case studies on the use of smart systems in the educational process, in particular to consider the pros and cons of adaptive systems and generative AI assistants, and the interconnection between students, lecturers, and the learning management system to identify best practices and the risks of algorithmic bias.

MATERIALS AND METHODS

The methodological framework of the study involved structural-functional analysis, content analysis, a comparative approach, the case study method, and institutional-comparative analysis. The application of these methods provided a multidimensional insight into the processes of implementing intelligent systems in higher education and enabled consideration of learning personalisation from technological, organisational, and methodological perspectives. The content analysis embraced adaptive LMS, AI-based tutoring tools, algorithms for predicting students' learning behaviour, and feedback mechanisms. Within the framework of the analysis, the key functional characteristics of these tools, principles of adaptivity, and approaches to personalising educational trajectories applied in modern educational platforms were synthesised.

The case study method in this research was applied as an approach to the in-depth analysis of individual educational institutions and practices, with the aim of examining in detail the mechanisms for integrating machine intelligence solutions into the teaching and learning process. Its selection was justified by the need to examine real-world examples of the implementation of intelligent technologies in higher education in the United Kingdom and to trace the interrelationships between technological solutions, organisational strategies, and pedagogical practices. In the framework of the case study, official documents, the digitalisation of the universities, and educational policies at the University of Glasgow (n.d.), the Open University (n.d.), and the University of Manchester (n.d.), as examples of British universities with a systematic policy in the implementation of digital and AIbased educational strategies, were analysed. Particular attention was paid to new solutions such as the Early Alert Indicators (EAI) system, which was implemented at the Open University, and the TeachMateAI (TMAI) (n.d.) used in the practice of the Manchester Institute of Education.

The analysis of the integration of adaptive platforms and AI-based tutoring systems was conducted in order to assess their use in programmes aimed at enhancing learning effectiveness at the University of Glasgow, particularly in the context of applying Learning Analytics and Learning Design tools (n.d.) to personalise educational pathways. At the same time, a limitation of the study was the lack of detailed information on the platforms, analytical systems, and tools actually used in the university. A comparative analysis of the functionality, opportunities, and subject orientation of adaptive platforms, including Knewton Alta (n.d.), Synap (n.d.), Edumentors (n.d.), and the main LMS with embedded AI modules – Moodle (n.d.), Blackboard (n.d.), Canvas (n.d.), Brightspace (n.d.), and FutureLearn (n.d.) was carried out. The comparative method was used to systematise the differences between the identified platforms in terms of the degree of integration of machine intelligence solutions, types of predictive models, depth of content personalisation, forms of feedback, and tools for real-time student support. In addition, a structural and functional analysis was used to assess the role of these tools in the construction of an individual educational trajectory and the prevention of academic risks. The final stage of the study consisted of an institutional and comparative analysis aimed at comparing the approaches of British universities to integrate AI into the educational process and synthesising the strategy for the implementation of intelligent technologies in educational practice.

RESULTS

Theoretical foundations of learning personalisation through artificial intelligence. Learning personalisation in the higher education system is understood as an educational approach focused on the individual needs, learning style, and academic potential of university students. The main goal of this approach is to form a variable educational process that allows each student to learn at an individual pace and master the content as efficiently as possible. First and foremost, adaptive learning trajectories (Fig. 1) are used, which make it possible to adjust the trajectory in real time depending on the student's fulfilment of learning tasks and their initial preparation. The students who demonstrate high academic results are offered more complex tasks aimed at further academic development, while the students who face learning difficulties are provided with the possibility of repeated explanations or revision of the material. Such step-by-step adjustment of the learning trajectory increases students' motivation and academic effectiveness. Another component is the individual learning plan (ILP), which structures the adaptive educational trajectory and includes students' personalised learning goals, a list of mandatory and elective disciplines, recommendations for additional educational resources and methods of assessing academic achievements, as well as a distribution between independent and group work. Due to ILP, students can clearly articulate their educational goals and ways to achieve them, which increases their involvement in the educational process. For example, an ILP may include core disciplines and additional online educational resources such as the Knewton Alta (n.d.) or Coursera (n.d.) platforms to support the mastery of a discipline. Differentiated learning tasks also play an important role as they allow changing the complexity, form, and type of learning activity in accordance with the individual educational needs of the students. Learning tasks may be extensive for students with a high initial level of preparation, basic for students who need academic support, and repetitive for mastering and revising educational material. Using differentiated tasks, it is possible to find a balance between the need to provide high-achieving students with more complex tasks and the need to provide lowachieving students with academic support, which ultimately increases the effectiveness of the learning process.

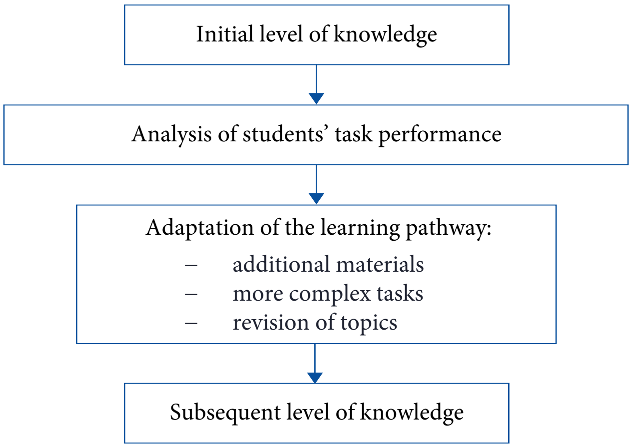

Figure 1. Principle of the adaptive learning pathway
Source: developed by the authors based on the study by S. Zhao *et al.* (2024)

The effectiveness of personalised learning at the university is determined by the ability of AI systems to analyse and adjust the educational process based on the analysis of students' behavioural data. The main tools for conducting such an evaluation are Learning Analytics and Learning Design (n.d.), which provide possibilities for the collection and analysis of digital footprints of students' activity on educational platforms. On the basis of these data, it is not only possible to estimate the actual knowledge level, but also to forecast the risk of academic failure, detect weaknesses and create adaptive advice. It is even possible to identify the course modules that are the most challenging for the student, as well as to estimate the success of AI personalisation algorithms that are built in the system.

Another tool for assessing the effectiveness of individualised learning is adaptive educational platforms. These platforms combine testing, recommendation, and learning analytics modules that allow obtaining an objective view of students' achievements in real-time. They allow both individual and generalised analyses to identify general trends and evaluate the effectiveness of the personalised approach at the group level. Moreover, they provide an opportunity to compare traditional teaching methods with AI-personalised approaches, which allows for identifying the advantages and disadvantages of new technologies based on evidence. Different approaches, indicators, and their impact on learning outcomes are presented in Table 1.

Table 1. Comparative analysis of approaches to evaluating the effectiveness of AI-personalised learning

Evaluation model	Core functions	Performance indicators	Potential impact on learning
Learning Analytics	Collection and analysis of data on student behaviour	Number of completed tasks, time spent on modules, assessment performance	Prediction of learning gaps, support for individual learning
Adaptive platforms	Integration of testing, recommendation, and analytics	Course progress, level of content mastery, student engagement	Adjustment of learning pathways, increased effectiveness of knowledge acquisition

Source: developed by the authors based on the study by D. Iqbal *et al.* (2025)

Table 1 summarises the two main approaches to evaluating the effectiveness of personalised learning that differ functionally and methodologically. Learning Analytics is aimed at collecting and analysing big data about students' learning behaviour that allows identifying hidden gaps in knowledge, predicting the risk of underperformance, and providing support. Adaptive platforms play a more applied role: they use the results of analytics to directly influence the learning trajectory by adjusting the level of difficulty, depth, and speed of the delivery of learning content. Thus, the first model has a diagnostic function, while the second model is a means of applying a personalised intervention. They form an integrated system that contributes to improving learning effectiveness.

It is necessary to note that the effectiveness of these models is not evaluated by academic achievement but also by the level of motivation, engagement, and satisfaction of students with the learning process. Therefore, the combination of Learning Analytics with adaptive platforms forms a complex framework for evaluating personalised learning, which allows evaluating both an individual student and the whole system on the level of outcomes. A comparative analysis of traditional learning models with models that involve AI-personalisation allows identifying both benefits and drawbacks of the application of contemporary technologies in higher education. Traditional learning is usually based on a standardised curriculum and assessment that are targeted at the average student and imply the same amount of learning materials, tasks, and speed of studying for all students. Within this system, a lecturer is not always able to respond to the needs of each student in a timely manner, which can lead to a gap in the acquisition of knowledge and, as a result, lower motivation and engagement of students. In contrast to traditional models, AI-personalised learning involves adaptive technologies and algorithms that allow creating an individual learning trajectory optimised for each student. Moreover, not only enhances motivation and engagement but also provides flexibility in the learning process that is targeted at the needs of each student. Personalisation based on intelligent systems allows students to study at an individual speed, receive tasks that correspond to their level of readiness, and provide feedback in a timely manner that contributes to a better understanding and mastery of subject material (Maphosa & Maphosa, 2023).

At the same time, the application of machine learning-based personalisation is not devoid of disadvantages. The technical difficulties related to the embedding of adaptive systems into existing digital learning platforms, as well as the low level of digital literacy of lecturers and students, can dramatically decrease the effectiveness of technologies. Moreover, the application of personalisation algorithms can lead to bias when systems incorrectly interpret data or provide recommendations that enhance existing inequality in education. To systematise the comparison, the main differences between traditional and AI-personalised learning are presented in Table 2.

Table 2. Comparative analysis of traditional and AI-personalised learning

Analysis parameter	Traditional learning	AI-personalised learning
Approach to students	Standardised, oriented towards the average level of preparation and learning pace, without accounting for individual differences	Individualised, adapted to each student
Motivation and engagement	Dependent on personal student factors	Enhanced through personalised tasks and timely feedback
Flexibility of the educational process	Limited, standard pace	High, with the ability to adapt pace and task complexity
Technical requirements	Minimal; the lecturer does not require specialised tools	High: requires AI integration and platform configuration
Risks	Limited, mainly human factor	Present: algorithmic bias, errors in personalisation

Source: developed by the authors based on the study by K. Amoako *et al.* (2024)

The comparative data presented in Table 2 illustrate the fundamental differences between the traditional pedagogical model and an approach based on artificial intelligence and personalisation. Traditional learning is built on a standardised logic of organising the educational process, in which educational interventions are largely uniform and oriented towards the "average" student, inevitably limiting pedagogical flexibility and the variation of learning pace. By contrast, AI-personalisation creates a highly dynamic learning environment in which adaptive and predictive algorithms enable individual adjustment of tasks, complexity, and pace. This stimulates motivation, increases cognitive engagement, and enhances progress in knowledge acquisition. Simultaneously, the technological complexity of the educational environment dramatically increases: in contrast to the traditional approach, personalised systems require more advanced technical opportunities, effective embedding into LMS, and lecturers' readiness to work with analytical tools. Another aspect here is the appearance of new challenges, first of all, algorithmic bias and recommendation errors, which necessitate the controlled and methodologically competent introduction of machine learning technologies in the educational process. In this sense, AI-personalisation creates a synergetic effect, which consists of the sum of the advantages of individualised and learning-behavioural approaches to knowledge acquisition. Simultaneously, the effective introduction of these technologies requires consideration of technological, organisational and ethical factors, which can affect the results of the educational process.

Review of AI application practices in British universities. The application practice of AI technologies in the United Kingdom's higher education institutions involves a variety of platforms for the creation of individualised educational trajectories and the increase of learning efficiency. For example, the Knewton Alta system (n.d.) specialises in adaptive learning of students in Mathematics and Science, Technology, Engineering, and Mathematics (STEM) fields. Alta uses algorithms to diagnose the current level of knowledge of the students, and, accordingly, changes the complexity of tasks and offers an individual educational trajectory. A peculiar feature of this system is the inclusion of assessment tools in educational content, which enables the assessment of the current level of knowledge of the students and learning activities, and, thus, more accurately identifies gaps in their academic and professional training. Another example is the Synap platform (n.d.), which specialises in adaptive assessment and revision of educational content. The system analyses the responses of the students and identifies knowledge gaps, and generates individual blocks of practice tasks to address these gaps. The system also uses spaced repetition algorithms and reduces the time of mastering key concepts, which enables students to achieve better retention of the material. In other words, Synap not only assesses the students' knowledge but also supports individualised construction of the learning process by automating educational content. The Edumentors platform (n.d.) realises the AItutor model and offers students individual educational trajectories and recommendations. The system combines adaptive assessment tools, learning-behavioural analytics and individualised support to learning activities, which enable students to receive educational content in accordance with their academic strengths and weaknesses, pace and goals of learning. One of the key functionalities of the tool is its interactivity, which allows immediate feedback and further understanding of the material. To further organise the functionalities and characteristics of these tools, Table 3 is presented.

Table 3. Functional and personalisation characteristics of leading AI tools used in British universities

Platform	Core functions	Target disciplines	Personalisation capabilities
Knewton Alta (n.d.)	Adaptive learning, integration of testing and content	Mathematics, STEM	Dynamic task adaptation, individual learning pathways
Synap (n.d.)	Adaptive tests, spaced repetition	General courses, STEM	Personalised revision blocks, identification of weak areas
Edumentors (n.d.)	AI tutoring, individual learning plans	Various disciplines	Personalised plans and recommendations, interactive feedback

Source: developed by the authors based on analysis

As can be inferred from the comparison of tool functionalities, each tool serves different learning purposes and personalisation strategies. Knewton Alta is most effective in Mathematics and STEM disciplines due to structured adaptive educational trajectories, which enable more precise identification of knowledge gaps and quick adjustment of the complexity of tasks. As a result, the accuracy of learning grows, and the risks of underperformance of students are minimised. The system Synap focuses on spaced repetition and adaptive assessment, which ensures the durability of knowledge acquisition and development of cognitive skills, due to which students demonstrating better retention and stability of academic achievements. The Edumentors system is characterised by interdisciplinarity and interactivity of AI-tutoring, which stimulates the development of metacognitive competencies and supports self-regulated learning, which, in turn, contributes to the academic engagement of students and their autonomy. In general, the differences in the functional orientations of the systems cause differences in their application focus and models of learning interaction, which resulted in three models of individualisation: structured adaptivity, cognitive consolidation and interactive support of learning activities. Overall, the table suggests that these platforms are not only an opportunity to extend the potential of personalisation but to make it multidimensional, i.e. to include content, pace, feedback, and cognitive support all at once.

LMS is essential in the provision of personalised learning to higher education students, especially if linked with AI tools. LMS tools used by British universities are mostly Moodle (n.d.) and Blackboard (n.d.). Both tools can be linked with AI tools to support adaptive learning in the provision of individual learning pathways and creation of an individual learning plan (Badaru & Adu, 2022). Recommendation algorithms, adaptive testing modules, and learning analytics are embedded in the platforms, which provide the ground for real-time support of students. For instance, adaptive quizzes and completion tracking modules are employed in Moodle. They not only control the knowledge of the students but can also adapt the complexity of the tasks according to the students' progress. In addition, the system can be linked with machine intelligence tools such as the Learning Analytics Toolkit, which helps lecturers to predict at-risk students, trace the progress and make individualised recommendations. The system allows for the construction of personalised learning trajectories that are tailored to the student's current level of knowledge and the rate at which they learn in order to maximise both challenge and motivation. Blackboard offers the possibility to use more sophisticated analytical tools, such as Blackboard Predict, that traces the student activity, estimates the chance of success and allows automated tuning of the individual learning pathway. The tool allows the insertion of additional learning materials, individualised assignments, and interactive tools for students who need additional support, which reduces the rate of drop-outs and increases academic achievement.

Along with Moodle and Blackboard, British universities mostly use Canvas (n.d.), Brightspace (D2L) (n.d.) and FutureLearn (n.d.). All of them demonstrate a wide range of personalisation potential. Canvas can be linked with Canvas Analytics and third-party AI plugins to trace the engagement of the students and provide individualised recommendations. Brightspace employs Predictive Learning Analytics, which predicts the risks and triggers the automated intervention with some corrective tasks. FutureLearn can also be linked with a machine intelligence tool to provide adaptive learning opportunities through Massive Open Online Courses (MOOCs). The content can be adapted to the individual students according to the students' interaction with the content and assessment results. The integration of intelligent tools into LMS tools allows for the creation of an individual learning pathway for each student who receives individualised tasks, materials and traceability. This approach promotes greater student engagement, reduces the risk of falling behind, and fosters deeper learning. In addition, the role of a lecturer changes from the lecturer to the facilitator who monitors the process and traceability and provides additional support if needed. Table 4 presents a systematic overview of functions and contributions of LMS tools linked with AI tools.

Table 4. Comparative analysis of LMS tools with integrated AI tools used in British universities

LMS platform	Integrated AI tools	Core functions	Impact on personalisation of learning
Moodle (n.d.)	Adaptive Quiz, Learning Analytics Toolkit	Adaptive testing, progress monitoring	Individual learning pathways, risk prediction
Blackboard (n.d.)	Blackboard Predict, IIII Recommendation Engine	Success forecasting, personalised resources	Creation of individual pathways, increased engagement
Canvas (n.d.)	Canvas Analytics, third-party AI plugins	Activity monitoring, adaptive learning	Personalised resources, recommendations, integration of external AI
Brightspace (D2L) (n.d.)	Predictive Learning Analytics	Corrective assignments, adaptive planning	Support for mixed-ability groups, forecasting and personalisation
FutureLearn (n.d.)	AI content recommendations	Personalisation of MOOC pathways	Adaptive learning, increased motivation and student retention

Source: developed by the authors based on research

Comparative analysis of the LMS tools with integrated AI tools demonstrated the different models of support for personalised learning in British universities. Firstly, the Moodle tool, through the adaptive testing and Learning Analytics Toolkit, demonstrates the rapid monitoring of student learning and risk prediction, which allows for the creation of individual learning pathways. Blackboard and Canvas provide the possibility to personalise the resources and assignments, which allows for increasing the engagement of the students and the opportunity to dynamically adjust the learning process to the needs of the learner. Brightspace stands out with support for mixed-ability groups and corrective assignments, which enables planning adapted to the needs of heterogeneous classes. FutureLearn specialises in MOOCs and provides AI-driven content recommendations aimed at enhancing student motivation and retention in online courses. In general, the differences in functional approaches of the above-mentioned platforms can be explained by the specificity of educational settings and target audience, from individual learning pathways and adaptive testing to support of massive online courses and behaviour analytics. The incorporation of machine learning solutions leads to the creation of a holistic ecosystem for individualised learning consisting of analytics, adaptive tasks and recommendations to improve the acquisition of learning material and the overall academic achievement of students.

Critical discussion of AI adoption in British universities and its influence on student academic achievement. The adoption of artificial intelligence in higher education in the United Kingdom is a complex and multi-faceted process, including technological, pedagogical and organisational dimensions. AI tools capable of modelling individual learning trajectories and adjusting learning materials to meet individual students' needs are gradually changing the classical educational paradigm, increasing engagement and motivation, but also raising new challenges in terms of ethical use, data management and academic staff professional development. University practices demonstrate the potential of artificial intelligence not only as a technological tool, but also as a driver of strategic innovation in the educational process and in the development of competences of future professionals in the conditions of rapid digitalisation.

The University of Glasgow (n.d.) demonstrates a pro-active and well-balanced approach to the incorporation of GenAI into the learning process. In particular, the official university policy highlights the importance of ethical, critical and transparent use of GenAI: instead of a ban, the University is willing to teach students to work with these tools in an effective and responsible manner, acknowledging their potential role as an innovation driver in future professional activity. In the area of learning support, the Student Learning Development service offers students resources, workshops and one-to-one tutorials to develop digital literacy in the sphere of AI, acquire skills of critical thinking in the analysis of AI-generated content and proper integration of the tools into the learning process. In terms of assessment policy, the University works on the redesign of assessments: academic staff is encouraged to rethink the assessment structure to ensure that the GenAI use is not punished, but understood as a learning tool, for instance, through reflection, analysis or explanation of AI-generated results. Another valuable practice is the creation of spaces for student participation and discussion. The University organises AI student panels, surveys (in which the majority of students admit that they regularly use ChatGPT (n.d.) or other similar tools), and a series of educational activities aimed at raising a collective understanding of the opportunities and challenges provided by the machine-intelligent solutions. It is also worth mentioning that the University of Glasgow provides students with explicit guidelines on the responsible use of GenAI, particularly in Life Sciences, where relevant documents clarify that AI can and should be used as a facilitating tool and not as a replacement for the independent academic work (Hough *et al*., 2023). This example illustrates a systemic approach: the University not only elaborates a policy, but also develops practical programmes of digital skills acquisition, assessment support, as well as community involvement. This experience shows that AI-based personalisation in universities can grow not only as a technological prototype but also as a part of a long-term approach towards preparing students to live and work in a world in which GenAI will be widely used.

Similarly, the Open University (OU) (n.d.) is one of the most forward-looking British universities in terms of Learning Analytics and machine-based technologies. In the Institute of Educational Technology (IET) at OU, the research group on Learning Analytics and Learning Design (n.d.) collects the "digital traces" of student behaviour in the virtual learning environment and analyses them in order to boost engagement, satisfaction and success. OU also applies predictive analytics via the EAI, which sends a notification to associated lecturers (ALs) if the student is possibly experiencing problems. However, some research reveals that not all staff engage with this tool: in an EdD dissertation, A. Gillespie (2022) explored barriers to the use of predictive learning analytics (PLA) among ALs. They include, in particular, scepticism, lack of experience, and unwillingness to change the teaching practices. Another area of machine-intelligent technology is explored at OU: researchers examine the possibility of using generative AI for creating and adapting content. For example, an exploratory study was conducted on how ChatGPT and similar models could assist with the creation of distance learning materials for more efficient curriculum development. The OU developed a policy for responsible use of generative AI in teaching and assessment, which covers ethical issues, academic integrity, and inclusion. In general, the OU's journey proves that the adoption of AI tools in a large-scale distance teaching university has promising prospects, yet also encounters a range of organisational difficulties, such as staff uptake of analytics, professional development and development of responsible AI-use policies.

The University of Manchester (n.d.) offers several examples of good practice for incorporating AI into the teaching process. L. Birchinall *et al.* (2025) have recently found that the adoption of generative AI, in particular through the TeachMateAI tool (n.d.), in teacher education can assist in the development of future educators. The results of the first year of the study have revealed that trainee teachers engaged with AI in a critical, creative and contextual way: they did not simply follow AI recommendations but rather developed professional judgment, creativity, and situational sensitivity. The University of Manchester is also exploring how machine-intelligent solutions can contribute to the development of teaching competencies. This example shows that AI-driven personalisation in British universities can be extended from student learning to the development of teaching practices.

A critical overview of these three universities reveals a variety of practices in the integration of AI and analytics into the educational process (Table 5). The OU, with its background in distance education, is the most advanced in the application of Learning Analytics for risk prediction and generative AI for content generation. However, at the same time, lecturers face barriers related to the use of analytics dashboards and the development of a policy on responsible use of intelligent technologies. In Manchester, the TMAI case shows that AI can also be used as a tool for lecturer development, expanding the scope of personalisation: it is not only learning paths that can be personalised through AI but also pedagogical practices.

Table 5. Comparison of AI implementation practices in British universities

University	Main AI/analytics strategy	Tools and approaches	Key outcomes and challenges
University of Glasgow	Integration of generative AI in teaching and digital literacy development; emphasis on ethical and critical use	Generative AI (ChatGPT), student panels, learning workshops, policies on responsible AI use	Enhanced digital literacy and critical thinking regarding AI; challenges – need for development of teaching competencies and alignment of AI-use policies
Open University	Predictive analytics (Predictive Learning Analytics) and integration of generative AI for adaptive distance learning	Early-Alert Dashboard, ChatGPT for content creation, Learning Analytics Toolkit	Increased student engagement and retention, personalised learning pathways; challenges – low uptake of analytics tools among some lecturers, need for staff training
University of Manchester	Pedagogical integration of AI to develop teaching skills; support for critical and creative use of AI	TMAI (generative AI for Postgraduate Certificate in Education programmes), integrated workshops, modular cases for student-lecturers	Positive impact on professional judgment and creativity of future lecturers; challenges – limited scalability of tools and need for adaptation to different disciplines

Source: compiled by the authors based on studies University of Glasgow (n.d.), Open University (n.d.), University of Manchester (n.d.), ChatGPT (n.d.), TeachMateAI (n.d.), A. Atkinson-Toal & C. Guo (2024)

Table 5 provides an overview of the ways in which these three British universities are adopting machine-intelligent echnologies to support learning. University of Glasgow prioritises the critical and ethical use of generative intelligence and digital literacy development for all students, but acknowledges that staff competences need to be strengthened. The Open University uses predictive analytics and generative tools to support the personalisation of distance learning, but not all academic staff are using the analytic systems to their full potential. University of Manchester highlights the use of AI in pedagogical contexts to support the development of critical and creative thinking in student-lecturers, but points out that there are challenges for scaling and transferring the practice to other subjects.

Predicted impact on students' academic achievement. The introduction of individualised study trajectories with the help of AI in higher education modifies the traditional models of student motivation and engagement. In a traditional educational setting with the same academic content and tasks for all group members, individual motivation is quite low and negatively affects student activity and the efficiency of student engagement with the course. Personalisation of learning content and tasks using intelligent systems, responding to each student's current academic achievement and learning style, ensures more effective participation in the learning process.

Firstly, one of the key advantages of machine-intelligent systems is that they provide immediate differentiated feedback that allows students to rectify mistakes immediately and gain more profound knowledge of the subject. Such feedback mechanisms not only support the acquisition of cognitive knowledge but also cause a positive psychological effect: students feel more in control of their learning and immediately perceive evidence of their academic progress that significantly improves intrinsic motivation. From the perspective of self-determination theory (Vallerand, 2000), such a level of personalisation contributes to the development of autonomy, competence, and engagement, which are the basic determinants of learning motivation. Learning behaviour analytics supported by AI systems enables tracing students' interaction with learning content that helps assess the frequency and quality of activities, time spent on tasks, and the level of students' independent mastery. This lays the basis for constructing individualised trajectories responding to the academic needs of concrete students, primarily students with a low level of initial preparation or those prone to lagging behind. In its turn, this individualisation not only encourages motivation but also improves academic engagement and reduces passivity and the propensity to coast that is often observed in large group lectures.

Moreover, the empirical evidence from the experience of British universities proves the positive effect of these systems on students' motivation. Thus, in the Open University (n.d.), OU Analyse, a Learning Analytics system, is currently being used to identify students who are at risk of falling behind and intervene in a timely manner. In the study by B. Rienties (2021) as part of the OU Analyse initiative, it is proven that three module teams made changes to course design based on real-time analytics, with a positive effect on student retention. Besides, it was found that the frequency of lecturers' access to the OU Analyse dashboard was positively correlated with higher student completion rates, lecturers who made regular use of the analytics reported higher levels of module completion among their students. Additionally, Open University guidance mentions that data are used for monitoring, early identification of vulnerable students, and adjustments to course design. It proves that analytics is used not only as a technical tool but also as part of a proactive strategy for student support. Therefore, the introduction of machine-intelligent solutions in the process of individualised learning causes a synergy between the acquisition of cognitive knowledge and students' motivational involvement, leading to more effective and holistic engagement in the learning process.

It has already been proven in a number of studies that personalisation in terms of adapting the learning route depending on the learning analytics improves both the quality and speed of acquiring knowledge. For example, such tools as Knewton Alta (n.d.) and Synap (n.d.) use a combination of adaptive testing and spaced repetition algorithms that help to allocate additional exercises to students in their weak knowledge spots. Thus, there is a kind of closed cycle where students receive immediate feedback for the correct answers, or an indication that a student should repeat a piece of knowledge, which contributes to increasing the effectiveness of the time spent on learning and deepening the knowledge gained. Figure 2 presents a scheme that illustrates how an intelligent system processes learning analytics data and individual learning paths of students.

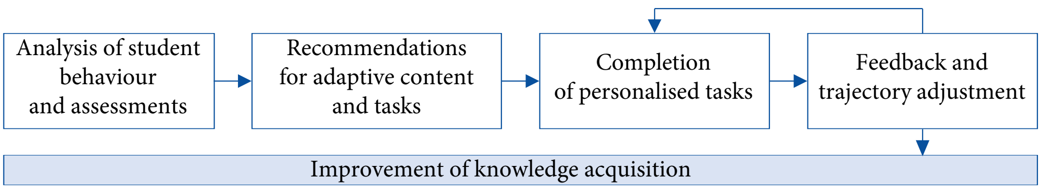

Figure 2. Learning-path adaptation through AI
Source: developed by the authors based on the study by M. Penmetsa (2025)

Besides, empirical evidence from the Open University (n.d.) suggests that applying an adaptive approach improves the quality of the learning process, especially in massive distance education courses where a conventional undifferentiated curriculum does not take into account the characteristics of individual students. In the study by B. Rienties (2021), it was found that students whose learning paths were adjusted using analytics showed a higher level of possession of key competencies and knowledge than students in a control group where this technology was not used. Table 6 shows the results of a comparative analysis of the quality of learning outcomes in the framework of conventional and AI-based personalised learning.

Table 6. Efficiency of adaptive and analytical technologies in improving learning outcomes in British universities

Parameter/category	Description/methodology	Type of impact on the learning process
Learning design structure	Analysis of 87 modules using Learning Analytics to assess the impact of student activities (communication, task completion) on outcomes	Indirect improvement of learning through module and activity adjustments
Interventions based on the OU analysis	Use of predictive models to identify students at risk of low performance and provide tutoring support	Direct enhancement of learning through personalised guidance and resources
Adjustment of learning trajectories	Application of analytics to modify tasks and course content in real time according to student behaviour	Increased cognitive efficiency and depth of knowledge acquisition
Prediction and feedback	Integration of predictive systems within LMS (e.g. Moodle, OU Analyse) to identify weak knowledge areas and recommend supplementary materials	Optimisation of individual learning pathways and improved accuracy of knowledge acquisition

Source: developed by the authors based on studies Open University (n.d.), P. Joseph-Richard *et al.* (2021), and B. Rienties (2021)

As seen from the data in Table 6, applying Learning Analytics and differentiating pedagogical influence contribute to an improvement in the effectiveness of learning. The results of the analysis of the structure of modules make it possible to differentiate students' activities, which indirectly has a positive effect on acquiring knowledge. Using tools such as OU Analyse and predictive analytics makes it possible to identify risk groups of students, which directly affects the quality of learning outcomes. Using real-time analytics to adjust individual learning trajectories leads to an optimisation of the educational route and a deepening of the acquisition of knowledge. All these instruments, in sum, form an effective ecosystem of personalised learning.

Personalised learning as a result of AI integration in higher education institutions in the United Kingdom has not only a cognitive but also a socio-pedagogical effect, in terms of which the integration of artificial intelligence affects students' retention and contributes to the reduction of the dropout rate. Indeed, in the case of distance education on a mass scale, which is practised, for example, by the Open University, conventional forms of pedagogical support of students cannot be adjusted to meet the individual needs of each student and, accordingly, the risk of students dropping out of the discipline or completely withdrawing from their studies is rather high. Using analytical and adaptive technologies integrated into LMS, it is possible to identify at an early stage signs of difficulties in mastering the discipline on the part of students and take prompt measures to eliminate the problems through the efforts of the lecturer or using automatic notifications.

According to the empirical data, the use of Learning Analytics for personalisation of learning contributes to an improvement in the retention rate. Thus, in the framework of the above-mentioned study by B. Rienties (2021), it was found that students whose individual learning paths were adjusted using real-time analytics had a 15-20 % lower risk of dropping out compared to students in a control group where the technology of personalisation was not used. The use of such an analytical tool as OU Analyse makes it possible to identify students who are at risk of failing a discipline and take relevant measures in the form of individual recommendations, reminders, and adaptive tasks to level the students' academic achievement. Table 7 presents the main differences in retention and dropout rates in the context of conventional and AI-based distance learning.

Table 7. Impact of AI-based personalisation on students' retention and dropout

Parameter	Traditional learning	AI-personalised learning
Student dropout (%)	22-25	15-20
On-time module completion (%)	75	85-88
LMS activity (logins and completed tasks)	60-65	75-80

Source: developed by the authors based on studies Open University (n.d.), B. Rienties (2021)

As can be seen in Table 7, the use of intelligent technologies makes it possible to monitor students at risk and organise relevant and timely measures of individual support, which contributes to the growth of passing and completion rates and reduces student dropout. In addition, the use of analytical data makes it possible to improve the design of the course and make more efficient decisions about the distribution of teachers' time, which contributes to the growth of academic stability in the student body. In terms of the personalisation of learning through the use of AI, the lecturer's role changes from a lecturer or mentor to a coordinator, analyst and adaptive tutor. Analytical systems embedded in LMS systems such as OU Analyse, Moodle (n.d.) or Blackboard (n.d.) enable the lecturer to monitor the current progress of students, identify areas of potential difficulties, and take timely measures to optimise the students' individual trajectory. This is especially relevant in distance or blended learning formats, where the absence of direct face-to-face communication increases the likelihood of truancy or a decrease in student activity.

The lecturer has access to a wide range of indicators of student activity and progress, such as frequency of logging into the system, completion of tasks, results of adaptive tests, and work with educational content. Based on the results of the analysis, the lecturer can change the learning task, provide additional resources, adjust the level of difficulty of the material, or organise an individual consultation. According to the results of scientific research by B. Rienties (2021), the use of analytics in support of the educational process helps reduce the differentiation between students with different levels of readiness, thereby contributing to a more efficient distribution of attention and educational resources, which has a direct impact on academic achievement and student retention. The lecturer's role in the process of personalisation of learning is presented in Figure 3.

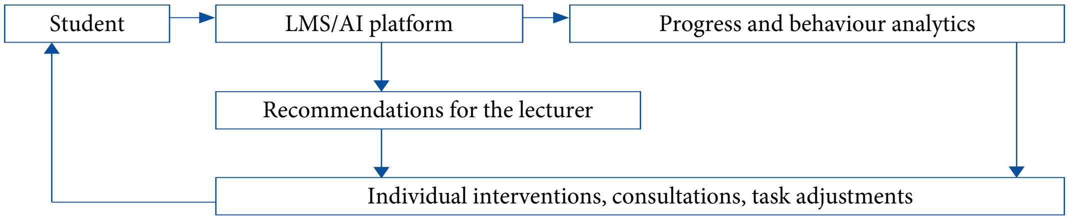

Figure 3. Lecturer's interaction with the AI system in personalisation of learning
Source: developed by the authors based on the study by Y. Copur-Gencturk *et al.* (2024)

The figure shows a conceptual model of cyclical interaction of the student, lecturer and intelligent system, in the process of which machine learning algorithms constantly monitor student progress, cognitive features and behavioural actions. The data obtained is translated into pedagogical recommendations that are sent to the lecturer and serve as the basis for the introduction of individual educational interventions, such as changes in tasks, pace of study, or individual consultations. Due to this, with each new student interaction with the AI system, a new analytical data set is formed, which not only allows the lecturer to respond to the challenges but also to predict and prevent them. This strengthens the personalisation of the educational process and contributes to academic resilience and student engagement. A comparative analysis of the lecturer's role in the traditional and AI-based personalised educational process is presented in Table 8.

Table 8. Comparative analysis of the lecturer's role in traditional and AI-personalised learning

Role aspect	Traditional learning	AI-personalised learning
Monitoring student progress	Visual/manual observation, periodic assessments	Real-time tracking via analytic dashboards, automatic risk detection
Individual support	Limited by time and resources	Personalised interventions, material adaptation, AIgenerated recommendations
Task planning and assessment	General tasks, identical for all students	Dynamic adaptation of task difficulty, content selection tailored to student needs

Source: developed by the authors based on studies M. Pratama *et al.* (2023), A. Bhatia *et al.* (2024)

As can be seen in Table 8, the introduction of intelligent technologies changes the functionalrole structure of the lecturer in the educational process. While in the traditional format, the monitoring of progress is limited to carrying out periodic assessments and visual control, and individual support is limited by the time and resources of the lecturer, in AI-personalised learning, the use of analytical dashboards allows the lecturer to monitor the current progress of students in real time and automatically identify students who are at risk of falling behind. Personalised interventions, adaptive educational content and AI-generated recommendations allow for more accurate and timely support of students. Dynamic adaptation of the level of difficulty and content contributes to the optimisation of the educational process for each student. This indicates a qualitative improvement in the efficiency of educational activity and the accuracy of the individualisation of the educational services provided with the use of AI technologies. A lecturer who successfully incorporates analytics received from intelligent systems into their pedagogical activities not only increases the effectiveness of their work with students but also optimises it, devoting more time to those students who need it and delegating routine tasks of control and monitoring to intelligent systems. Thus, AI technologies do not crowd out the lecturer but rather intensify their activities, and a new model of pedagogical assistance emerges in the form of synergy of actions of technologies and the professional potential of the lecturer, which together increase the effectiveness of the educational services provided.

Inclusion of intelligent systems in the system of individualised learning in the higher educational institutions of the United Kingdom has a positive effect on the motivation and involvement of students in the educational process, increases the effectiveness of individualised learning, reduces the time of its implementation, improves the accuracy of performing tasks due to adaptive learning paths, immediate feedback, and AI technologies' predictive analytics. In this case, the lecturer performs the function of a coordinator and a lecturer whose task is to promptly respond to the analytics received and adjust the individualised educational content, and provide students with necessary support. The use of AI systems for the individualisation of the educational process gives a synergistic effect, enhances the pedagogical influence, and generally improves the quality of the educational process.

DISCUSSION

In recent years (2021-2025), publications have appeared that consider the problem of changes in the lecturer's role and the student's experience, and the evolution of the educational ecosystem under the influence of AI technologies. The results of the studies of other researchers do not contradict the results obtained in the present study, which indicates an increase in the efficiency, flexibility, and individualisation of educational services in the system of higher education in the United Kingdom as a result of the implementation of machine-intelligent systems. Thus, in their conceptual article, X. O'Dea & M. O'Dea (2023) note that AI in higher education is often positioned as "the next big technological innovation" while universities and colleges are not yet ready to implement it. The authors paid attention to the danger of the formal implementation of AI without a pedagogical strategy. Compared to the results obtained, these researchers emphasised a strategic and cultural perspective, while the conducted study focused more on the effect of individualisation and analytical opportunities of the platform. Concurrently, S. Maghsudi *et al.* (2021) discuss the concept of personalised learning with respect to machine learning, in which AI serves as an engine for knowledge gap prediction, recommendation and content adaptation. The findings are consistent with the results of the current study and suggest the importance of adaptive learning paths and adaptive educational models.

The study by A. Klašnja-Milićević & M. Ivanović (2021) focused on e-learning personalisation systems for sustainable education. The article focused on adaptive interfaces, recommender systems and cognitive models of users. While the conducted research highlights LMS systems with AI tools in addressing dropout rate and student engagement, this article, instead, puts the emphasis on the learning ecosystem and sustainability in the narrative. Likewise, A. Al-Badi *et al*. (2022) examine the attitudes towards AI of students and lecturers. The results showed that the students had high levels of expectation with respect to personalisation and a decrease in the workload, but they presented doubts with respect to the reliability of the algorithm and the objectivity of the evaluation. However, these results do not totally match the presented study: risk management and ethics governance in British universities in this study are better, which reduces the worry about intelligent technology application. The discrepancies may stem from the different environments that A. Al-Badi *et al*. investigated in Gulf Countries' universities, which may be at different levels of regulations and technologies. According to V. Kuleto *et al.* (2021), in the article, the main benefits of AI in higher education include flexible learning, data analytics, and decision support, while the most significant drawbacks are ethical concerns and inequalities. Their results are consistent with those of the current study, underlining the importance of institutional policies and lecturers' digital literacy. While V. Kuleto *et al.* discuss the macro-level issues (management and strategy), this study addresses the micro-level (the models of personalisation itself), in the United Kingdom context. According to C. Zhou (2023), the universities that are most effective are those that infuse AI into content, course management, and student support at the same time, resulting in an "ecosystem" model of digital learning. The outcomes of this study are in line with the current observations of the broader picture of the overall ecosystem of personalised learning in the University of Glasgow, the Open University and the University of Manchester. Meanwhile, C. Zhou emphasises a variety of technologies (VR/AR, big data, AI). In addition, according to the study conducted by J. Hutson *et al.* (2022), when successfully implemented, the role of the lecturer using intelligent machine-based innovations becomes one of a facilitator, mentor, and moderator of technology. These findings are fully consistent with the results of the current study concerning the hybrid model of pedagogical support in the United Kingdom universities. However, the authors pay more attention to inter-disciplinary applications of AI, while the current study offers a more in-depth analysis of the use of adaptive algorithms within particular platforms (Knewton Alta, Synap, Edumentors).

The most recent bibliometric review study published by V. Maphosa & M. Maphosa (2023) suggested that the most prevalent keywords in the global research articles include personalised learning, AI ethics, and learning analytics, which proves that the theoretical framework of the current research is not outdated. However, the authors acknowledged the theoretical bias in the current literature and the absence of empirical studies, which offer in-depth discussions about practical personalisation models. For this reason, some of their conclusions (e.g. the insufficiency of empirical evidence for assessing AI effectivity in actual classes) partially diverge from the conclusions of the current study. The current research provides more empirical evidence from the British university cases with more practical granularity. This contradiction may be due to the level of evidence: bibliometric review research provides a macro-level view, while the current research provides microlevel views. This systematic review, done by H. Crompton & D. Burke (2023), demonstrates the situation of higher education and its utilisation of machine-intelligent software. The authors of the review discuss that personal learning is one of the emerging trends. Their findings on the efficiency of intelligent systems in the form of interactive prompts, adaptive modules, and a decrease in cognitive load are in line with the current results, which point to the improvement in motivation and engagement. However, H. Crompton & D. Burke state that the improvement of academic performance through AI-enabled systems is not yet "empirically validated", which contrasts with the present results on the improvement of academic performance in British universities. This disparity may be attributed to the authors' use of international data, whereas this study is using local data where AI use is more standardised and technologically advanced. On the other hand, K. Nikolopoulou (2024) studied the effect of generative AI, ChatGPT in particular, on the pedagogical practices and highlighted the need to develop the critical thinking of the students. The results are in line with the results obtained by K. Nikolopoulou about the potential of AI-assisted tutoring to facilitate creative learning and foster digital literacy skills. At the same time, the author points to the potential dangers of addiction to AI, whereas in the current research, such problems were not observed in the British due to the active role of the lecturer.

The review of O. Ayeni *et al.* (2024) systematises the studies on individualised learning and shows that AI contributes to better learning outcomes due to individualised pathways and continuous feedback. These results fully coincide with the current study in terms of the functionality of platforms such as Knewton Alta and Canvas. At the same time, the authors state that in the majority of countries, teachers have low levels of preparedness to work with intelligent systems, whereas in British universities, they are highly digitalised. This difference, therefore, can be explained by the difference in lecturers' training and support provided by universities. In the systematic review, S. Essa *et al.* (2023) discussed the adaptive learning technologies, which detect the learning style of the student using machine learning techniques. The results support the current hypothesis about the role of data collection and analysis in individualised learning. At the same time, S. Essa *et al.* are critical of the "learning style" concept, pointing to the low empirical validity of the theory. In the current research, the UK-based system does not rely on learning style but rather on dynamic performance metrics, avoiding, thus, controversial concepts. On the whole, the literature overview shows that there is a global tendency toward shifting from the uniform approach toward more flexible and individualised models of learning, which supports the results of the current research. The discrepancies between the studies can be explained by the contextual differences, digital infrastructure, and the differences in platforms used in the countries.

CONCLUSIONS

The study showed that individualised learning in higher education leads to the creation of a flexible educational process that can be adapted to the individual needs of the students, their learning style, and academic abilities. The application of individualised trajectories, learning plans and differentiated assignments allows for dynamic adaptation of the educational trajectory in accordance with the students' academic performance and level of preparation, which in turn has a positive effect both on motivation and learning outcomes. Learning Analytics systems and adaptive educational platforms make it possible to quickly collect and process data about the educational activity of students, identify gaps in their knowledge and skills, and provide recommendations for further education. This allows creating a full-fledged ecosystem of individualised learning, which in turn has a positive effect on students' engagement and effectiveness of mastering the material.

This difference between the traditional approach and AI-personalised learning (when the traditional approach is not very flexible and based on the "average" student, and AI personalisation is more individualised, based on real-time task automatic adjustment and real-time feedback) also shows that the effectiveness of AI personalised learning depends on technological infrastructure, lecturer training and minimising the risks of algorithmic bias. In British universities, integration of intelligent systems in learning platforms (such as Knewton Alta, Synap, Edumentors) has allowed for the implementation of different adaptive learning models: structured learning pathways for teaching STEM disciplines; interval-based quizzing to reinforce learning, and AI-powered tutoring coupled with individualised learning pathways. LMS platforms (Moodle, Blackboard, Canvas, Brightspace, FutureLearn) provide functionalities to individualise learning pathways, predict student underperformance risk and adjust learning content based on the student learning outcomes. This results in lower dropout rates and higher completion rates of modules and students' engagement within the systems.

The use of generative intelligence for education in the University of Glasgow, the Open University and the University of Manchester contributes to fostering the digital literacy, critical thinking and creativity of both students and lecturers. Intelligent systems allow real-time adaptation of the learning material, provide immediate, individualised feedback, increase cognitive gains, and increase motivation and engagement. Integration of intelligent systems has changed the lecturer's role from lecturer to coordinator and mentor, using analytics to adjust learning content and learning pathways and provide individualised support. A combination of lecturers' professional teaching competences and intelligent systems has created the new "hybrid" model of pedagogical support, enhancing both the process and quality of education. Thus, personalisation via AI-powered learning systems produces an all-encompassing positive effect: it enhances academic resilience, student engagement and learning outcomes in the United Kingdom higher education. This study is limited to the analysis of practices of integration of intelligent systems in the United Kingdom higher education and has not covered international comparative perspectives. Future research might focus on scaling up personalised AI-driven solutions to different countries and their effect on academic performance and teaching competences, as well as risks associated with this process (e.g. algorithmic bias, predictive inaccuracy, violation of students' data security, over-dependence on automated systems and decrease of the lecturer's role in the learning process).

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CONFLICT OF INTEREST

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Integration of technology in teacher education in the United Kingdom and Canada

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Abstract. The study aimed to reveal the efficacy of integrating the use of digital technologies in training prospective teachers by comparing the British model of online courses and the Canadian model of virtual classrooms based on simulations of pedagogical situations. The study used the comparative case study of two models of teacher education and a quasi-experiment. The key findings are as follows: the use of specialised online digital systems increases the professional competences of students. During the experiment, in the group after an eight-week course, the share of students receiving the highest grade of "5" reached 40-50%, and in the standard survey – 45-48%; for students of the control group, such an increase was not significant (highest grade was 8-12%). The most substantial progress was observed in the modelling of pedagogical situations and the development of interactive learning materials. That is, during the digital educational process, students developed practical and innovative skills. Comparative analysis of the models showed that in the British system, there is a more flexible acquisition of theoretical knowledge, while the Canadian system ensures the development of interactive practical competences. This is because such a model has a balance in the provision of theoretical and practical components and the organic integration of both through the medium of digital technologies. The study demonstrated that the use of digital technologies, especially the usage of online courses, virtual classrooms with simulation environments, can lead to students' greater digital competence, confidence in using the technologies and readiness for innovative pedagogical design. The practical significance of this study is related to the implementation of results in the teacher training system as follows: in creating teacher training programmes, implementing online courses, organising practice-based virtual classrooms for simulations, and assessing the students' competencies. The results of the research conducted can be applied by teachers of departments of pedagogy, online course designers, heads of university departments, and educators and scientists working on the problems of digital pedagogy and professional preparation of future teachers

Keywords: practical skills; digital tools; interactive learning materials; pedagogical situations; online interaction

INTRODUCTION

The issue of integrating technology into teacher education in the United Kingdom and Canada is of particular relevance, as the educational systems of these countries are actively rethinking approaches to the development of professional competence among prospective teachers. A case in point is the education systems in the United Kingdom and Canada, where the digital shift has created the urgent requirement to find the best possible ratio between the methodological tradition and the new generation of skills that shape the learning process, organisation and the teacher-student relationship. Studying this issue makes it possible to outline the prerequisites that guarantee the productive embedding of the technologies into the future teachers' formation and to draw up substantiated conclusions for the improvement of the teacher training system.

Studies devoted to teacher education in the United Kingdom and Canada indicate a shift towards the incorporation of digital solutions into pedagogical programmes. The publication by W. Kidd & J. Murray (2020) indicates that the move to distance learning in the United Kingdom necessitated the quick adaptation of university educators who integrated their own mentoring and evaluation systems in the online format. The researchers show that such changes have already generated new approaches to supporting

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student teachers and have highlighted the need to reconsider technological support within teacher education programmes. According to the publications about the teacher education system in Canada, there has been a change in the orientation of the focus. C. Hill *et al.* (2020) have reported that the Canadian university teacher education programmes have been reorganised after the pandemic, and the main emphasis of the education has shifted to the teacher's readiness to operate digital platforms, to engage students interactively in a blended mode, and to provide students with their maximum level of participation. In particular, A. Hargreaves (2021) demonstrated that the Canadian education system has reassessed the role of the teacher as a facilitator of digital processes, highlighting that the technological environment has changed the expectations of professional responsibility and institutional support. I. DeCoito & M. Estaiteyeh (2022) have proved that within Canadian teacher education programmes, the digital tools have transformed into the means of creating novel approaches to students' assessment from the auxiliary component. The researchers have shown that Canadian STEM teachers have reformed their classes with the help of digital laboratories, electronic student portfolios, and the technologies for the data capturing on the learning process. D. Gill (2025) has emphasised that Canadian teachers of the technological education have faced both the enabling and constraining factors to the technological innovations that have required system wide reform of the approach to mentoring and the access to materials as well as the teacher preparation.

A review of the literature on an interdisciplinary level show that the Canadian and British models share some common characteristics. According to the study by T. Valtonen *et al.* (2022), this educational technology area is based on the following theoretical and methodological foundations: learning analytics, the learning environment design, and teachers' digital competence. These results have confirmed that the United Kingdom and Canada are following a similar change trend. At the same time, T. Bui (2022) has indicated that the teacher's preparedness to use the new digital technologies has depended on the teacher's experience, the access to the digital technologies and the support by the organisation. It was highlighted in this study that teachers were already widely using various digital tools and that the nature of this usage was linked with the digital culture specific to the educational programme where the work was taking place. A. Rodrigues (2020) demonstrated that models of active teacher education have already integrated the use of digital tools for practice at the levels of training and simulation, thereby increasing the students' opportunities to successfully use digital technology in their future professional work. Subsequent research has focused on the role of artificial intelligence and analytics. A systematic review by S. Salas-Pilco *et al.* (2023) indicated that teacher education programmes on both sides of the Atlantic have begun to adopt learning data analytics tools, personalised learning systems, and decision-support models in teaching. Such an approach to the study allowed researchers to say that teacher students were ready to face the changes in the technologies due to the introduction of such elements into the learning content and teaching processes.

Although this and a few other studies have helped with the field of digital transformation in teacher education, some questions remain, such as the number of models of long-term mentoring for teachers in online environments, and the compatibility of online preparation of teachers in universities with the technological demands of schools. The research has not yet addressed differences in technological capacity across regions of the United Kingdom and Canada, which affect the level of preparedness of prospective teachers to use digital tools. This study aimed to evaluate the effectiveness of digital technologies implemented in the education of prospective teachers. The objectives were to conduct a comparative analysis of teacher education models in the United Kingdom and Canada; to carry out an international experiment in the digital preparation of prospective teachers; and to formulate recommendations for enhancing the effectiveness of integrating digital technologies into teacher education.

MATERIALS AND METHODS

A comparative case study was employed, based on the analysis of two models of technology-based teacher education. The study included open-access educational modules: Online Programs (n.d.) (PGCE is Postgraduate Certificate in Education), PGCE Teacher Development (n.d.), SimSchool (n.d.), and International (Distance Learning) PGCE (2025). These modules were compared in order to identify the logic of the technologies in professional preparation and the organisation of the practice part of the course, as well as the use and effectiveness of simulation in the virtual classroom.

The quasi-experiment was carried out in online format within 8 weeks with 48 students who were enrolled on the education of the teachers programme in the United Kingdom and Canada, 24 people from each country were included in the experiment. The criteria to enter the study were: students had enrolled on the education of the teachers within the last two years (2024-2025), participants did not have formal digital pedagogy certification, were not experienced in teaching for more than a year, and were ready to participate in an online format regularly. Exclusion criteria included: having completed digital pedagogy courses before, having had teaching experience for more than a year, and not being ready to engage with the online format.

The participants were grouped as follows: the experimental group (EG) and control group (CG) were included proportionally with students from the two countries. The control group worked within a general online format and was given general pedagogical tasks, conventionally using digital tools, while the experimental group was divided into two models: the British model, which involved completing educational cases in the form of online courses, as well as interactive modules, and the Canadian model, which involved working in a virtual classroom in the form of virtual lessons. Three main practical tasks were assigned to the students. The first one was to create a segment of the lesson in digital format: for the experimental group, a learning segment was created either in the form of an online course or a simulation, and for the control group, the participants prepared a lesson plan in text format. The second task was to create interactive materials for learning (video, interactive content or a digital training tool) for students in the educational process. In the experimental group, these were created using platforms corresponding to national models of digitalisation of the education system. The students in the control group performed this task using freely chosen tools with limited interactivity. The third task was the modelling of a pedagogical situation: in the experimental group, this was done using a simulation-based approach, while in the control group, students were required to present a possible solution in writing.

Experts (8 people) assessed the students' final work using a checklist with the following criteria: the level of technology used (level of digital tools and their relevance to the training goals); level of pedagogical validity (structure, appropriateness to learners' age); level of innovation (originality of the methods used and level of student interaction). The specialists who participated in the evaluation process were selected on the basis of their knowledge and experience in the field of digital education and pedagogy (publications or practical experience in integrating digital technologies in the educational process). Specialists who do not have verified experience of working in higher education were not involved in the assessment process. Each criterion was scored on a five-point scale, which ensured the quantitative suitability of the results obtained for further processing with statistical methods. In addition, a standardised survey was administered to all students at the beginning of the study, which was based on the Digital Competence Framework for Educators (DigCompEdu) (n.d.). The survey contained 9 questions, which were answered using a 5-point Likert scale (1 – "strongly disagree" to 5 – "strongly agree"). Answers were recorded on the Google Forms (n.d.) online platform, which allowed for collecting student responses, generating tables automatically and exporting the obtained results in Excel format, which made it easier to process the data using statistical methods. The participants were presented with the following statements:

1. Digital tools are used confidently in lesson planning.
2. Interactive learning materials can be created independently.
3. Digital resources can be adapted to learners' needs.
4. Online interaction with learners can be organised with ease.
5. The educational process can be managed effectively within a digital environment.
6. The use of digital technologies improves the quality of teaching.
7. Technical issues arising during lessons can be resolved promptly.
8. Learning outcomes can be assessed using digital tools.
9. Working with educational platforms does not present difficulties.

Statistical significance of changes was determined using Student's t-test to compare the initial and final indicators for both groups of students, as well as the one-way analysis of variance (ANOVA) to check the statistical difference between the groups of students, depending on whether they worked under the conditions of the British or Canadian model of digitalisation of the education system. All the procedures were carried out in compliance with the ethical standards and recommendations of the American Sociological Association (1997). Each participant was informed of the purpose, format, and potential risks of the study, provided written consent, and had their data stored anonymously. Participants were free to withdraw at any time without any adverse consequences for them. A number of recommendations for further work were formulated to increase the effectiveness of the process of digital technologies' integration in students' preparation for teaching, such as the use of online courses, virtual classrooms with the modelling of pedagogical situations and the development of students' digital competence.

RESULTS

Comparative analysis of teacher education models in the United Kingdom and Canada.

The preparation of future teachers now incorporates, as an important tool, various digital technologies for the formation of future teachers' professional skills. The use of online courses, virtual classrooms, simulation environments and interactive platforms allows students to acquire knowledge by using theory and practising in applying it in practice in the digital environments. Digital competences are now reflected in international and national documents, such as DigCompEdu (n.d.), with its six areas of professional competences in using digital technologies: professional use of digital technologies, pedagogical use, creation and adaptation of learning materials, assessment, supporting learners and continuous professional development (Punie & Redecker, 2017). The integration of online courses and virtual classrooms in the teacher education system will also allow students to get the experience in such pedagogical situations, which, due to time limitations, class size, and the availability of the material and technical base, is difficult to carry out in a real school environment. For example, students can conduct lessons for certain groups of students, observe class dynamics, test new teaching methodologies, and get feedback from the tutor and their peers in this environment. It also allows for standardising conditions for evaluating practical skills and systematic recording of the student's personal progress when using electronic portfolios and tasks of an interactive nature (Rakisheva & Witt, 2023). Hence, digital tools for teacher education are not only about means of knowledge delivery but also about modelling pedagogical process, interactive engagement and competence assessment, which thus affords a system of comprehensive preparation within educational contexts.

Table 1 presents the main commonalities and differences between the models of digital and online preparation for future teachers in the United Kingdom and Canada. The comparison covers not only the type of technologies and forms of training used, but also the development of professional competences, the use of simulation environments, and the mechanisms for assessing student skills. The information on which this article is based shows how, in both models, there are features of their technology and ways of training that will be implemented, taking into account national educational programmes and the resources of institutions.

Table 1. Comparison of models of digital and online training of future teachers in the United Kingdom vs. Canada

Criterion	United Kingdom model (online/distance courses)	Canadian model (virtual classrooms, online preparation)
Programme example	PGCE Teacher Development – a fully online course offered by UCL/University of London	BEd at Ontario Tech – one semester fully online using "virtual classrooms" in the preparation of prospective teachers
Online course/ digital learning format	Courses, lectures, seminars, distance modules, reflective activities, asynchronous resources (e.g. PGCE International Distance Learning)	Comprehensive online teaching programmes, for example, media-focused online education programmes at UBC (Online Programs – UBC Faculty of Education)
Simulation/virtual environments	Primarily theoretical modules combined with reflection	Research on the design of online simulations for teacher education, for example, the evaluation of the SimSchool online simulation (v.1)
Professional development (inservice)	Limited number of programmes specifically focused on online professional development; however, distance PGCE programmes and professional development courses are available	Canadian teachers demonstrate positive attitudes towards online professional development (survey-based evidence). Online pathways also exist for preparing K-12 teachers (virtual clinical experiences)
Competences developed	Theoretical pedagogy, reflective practice, professional writing, pedagogical theory	Educational technologies, online classroom management, learning resource design, interactivity, adaptive methods; also research on VR-based teacher training, for example, virtual reality as a classroom simulation for student management
Advantages	High flexibility, accessibility regardless of location, possibility of combining study with employment	Opportunity to practise complex pedagogical scenarios in a safe virtual environment, reduced risk of errors in real classroom settings
Challenges	Potential isolation, reduced interaction, lack of physical practice	Technological requirements, need for high-quality simulation design, resources for the development and maintenance of virtual classrooms

Note: VR – Virtual Reality, UBC – University of British Columbia, UCL – University College London, BEd – Bachelor of Education
Source: compiled by the author based on X. Zhang (2024), X (2025), YouTube (2025), Instagram (2025), Facebook (2025), E. Mendenhall *et al.* (2025)

The analysis of the models of training future teachers in the United Kingdom and Canada demonstrated that in both countries, there is the formation of future teachers' professional competences with the use of digital tools, but in different ways. In the United Kingdom, the focus is on distance online courses and theoretical training, but with the opportunity to model the teaching practice, which gives students in different regions and schools a high opportunity and convenience of online access to training. In Canada, the focus is on teaching skills by using interactive teaching in virtual classrooms and simulation platforms, which allows future teachers to form necessary practical skills and interaction with students in a similar way to the real school environment. An overview of the comparison shows that the two models complement each other: the British model is better suited for building a strong theoretical and flexible educational base, while the Canadian model is focused on practical skills and the development of digital interactivity. This approach indicates the possibility of using a mixed model of teacher preparation, in which theoretical knowledge and practical skills complement each other, and a professionally competent and digitally literate teacher is formed.

Quasi-experiment on the digital preparation of prospective teachers

The control group was studying using the traditional online format, while the experimental group studied using one of the two technology-oriented models, the British model of interactive online modules and the Canadian model of virtual lesson simulations. These three groups have some differences in the structure of the educational programmes, the interactivity levels, the nature of practical tasks, and the technologies used, which resulted in different levels of students' inclusion in the digital educational space. Table 2 demonstrates the results of the quasi-experiment on the effectiveness of digital technologies in the field of teacher education and training. The table presents the results for the control and experimental groups before and after performing practical tasks, based on expert assessments according to the rubric, and a standard questionnaire measuring students' digital competence according to the DigCompEdu (n.d.) framework. Students were given tasks to develop lesson segments using the Moodle and Canva digital platforms, including the integration of multimedia resources, the development of interactive tests, and online collaboration tools. The tasks varied in difficulty. The first 2 weeks of practical work focused on basic lesson preparation and the creation of learning materials; the 5th week included the creation of a complete interactive lesson segment with the use of self-testing and testing software; the 8th week included independent development of the lesson scenario and development of digital simulations by students. The result of the practical task performance is evaluated by independent experts according to the assessment rubric, which includes: the pedagogical justification, the use of digital tools, interactivity, logical construction, and innovation. Each assignment received detailed feedback indicating the strengths and providing recommendations on areas to improve, thus enabling students to progressively improve their performance. The table allows for a clear visual representation of changes in students' skills and attitudes towards digital technologies, as well as the effectiveness of both training models – the British online course model and the Canadian virtual classroom model.

Table 2. Results of the experiment: Assessment of practical tasks and students' digital competences

Expert assessment of practical tasks				
Practical tasks	CG before	CG after	EG before	EG after
1. Lesson segment	1-10% / 2-20% / 3-40% / 4-20% / 5-10%	1-8% / 2-22% / 3-42% / 4-20% / 5-8%	1-12% / 2-18% / 3-38% / 4-20% / 5-12%	1-0% / 2-5% / 3-15% / 4-40% / 5-40%
2. Interactive learning material	1-15% / 2-25% / 3-35% / 4-15% / 5-10%	1-12% / 2-28% / 3-34% / 4-16% / 5-10%	1-18% / 2-22% / 3-32% / 4-18% / 5-10%	1-0% / 2-5% / 3-20% / 4-35% / 5-40%
3. Modelling of a pedagogical situation	1-20% / 2-25% / 3-30% / 4-15% / 5-10%	1-18% / 2-27% / 3-28% / 4-15% / 5-12%	1-22% / 2-23% / 3-30% / 4-15% / 5-10%	1-0% / 2-3% / 3-12% / 4-35% / 5-50%
Standardised DigCompEdu survey				
Question	CG before	CG after	EG before	EG after
1. Digital tools are used confidently in lesson planning	1-12% / 2-18% / 3-40% / 4-20% / 5-10%	1-10% / 2-20% / 3-42% / 4-20% / 5-8%	1-15% / 2-20% / 3-35% / 4-20% / 5-10%	1-0% / 2-3% / 3-15% / 4-37% / 5-45%
2. Interactive learning materials can be created independently	1-14% / 2-20% / 3-38% / 4-18% / 5-10%	1-12% / 2-22% / 3-38% / 4-18% / 5-10%	1-16% / 2-18% / 3-35% / 4-20% / 5-11%	1-0% / 2-2% / 3-18% / 4-35% / 5-45%
3. Digital resources can be adapted to learners' needs	1-15% / 2-22% / 3-35% / 4-18% / 5-10%	1-14% / 2-20% / 3-36% / 4-18% / 5-12%	1-17% / 2-20% / 3-33% / 4-18% / 5-12%	1-0% / 2-3% / 3-17% / 4-35% / 5-45%
4. Online interaction with learners can be organised with ease	1-18% / 2-22% / 3-34% / 4-18% / 5-8%	1-16% / 2-22% / 3-36% / 4-18% / 5-8%	1-20% / 2-20% / 3-32% / 4-18% / 5-10%	1-0% / 2-3% / 3-15% / 4-37% / 5-45%
5. The educational process can be managed effectively within a digital environment	1-14% / 2-20% / 3-36% / 4-18% / 5-12%	1-12% / 2-22% / 3-38% / 4-18% / 5-10%	1-16% / 2-20% / 3-34% / 4-18% / 5-12%	1-0% / 2-2% / 3-15% / 4-35% / 5-48%
6. The use of digital technologies improves the quality of teaching	1-15% / 2-22% / 3-35% / 4-18% / 5-10%	1-14% / 2-20% / 3-36% / 4-18% / 5-12%	1-17% / 2-20% / 3-33% / 4-18% / 5-12%	1-0% / 2-3% / 3-17% / 4-35% / 5-45%
7. Technical issues arising during lessons can be resolved promptly	1-18% / 2-22% / 3-34% / 4-18% / 5-8%	1-16% / 2-22% / 3-36% / 4-18% / 5-8%	1-20% / 2-20% / 3-32% / 4-18% / 5-10%	1-0% / 2-3% / 3-15% / 4-37% / 5-45%
8. Learning outcomes can be assessed using digital tools	1-14% / 2-20% / 3-36% / 4-18% / 5-12%	1-12% / 2-22% / 3-38% / 4-18% / 5-10%	1-16% / 2-20% / 3-34% / 4-18% / 5-12%	1-0% / 2-2% / 3-15% / 4-35% / 5-48%
9. Working with educational platforms does not present difficulties	1-15% / 2-22% / 3-35% / 4-18% / 5-10%	1-14% / 2-20% / 3-36% / 4-18% / 5-12%	1-17% / 2-20% / 3-33% / 4-18% / 5-12%	1-0% / 2-3% / 3-17% / 4-35% / 5-45%

Source: compiled by the author

The results of the experiment indicated a trend towards the change of skills and digital competence levels of international online study participants in this way. In the control group, before and after the completion of the task, the differences in the results were not significant, with the largest values of expert evaluation and survey in 40-42% at levels "3-4", and the smallest ones were 8-12% at level "5", indicating the stability of the results of ordinary online learning without the use of special digital technologies. The students kept their level of digital competence at the initial level, but did not show dynamics of skill improvement. In the experimental group, the pre-intervention indicators were comparable to those of the CG. The results are concentrated in the intermediate levels "3" and "4", the lowest values are 10-12%, the highest are 38-40% at level "5". After eight weeks of adaptation of the British online course model and the virtual classroom model, there was an overall increase in all indicators. The lowest values, "1", were completely absent for all tasks and survey results, and the highest values, "5", reached 40-50% for the practical assignments, and 45-48% in the DigCompEdu survey. The results of the practical task of modelling pedagogical situations and creating interactive materials showed the highest dynamics in the experimental group. This means that students not only know how to apply digital tools, but are also able to find their own creative ways of building the educational process. Table 3 shows the mean values and levels of statistical significance for comparisons between the control and experimental groups, using Student's t-test and one-way ANOVA, in the performance of practical tasks and the development of digital competencies.

Table 3. Results of Student's t-test and ANOVA to assess the performance of practical tasks and the digital competence level of students in the control and experimental groups

Indicator/Task	CG before (M)	CG after (M)	EG before (M)	EG after (British) (M)	EG after (Canadian) (M)	t-test CG (p)	t-test EG (p)	ANOVA F	ANOVA p
1. Lesson segment	2.90	3.00	3.02	3.85	4.25	0.412	0.0004	6.42	0.014
2. Interactive material	2.90	2.93	2.85	3.90	4.30	0.521	0.0002	7.15	0.011
3. Modelling of a pedagogical situation	2.70	2.82	2.67	4.10	4.45	0.338	0.0001	5.88	0.018
Average mark DigCompEdu	2.90	2.94	2.86	4.05	4.30	0.487	0.0003	4.92	0.028

Note: the level of statistical significance indicates that changes in the control group were not significant ($p > 0.05$), whereas in the experimental group, all improvements in practical tasks and digital competences were statistically significant ($p < 0.001$). Units of measurement in the table are as follows: mean values (M) are presented as scores on a five-point scale, while t-test (p), ANOVA p-values, and F-values are unitless statistical indicators

Source: compiled by the author based on the conducted study

In Table 3, there are mean values (M) of performance of practical tasks and average digital competence according to DigCompEdu in control and experimental groups pre- and post-intervention. For instance, a lesson segment task in the experimental group increased from 3.02 to 3.85, in the British model and 4.25 in the Canadian model. An interactive learning material task improved from 2.85 to 3.90 and 4.30, respectively. There was a visible increase in skills as measured by these tasks, and the t-test measures between pre-test and post-test values in the groups (p), while ANOVA between the British and Canadian model values showed a difference in these results for practical tasks and development of students' digital competencies.

The combined analysis of the findings reveals that the implementation of specialised digital platforms in teacher training increases participants' digital literacy, ability to design interactive educational content, and skill in pedagogical design. Simulated classroom environments combined with interactive online courses allow students to master challenging pedagogical scenarios, receive meaningful feedback and support, and increase their confidence in using information technology tools and resources. The experiment results show that the merger of the British and Canadian teacher training models resulted in a consolidated learning system that enables the training of teachers competent in introducing technologies into the learning process.

Recommendations on improving the effectiveness of the integration of digital technologies in teacher education. To develop the digital literacy of future teachers through teacher training, a comprehensive approach must be applied that includes, alongside gaining theoretical knowledge and skills of prospective teachers, using digital technologies in the learning process. The analysis of international experience and the results of current experiments in the United Kingdom and Canada suggest the following recommendations to increase the effectiveness of digital technology integration in teacher training. Organise the training process for students using online courses with interactive modules to gain theoretical knowledge at the same time as mastering practical skills. It is suggested to include such courses in the educational process of universities within teacher training, for example, during the 2nd and 3rd year of a bachelor's degree, when students already have certain pedagogical knowledge. Online courses should be structured in such a way that each module includes a theoretical component, a practical task, and a system of reflection. For example, students might have designed lesson fragments using digital platforms, and lecturers gave their feedback about the tasks performed in detail through comments within the educational environment. Such courses can be developed on various platforms (e.g. Moodle (n.d.) or Canva (n.d.)). It is recommended to create interactive forums in such platforms and tests that automatically check and allow real-time feedback on the students' performance (Gamage *et al.*, 2022).

It is also advisable to create virtual classrooms and environments for student teachers to practice pedagogical situations difficult to recreate in a real classroom. Simulation scenarios can be a part of student teachers' practicum, preferably for 4th-year university students who already have some knowledge of classroom practice, or master's students who already have some experience working with pupils in the classroom. For instance, platforms like SimSchool (n.d.) or ClassVR (n.d.) enable students to practice various scenarios from working in the classroom to working with special needs learners to organising interactive activities for students, while teachers can provide clear instructions on what simulation objectives need to be achieved, as well as provide assessment criteria and desired outcomes to enable student teachers to interact with the virtual environment and learn from it more effectively. Another promising approach is to systematically incorporate practical work with digital technologies across all stages of teacher education. Regularly having students perform assignments, such as developing interactive educational content, planning lesson scenarios, and designing content for different categories of learners, is recommended. These assignments, whether as coursework or lab exercises, should be introduced at least once every two weeks throughout the semester. It makes sense to create rubrics for assessing this kind of coursework, considering the level of integration of technologies, the pedagogical quality of the material, and the level of innovation; in addition, use systems for automated information collection to later process the results. For example, using the HTML5 Package platform (H5P, n.d.), students might have designed interactive presentations or short video lessons, and the lecturers assessed the students' performance based on the assessment scales and rubrics, as well as provided guidance using structured feedback.

It is important to pay more attention to students' digital competence and confidence in using the technologies. This can be done through training sessions and specialised seminars with a focus on the practical application of digital platforms in teaching. Ideally, this is done at the start of the academic semester, which will allow students to get to know technologies before they start working on course assignments in that semester, when students can also enrol on short training courses, one to two weeks long, that would cover the main aspects of lesson planning using technologies, creating teaching materials, organising online communication, and assessing the learning results. A series of practical activities on a Learning Management System, such as Moodle (n.d.), with tests, video lectures, and simulated educational and managerial activities could be used. Another useful technique involves using gradual pedagogical modelling that helps students become more experienced in classroom management and student interaction. First of all, a student may prepare a text description of the solution to pedagogical situations. The second stage involves students playing out the same scenarios in the virtual classroom, with simulated students in the role of pupils, their communication in groups (Guillén-Gámez *et al.*, 2023). At the third stage, students should be allowed to create and model their own scenarios with the interactive digital tools themselves. This gradual training allows for increased confidence in working with technology, as well as skills for managing and analysing.

It is recommended that regular standardised assessment of students' digital competences be implemented, with the use of frameworks such as DigCompEdu (n.d.) or other international standards. Such assessments should be conducted at the beginning and at the end of the semester in order to monitor student progress. They can be implemented as online questionnaires with five-point Likert scales to collect a statistical analysis of the students' level of confidence in planning lessons using technologies and creating interactive materials, in the organisation of interaction with students online, in managing the educational process, and evaluating learning outcomes. Data obtained in this form can be collected at course levels and faculty-wide, which will provide a basis for changing and modifying training programmes, as well as the development of additional support measures. The other vital aspect is to introduce a feedback loop from teachers and peers in digital learning. Students should regularly receive feedback on what they have been doing, with focus given to technological integration level, pedagogical soundness, and innovation. It is suggested to organise online forums for discussing practical cases where students present the results of their work and receive feedback from their peers, together with teachers, in a structured way. Such forums can be organised at least once every two weeks throughout the semester and added to the course syllabus. This way, students get assessed and also have an opportunity to analyse different strategies and pick the most appropriate for their own practice (Morse *et al.*, 2021).

An essential component of the recommendations is the combination of British and Canadian models in teacher education. It is suggested that students first work with the online courses that allow them to acquire a theoretical base and familiarise themselves with structured cases, and then go on to virtual classrooms with simulations for acquiring and honing interactive pedagogical skills. Such a hybrid approach would make it possible to take advantage of the benefits of both models: the flexibility and reach of online courses, and the realism and practical focus of virtual simulations. This can be achieved if the programmes are organised in a way that the first four weeks are spent by students with the courses in the form of online courses for theoretical training, and the following four weeks are allocated for simulations with regular monitoring of the results and evaluations. An additional specific suggestion involves providing technical support and access to the platform. Universities ought to set up a centralised support for students, which could include guides, video guides and a support hotline with explanations on how to use the platforms. The idea being that this would prevent complications during synchronous sessions, would help students get familiar with the digital tools more quickly and would make sure the simulations run smoothly. Students who are studying remotely could be offered weekly webinars and interactive consultations where they can ask questions and get assistance in solving technical issues when doing assignments.

There is also a recommendation that students are engaged in project-based work in which students have to utilise digital tools in authentic pedagogical situations. For instance, students might need to create a lesson for actual students from partner schools, utilising a virtual classroom, or create digital learning resources for a specific curricular topic. It is necessary to plan such projects for a period of 6-8 weeks and to give feedback regularly to mentors and teachers from partner schools; thus, students will be able to practice their skills in real educational situations and be well prepared to start their professional careers after studying. It is also recommended to conduct continuous evaluation and adjustment of the educational programme based on assessment data and feedback. For example, teachers may assess the statistics of the completion of various tasks, results of DigCompEdu (n.d.) surveys and feedback from students once a semester and introduce changes in the programme, including additional classes, changing the level of complexity of tasks, adjusting virtual simulations to fit students' needs, and updating digital materials. In addition, a particular focus should be placed on the need for training in digital ethics and safety. At the beginning of the course, students should be trained on how to use online platforms and tools safely, keep their personal data protected and behave ethically when they are in a digital classroom. It is also recommended to repeat such training once a year and include it in courses on educational ethics and so on. In this way, not only technical competences will be developed but also the sense of a responsible attitude to the safety of the learning environment. Lastly, it is suggested that the results and guidelines be shared with teachers and students from other programmes and universities, allowing effective models to be scaled up and professional development to continue (Kaliuzhna, 2024). This could be done via online resources, webinars, conferences, and research publications. Implementing the proposed recommendations enables wider use of effective approaches to the integration of digital technologies in the training of teachers and makes it possible to form a professionally competent teacher ready to cope with modern educational challenges.

DISCUSSION

Digital technologies in teacher education in the United Kingdom and Canada have been associated with a complex process involving the development of methodological competence, digital competencies, and teacher professional development. The introduction of digital tools and blended learning practices to online platforms and simulations has changed the way of organising training; the data from the analysis of programmes is aligned with research from a range of other countries. It seems that this model fits well with the conclusions made by A. Clark-Wilson *et al.* (2020), who stated that digital tools have already transformed how teaching and learning activities are organised. The authors noted that technology offers the opportunity to expand the range of pedagogical practices and enhances the ability to modify and adapt learning resources for teachers. As a result of the study, it has been found that digital tools in the United Kingdom in programmes at UCL and Manchester University are mainly used in the format of online courses and modules on distance learning; whereas in Canada in programmes at the University of Toronto and UBC, virtual classrooms and simulation platforms, as well as practice-oriented interaction, are being actively used.

It was found that the introduction of technology into teacher education has also resulted in increased demand for the self-management of professional development. These findings are consistent with the study by T. Morris & M. Rohs (2023) on the potential of digital technologies for self-directed learning in formal education. The results of the study confirm that the British model is characterised by a stronger emphasis on theoretical preparation and reflection, whereas the Canadian model focuses on the development of practical skills through VR and simulation-based learning. This, in turn, contributes to the formation of independent planning of learning activities and the analysis of individual training trajectories. The use of interactive platforms helped to develop the practical readiness of teachers, which is consistent with the study by M. Hakami (2020), which found that the use of interactive platforms increased students' motivation to learn and improved the precision of their interaction with learning resources. According to the results of the group experiment, the use of simulations and interactive platforms resulted in an increase in the highest level of competence ("5") to 40-50%, whereas changes in the control group were minimal (8-12% at level "5"). These results are in line with the findings of teacher education in the United Kingdom and Canada. Presented observations of blended learning technologies used in both of the examined countries align with the study of D. Leidl *et al.* (2020), whose results demonstrated that blended learning leads to greater ease of access to resources and allows for a combination of structure and flexibility. The findings of this study suggest that online courses in the United Kingdom are highly flexible, while in Canada, the virtual classroom creates conditions for structure and interactivity, providing students with comprehensive training.

It was also found that in teacher training, such technologies enable the combination of distance learning and face-to-face formats and encourage more students to study independently. According to the presented data, the use of virtual simulations had an impact on the mastery of teachers' classroom management and behavioural strategies. The results of the current study also coincide with the conclusions of L. Lorenza & D. Carter (2021), stating that the fast transition from traditional to online learning during the COVID-19 pandemic forced the student population involved in teaching and the creative industries to demonstrate a considerable level of autonomy and be flexible to new digital formats in response to changes. This confirms the importance of creating a structured system of student support, which has to be focused on improving the effectiveness and quality of education. Current results also showed the impact of simulation and training on teachers' performance, which coincides with the findings of O. McGarr (2021). In particular, after the completion of the eight-week experiment, the proportion of students at a "high" level (4-5) in the modelling of pedagogical situations increased from 25-30% to 70-85%, confirming the effectiveness of simulations as a tool for professional training. The active use of digital technologies has also necessitated more flexibility in changing conditions and caused certain emotional difficulties, which is consistent with the conclusions of J. FernándezBatanero *et al.* (2021), who found the risk of the emergence of additional emotional strain during the implementation of digital technologies. The level of confidence in the use of digital technologies was somewhat lower in the control group (about 40-42% at the levels of "3-4"), whereas in the experimental group it increased to 82-85% at the levels of "4-5" after the training.

The adoption of digital technologies also contributed to intergenerational communication in professional development. This is consistent with S. Freeman *et al.* (2020), who found that technology has different implications for different generations and promotes intergenerational peer learning. The teachers of different ages also demonstrated different levels of adaptation to digital technologies. According to the survey of the student group, it was observed that the growth of digital competence in the experimental group (the number of level "5" in the experimental group was 45-48%), which indicates the efficiency of the adapted methods of training. This coincides with the results of X. Chen *et al.* (2022), who concluded that digital technologies provide flexibility, automation of some processes in learning, and support assessment. In Canada and the United Kingdom, there are also teacher education courses where students are learning and practising skills to be able to use personalisation tools and get immediate automated feedback. This is consistent with the findings of S. Akgun & C. Greenhow (2022), who investigated the issue of the ethics of using artificial intelligence in educational practice. The researchers emphasised that teacher training should include an understanding of the ethics of algorithms, data processing, and the fairness of algorithmic decisions. They add that the development of the teachers' ethical competence helps them to use technologies safely and responsibly while learning. At the same time, these data coincide with the results of R. Ashcroft *et al.* (2022), in which it can be seen that due to the COVID-19 pandemic, social workers in Canada have had their professional activities changed due to increased stress and the need to adapt the methods and forms of work to online formats. This requires introducing a digital environment for social workers and ways of staff support in a flexible form that can guarantee the quality of social services provided to students at any time. It was found that structured assessment criteria for assessing the quality of students' work, such as rubrics used in practical tasks, enabled objective assessment of students' learning outcomes, and this result coincides with the conclusions presented by A. Alsalamah & C. Callinan (2022). The improvement of students' skills in creating interactive materials was particularly visible, with students reaching the level of "5" for 40-45% of experimental group members.

In this way, the development of effective models of assessing the level of students' learning and correcting the educational process was carried out in accordance with the needs of the educational process, in line with E. Winter *et al.* (2021), the study results of which state that due to the COVID-19 pandemic, schools and teacher education institutions in Ireland accelerated the introduction of technological innovations, leading to the development of teacher technology competencies in this country. Similar technological innovations are introduced in Canadian and British teacher education courses in the form of creating educational resources based on online platforms, online simulation exercises, and digital laboratories. At the same time, it was noted that the students of the studied teacher education courses were highly competent in the use of technological tools for communication and collaboration, and the creation of digital materials, which is confirmed in the research study of P. Twining *et al.* (2021), which indicates the need for systematic curriculum design and integration of technological innovations into the educational process. These data about the effectiveness of using digital platforms when preparing future teachers coincide with the findings of S. Paek & N. Kim (2021), the research results of which indicate that there is a global trend of using artificial intelligence and digital technologies for learning for the purpose of improving the accessibility of the learning process, and improving personalisation of the learning process. Technology facilitates the organisation of learning activities and promotes critical thinking and independence in learning.

Initially, there was low use of online platforms and digital tools, which then increased substantially. This observation was confirmed by N. Peimani & H. Kamalipour (2021), who found that educational institutions that adapted to delivery via online platforms managed to maintain learning continuity and provide a quality of teacher education practice. In both institutions under study (the United Kingdom and Canada), distance courses included interactive tasks in learning activities, the delivery of seminars via online platforms, and the use of an assessment system to assess students' competencies in real time. This confirmed the observations made by K. Smith *et al.* (2020) on the effectiveness of telepractice in the clinical and educational setting during the pandemic. In terms of student engagement levels, it was established that the most effective results were achieved in courses that incorporated both traditional methods of learning and technology. In so doing, it was observed that the hybrid learning model of R. van der Vlies (2020), who has studied Organisation for Economic Co-operation and Development policies on the use of digital strategies in educational institutions, was observed. The use of various platforms enabled adaptation of educational activities to meet the needs of each student, thereby setting the scene for the development of digital competence and the practice of teaching skills. According to the analysis, it was the adoption of digital strategies that most fully integrated the use of technology, which was further ensured by clear criteria for assessment. In terms of academic integrity policies and the implementation of artificial intelligence, M. Perkins & J. Roe (2024) pointed out the role of regulatory frameworks that facilitate the implementation of technologies in the field of education. The criteria established in the British and Canadian institutions included evaluation of students' digital competence, the assessment of students' ability to use learning platforms and the evaluation of technological effectiveness in the development of pedagogical competences. Such criteria enabled a systematic approach to the integration of technologies and the creation of conditions for the gradual development of student professional competences. Based on the above, it can be concluded that the gradual implementation of online platforms and digital tools into the learning activities contributes to the effectiveness of teacher education as they supplement and expand on the traditional and digital modes of delivery. A systematic implementation of the technologies, supported by clear assessment criteria, contributes to the development of digital competence and the formation of professional competences in pedagogical practice.

CONCLUSIONS

As conducted research findings suggest, digital competences are closely connected to digital technologies in the training process of teacher education at the university level. Analysis of British and Canadian models showed that they have proven their usefulness. The British model, for instance, consists primarily of online courses and theoretical preparation, while the Canadian approach includes mainly practical activities in virtual classrooms and simulations. The combination of these approaches provides a comprehensive training which offers high flexibility and accessibility while developing practical skills.

The results for pre-test and post-test for participants in the control group were more or less consistent and did not vary significantly. The proportion of results "3-4" was 40-42%, and the results of level "5" varied 8-12%. Conventional learning online without using the digital model does not provide effective support for students to progress. In the case of participants in the experimental group, initial results were also relatively close, results of level "3" was 32-38% and results of level "4" was 18-20%. After eight weeks, the digital models had a significant effect. Level 1 was no longer visible, while Level 5 was observed in the results of the practical tasks in the range of 40-50% and in the results of the questionnaire in the range of 45-48%. In particular, significant progress was observed in the case of models of pedagogical situations (from 10% to 50%) and creation of interactive materials (from 10% to 40%). In this particular case, the average score for lesson fragments grew from 3.02 to 3.85 points (using the British model) and to 4.25 (using the Canadian model) and for interactive materials grew from 2.85 to 3.90 and 4.30, respectively. Results of the t-test and ANOVA confirmed statistically significant differences between results before and after the experiment, as well as proved the different impact of the British and Canadian models on the process of digital competence development.

It can be stated that the use of a digital model of digital competences development supports the growth of digital competences, analytical and managerial competences, contributes to pedagogical design competence and helps to build trust in the usage of technologies and increase self-confidence in digital skills. The best results were obtained using the combined model, consisting of online theoretical courses and practical training using models and simulations. On the basis of the above, recommendations have been formulated regarding the introduction of a staged training of teachers to teach using a simulation platform, the development of practical training exercises, and project activities. The limitations of the study relate to the sample size and the online format. Further research should focus on increasing the sample size and improving the range of tools for learning digital technologies.

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The use of gamification in secondary schools in Great Britain and France

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Abstract. The aim of the research was to analyse the impact of various types of gamification on student motivation and learning achievements compared to traditional teaching methods. The research methodology included three main methods: structural-conceptual analysis, comparative analysis, and a pedagogical experiment conducted over four months (March-June 2024) involving 68 students equally from two countries: Great Britain and France. The research determined that gamification incorporates various elements and mechanisms, such as point and level systems, badges and achievements, leaderboards, learning quests, game scenarios, and role-playing games, which contribute to increased student motivation and activity. It was found that integrating these elements into the learning process stimulates the development of critical thinking, team interaction, and cognitive skills. After conducting the experiment, changes in motivation levels in the groups differed: in the control group, the proportion of students with low motivation levels (1-3 points) decreased by approximately 1-3%, while in the experimental group this proportion decreased to 12%, which is half of the initial level. In the control group, high scores (6-7) increased by 1-3%, while the proportion of high scores (6-7) in the experimental group increased 2-2.5 times compared to the results before the experiment. The level of knowledge also increased: in the control group, the proportion of correct answers improved to 60%, while this indicator in the experimental group reached 88-97%. The application of gamification methods enhanced the level of intrinsic motivation, interest, and learning activity among students, facilitated better material assimilation, and promoted the development of critical thinking and teamwork skills. Traditional methods ensured only a basic level of knowledge assimilation and moderate motivation, highlighting the effectiveness of the innovative approach in education. The obtained results can be used by secondary school teachers to implement gamification elements in curricula to enhance motivation and improve student learning achievements

Keywords: students; online platforms; game elements; enhancing motivation; learning activity

INTRODUCTION

Students interact with digital technologies and interactive gaming environments, causing traditional teaching approaches to lose effectiveness in engaging attention and stimulating interest. This manifests in decreased concentration and interest, particularly in the study of exact and natural sciences. The use of game mechanics in the educational process allows for the activation of cognitive activity and facilitates deeper material assimilation. However, the implementation of such approaches faces certain difficulties related to insufficient teacher experience and the limited capabilities of modern platforms, which do not always align with educational requirements. This creates a need to research the impact of interactive technologies on student engagement and performance, in order to identify the most effective teaching strategies that combine motivation, practical activity, and effective knowledge acquisition.

The authors W. Oliveira *et al.* (2022) explored the use of personalised gamification in education, analysing how tailoring game elements to individual students affects motivation, engagement, logical thinking quality, and learning outcomes. They identified key trends: adapting task difficulty levels, personalising rewards and feedback, integrating social and team elements, and utilising analytics, which contribute to enhanced learning effectiveness and the development of students' cognitive and social skills. Clarification of the role of gaming innovations

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became possible thanks to the work of authors A. Vrcelj *et al.* (2023b), which investigated teachers' attitudes towards gamification and documented a combination of interest in innovation with concerns regarding implementation complexity. Furthermore, the researchers pointed out the need to prepare teachers to create their own gamified materials, as ready-made solutions do not always meet the needs of specific classrooms. Concurrently, a study on the impact of gamification on grammar acquisition conducted by G. Koç & S.S. Sütçü (2023) proved that the use of points, levels, and interactive tasks positively influences the quality of grammatical structure assimilation in adolescents. Specifically, gamification is beneficial for students with lower initial academic motivation, as it creates additional incentives for participation.

A contribution to understanding digital teacher training was made by the research of T. Liu *et al.* (2023), who analysed gamified online learning programmes and showed that such programmes strengthen digital competence and promote active professional development of teachers. They also noted that teachers respond positively to interactive and game formats, as these create a sense of progress and reduce the psychological barrier to new technologies. The issue of digital gamification in secondary school was systematised in a review conducted by A. Faure-Carvallo *et al.* (2022) to summarise the advantages and limitations of this approach. The scholars emphasised that gaming technologies are effective provided there is high-quality pedagogical design. Moreover, they highlighted the existence of differences between short-term effects, such as increased attention and lesson engagement, and long-term effects, including improved learning achievements and the formation of sustained learning motivation. In their research, G. Kaya & H.C. Sagnak (2022) demonstrated a stable increase in students' oral activity and interest, and confirmed the selection of appropriate gaming methods. The researchers also concluded that gamification promotes the development of communicative confidence among students who typically avoid active participation.

Psychological aspects of applying gamification were investigated by V.J. Sotos-Martínez *et al.* (2022). It was determined that game mechanics now facilitate the satisfaction of students' basic psychological needs and enhance their intrinsic motivation. Furthermore, gamification creates an atmosphere of healthy competition, which encourages more active completion of motor tasks. At the same time, research conducted by A.M. León *et al.* (2022) demonstrated that gamified strategies make learning reading more conscious and structured for students. They also emphasised that the impact of gaming approaches is noticeable when working with texts, particularly scientific articles, literary works, and textbooks. In mathematics education, results from a multi-case analysis conducted by V. Malvasi *et al.* (2022) to assess the use of gamification and educational games confirmed that these approaches improve the understanding of abstract concepts and promote the development of logical thinking in schoolchildren. The authors noted that the use of gaming platforms facilitates error processing and fosters a more positive attitude towards complex mathematical tasks. Researcher M.K. Bharti (2023), who investigated the overall impact of gamification on motivation and learning outcomes, proved that game mechanics now significantly enhance the learning activity and success of secondary school students. In practice, gaming approaches support not only motivation but also the development of self-regulation, as students learn to plan their own progress. In practice, this occurs through the use of game mechanics that stimulate students to plan their own progress, independently monitor task completion, and sustain motivation and active participation in the learning process.

Despite the number of works, a noticeable gap remained in the research, related to insufficient analysis of the long-term impact of gamification on student learning motivation and the stability of results. There was also a lack of comprehensive comparative studies combining different secondary school subject areas and different models of implementing gamification strategies. Furthermore, authors rarely assessed individual differences among schoolchildren, which complicated the determination of which gamification elements work for different student types. The aim of the research was to ascertain how the use of gamified teaching methods affects student motivation and the outcomes of their learning activity. The objectives of the research were: to conduct a comparative analysis of the types of gamification in the educational process; to assess the impact of gamification on student motivation and their learning achievements; to formulate recommendations for implementing gamification in the educational process.

MATERIALS AND METHODS

The study employed the method of structural-conceptual analysis, which allowed for the systematisation and generalisation of scientific approaches to gamification in education, and for the identification of key concepts, interrelationships, and principles of its implementation. Using this method, the main aspects of gamification were determined, namely the integration of game elements into the learning process, the stimulation of motivation, the development of critical thinking and teamwork, as well as the dependence of effectiveness on the age characteristics of students, learning objectives, and the curriculum. Based on the method of comparative analysis, a review of the main types of gamification was conducted using sources Pavlohak (2024), The Gamification Guide (2025), Jacob (2026), , specifically point and level systems, badges and achievements, leaderboards, educational quests and missions, game scenarios, reward systems, role-playing games, and time-limited tasks. Furthermore, online platforms such as Classcraft (n.d.), Legends of Learning (n.d.), and Minecraft Education Edition (n.d.) were examined. Additionally, the functions and operational algorithms of Labster (n.d.), PhET Interactive Simulations (n.d.), and Kahoot! (n.d.) were studied. Features of programs with gamified elements such as Quizizz (n.d.), Gimkit (n.d.), and Classcraft Missions (n.d.) were also highlighted. These types of gamification were selected because they most effectively combine elements of motivation, interaction, and competition, contributing to increased student engagement and improved learning outcomes. The analysis was conducted taking into account aspects such as students' motivation level, intensity of cognitive activity, degree of engagement in the learning process, and the effectiveness of feedback between teacher and student.

The study also employed the method of pedagogical experiment, which was conducted over four months, from March to June 2024. The sample included 68 secondary school students, with 34 participants from the United Kingdom and 34 from France. For ethical and confidentiality reasons, the names of the participating schools were not disclosed. The schools were selected on the basis of their representativeness of secondary education, comparable educational profiles, and prior experience in the implementation of digital and gamified learning platforms. Inclusion criteria required participants to be enrolled in grades 8-9 at the time of the experiment, to attend classes regularly, to have parental consent for participation, and to possess basic digital skills necessary for working with online platforms. Exclusion criteria included absence from more than 20% of classes, chronic health conditions limiting participation in active forms of learning, prior experience of using gamified platforms in the educational process, and participation in parallel pedagogical experiments that could affect motivation and learning outcomes. Ethical requirements in accordance with the Helsinki Principles (World Medical Association, 2013) were observed, including the anonymity of responses, the right to withdraw from participation without negative consequences, and the secure processing and storage of the obtained data. The students were divided into control and experimental groups in a 1:1 ratio, with equal representation from both countries. In the control group, instruction was delivered through traditional methods, including lectures, quizzes, written assignments, and practical exercises. In the experimental group, teaching was organised through a gamification-based approach that incorporated point and level systems, badges and achievements, leaderboards, educational quests and missions, game scenarios, reward systems, role-playing games, and time-limited tasks, with particular emphasis on mathematics and natural sciences. To assess the effectiveness of the experiment, the level of student motivation was measured before and after the intervention using the Student Motivation Scale (n.d.), which evaluates subject interest, achievement orientation, and activity in the learning process. Responses were recorded on a seven-point scale, which allowed for a quantitative assessment of intrinsic and extrinsic motivation. The scale was adapted, resulting in the following questions being isolated:

1. I am interested in learning this subject.
2. I strive to achieve success in my studies.
3. I try to work actively during lessons.
4. I complete tasks because I want to learn more.
5. I feel satisfaction when I complete learning tasks.
6. I make an effort even when the task is difficult.
7. I can say that I have high intrinsic motivation.

Furthermore, at the beginning and end of the experiment, students were asked to complete seven multiple-choice tasks, which allowed for the determination of improvement or decline in their learning outcomes and the assessment of the effectiveness of the applied teaching methods. The tasks were as follows:

Task 1. Definition of the term

What is gamification in the learning process?

a) Using games for entertainment during lessons

b) Applying game elements to increase student motivation and engagement in learning

c) Mandatory completion of computer games during lessons

d) Solely using points and rankings without tasks

Task 2. Examples of gamification elements

Which of the listed elements is not an example of gamification?

a) Points and rankings

b) Virtual medals and badges

c) Homework without any additional rewards

d) Challenges and quests

Task 3. Mathematics + Gamification

Students are completing an algebra learning quest. They receive 10 points for correctly solving an equation.

How can the task be made more gamified?

a) Awarding extra points for solving speed

b) Reducing the number of equations

c) Eliminating any rewards

d) Prohibiting teamwork

Task 4. Scientific Experiments

Students are performing a series of virtual chemistry experiments in a programme where they receive "energy" for each successful task. Which gamification principle is used here?

a) Balance of difficulty and reward

b) A traditional lecture

c) Teamwork only

d) Assessment solely at the end of the semester

Task 5. Motivation and Engagement

How does gamification affect student motivation?

a) It decreases interest in the subject

b) It increases activity and the desire to learn

c) It makes learning more difficult

d) It replaces the teacher

Task 6. Reward Strategies

Students receive points when they complete mathematical tasks and can exchange them for "virtual items". What type of gamification is used?

a) Negative reinforcement

b) Positive reinforcement

c) Social pressure

d) Random encouragement

Task 7. Choosing a Gamification Programme

Which feature is most important when selecting an educational programme with gamification elements for mathematics and natural sciences?

a) The presence of bright colours

b) The balance between learning objectives and game mechanics

c) The ability to play without completing tasks

d) A large number of advertising banners

Student responses were checked and evaluated by six secondary school teachers from the United Kingdom and France who acted as independent assessors. The teachers were selected according to the following criteria: at least five years of teaching experience in secondary education, experience in using digital learning platforms, and knowledge of assessment methodologies used to evaluate learning achievements in accordance with national educational standards in the United Kingdom and France. Teachers were excluded if they had less than five years of teaching experience, lacked experience with gamified or interactive platforms, participated in parallel pedagogical experiments that could affect the objectivity of assessment, or refused to comply with confidentiality requirements during the marking process.

Ethical safeguards applied not only to students but also to the participating teachers. All teachers were informed about the aims and procedures of the study and provided voluntary consent to participate as assessors. Their involvement was treated confidentially, and they retained the right to withdraw from the study at any stage without negative consequences. To ensure objectivity and compliance with ethical requirements, all student responses were anonymised before evaluation.

Student responses were evaluated on a percentage basis: 10-20% correct answers indicated a low level of material assimilation, where students barely understood the topic; 21-40% – indicated an average level of understanding, meaning students partially mastered the material but required additional explanation; 41-60% – reflected a sufficient level, where the majority of students demonstrated correct understanding of basic concepts; 61-80% – corresponded to a high level of assimilation, indicating correct and comprehensive perception of the learning material; finally, 81-100% – showed a very high level, where almost all students gave correct answers and demonstrated excellent understanding of the topic.

The dynamics of changes in student motivation and learning outcomes were tracked using the method of repeated measurements and Cronbach's Alpha reliability coefficient. In the study, Cronbach's Alpha coefficient of internal consistency was used to assess questionnaire reliability, which allows for determining how consistently individual test items measure the target construct – in this case, student motivation level. The coefficient value ranges from 0 to 1; in the presented study, the calculated Cronbach's Alpha for the questionnaire is 0.84, indicating good internal consistency and reliability of the instrument for measuring student motivation. A limitation of the study is that the experiment was conducted only in secondary schools in the UK and France over one semester, which limits the generalisability of the results to other countries, age groups, and educational levels.

RESULTS

Gamification in education is considered as the integration of game mechanics and elements into the learning process to enhance student motivation, engagement, and performance. Gamification encompasses game elements (points, levels, badges, leaderboards, quests, story-based tasks), motivational mechanisms, the development of cognitive and social skills, as well as the adaptation of learning to individual student needs (Seeletse *et al.*, 2024). Specifically, properly integrated elements of game design stimulate active student participation, foster independent learning, and develop critical thinking and teamwork skills. Gamification promotes the development of critical thinking, as game-based tasks require analysis, planning, and decision-making. Students learn to evaluate their own actions, predict outcomes, and adjust strategies, thereby forming problem-solving and logical thinking skills. Team interaction manifests through group quests and collective tasks, which stimulate cooperation, communication, and the ability to work in a team, developing social skills and responsibility for the collective outcome (Gini *et al.,* 2025).

The effectiveness of gamification depends on student age, learning objectives, and the educational curriculum. For younger schoolchildren, simple tasks with visual rewards and short quests are suitable, supporting motivation and fostering interest in learning. For middle and high school students, complex game scenarios, integrated projects, and team competitions are applied, promoting a deep understanding of the material and the development of critical thinking. In exact sciences, game elements help progressively master abstract concepts and logical operations, while in humanities disciplines, they stimulate analysis, discussion, and creative thinking (Zeng *et al.*, 2024). Thus, gamification in education is a multi-level system that combines the integration of game elements, motivational strategies, the development of critical thinking, and team interaction, adapted to the age and cognitive abilities of students and the specifics of the educational curriculum. The application of these aspects increases interest in learning, improves knowledge acquisition outcomes, and contributes to the formation of key competencies in schoolchildren. Gamification and its individual types positively impact the learning process, as they integrate game elements that enhance motivation, activate cognitive activity, and increase student engagement. Points and levelling systems allow students to track their own progress and receive immediate feedback, stimulating further mastery of the material. Badges and achievements encourage students to reach specific goals and independently improve their skills, while leaderboards foster a competitive spirit and attention to the subject. Educational quests and missions form complex cognitive activity, forcing the application of knowledge in practice, analysis of results, and planning of next steps. Game scenarios and role-playing games model real-world problem situations, promoting the development of teamwork problem-solving skills and improved communication. Time-limited tasks stimulate thinking speed, concentration, and prompt decision-making, which is effective in mathematics and the natural sciences (Kien & Nguyen, 2021). Collectively, these gamification mechanisms increase motivation levels, student activity, and the effectiveness of feedback between teacher and student, making the learning process more interactive, structured, and effective. Table 1 summarises the key elements and mechanisms of gamification that are actively used in secondary education to enhance student motivation and engagement.

Table 1. Comparative analysis of gamification elements and mechanisms applied in secondary education

Element/Mechanism	Practical Application in the Learning Process
Points and Levelling System	Students receive points for completed tasks, participation in discussions or projects; accumulated points allow them to "advance" to new difficulty levels, motivating them to tackle more complex tasks.
Badges/ Achievements	The teacher awards badges for mastering specific skills or achieving certain results; students see their successes, which increases intrinsic motivation.
Leaderboards/ Rankings	Display student progress within the class or group; students strive to improve their positions, and the teacher can stimulate teamwork and healthy competition.
Educational Quests and Missions	Series of tasks or projects with specific goals that integrate different subjects; students plan actions, conduct research, and report results, forming critical thinking.
Game Scenarios	Implementation of thematic storylines into lessons (e.g., historical reenactment or scientific expedition), helping students immerse themselves in the material and increasing engagement.
Reward System	Students receive bonuses, additional tasks, or public recognition for successes; this stimulates consistency in learning and encourages active participation.
Role-Playing Games	Students perform roles (researcher, project manager, historical figure), promoting the development of strategic thinking, team interaction, and responsibility for decisions made.
Time-Limited Tasks	Tests or practical tasks with a timer increase concentration, thinking speed, and the ability to make decisions under tight deadlines; simultaneously, effective planning is practised.

Source: compiled by the authors based on Pavlohak (2024), The Gamification Guide (2025), Jacob (2026)

The comparative analysis determined that different types of gamification in secondary education differ in their functional focus and impact on the learning process. Points and levelling systems, as well as badges and achievements, primarily motivate students, demonstrating progress and specific achievements, which stimulates intrinsic motivation and the desire to tackle more complex tasks. Leaderboards and rankings are distinguished by their social aspect, as they foster healthy competition and team interaction, making students evaluate their own results in comparison with others. Educational quests and missions and game scenarios are focused on developing critical thinking and deep immersion in the learning material, integrating various subjects and forming skills in planning, analysis, and research work. The reward system is distinguished by its stimulating nature, encouraging consistency in learning and active participation in the process. Role-playing games concentrate on developing strategic thinking, team interaction, and responsibility for decisions made, while time-limited tasks focus on thinking speed, concentration, and prompt decision-making. The main difference between the types of gamification lies in the direction of their impact: some stimulate motivation and progress, others social interaction, critical thinking, or concentration and task execution efficiency, allowing them to be combined for the comprehensive development of students.

Points and levelling systems, badges and achievements, leaderboards, educational quests and missions, game scenarios, reward systems, role-playing games, and time-limited tasks function in practice as tools that structure students' learning activities and make them more manageable, measurable, and motivational. According to Pavlohak (2024), such mechanics form a sense of progress in high school students, as each element demonstrates a clear connection between the completed task and the achieved result. For example, a points and levelling system makes it possible to transform complex topics in algebra or geometry into sequential stages, where students receive points for correct solutions and advance to higher levels after mastering a block of material. Badges and achievements are useful in natural sciences when it is necessary to mark mastery of a specific skill – for instance, understanding chemical reaction formulae or successfully performing a virtual laboratory experiment. The study by Jacob (2026) highlights that leaderboards are effective for short, intensive topics where it is relevant to maintain competitiveness and thinking speed, such as training computational skills, working with formulae, chemical equations, or graph analysis. However, they should be applied cautiously to avoid excessive pressure; in higher grades, they are most appropriate for extracurricular activities, preparatory exercises, or practice tools for material review. Educational quests and missions work well in topics requiring interdisciplinary integration, for example in projects where students must calculate parameters of body motion, model an ecosystem, analyse statistical data, or create a simple mathematical model of a natural phenomenon. Game scenarios allow students to immerse themselves in the roles of researchers, engineers, or analysts, and such a format, according to The Gamification Guide (2025), helps retain complex information better and increases the level of understanding of abstract concepts. The reward system reinforces interest in lengthy or complex topics, as students receive virtual bonuses for sequential steps, completion of intermediate tasks, participation in teamwork, module completion, or independent improvement of results. Role-playing games are useful in natural sciences, where students can "try on" the role of a biologist, physicist, or ecologist, performing modelling, data analysis, or problem-solving. Time-limited tasks are suitable for training thinking speed and skill automation, for example when solving equations, performing chemical substitutions, or analysing functions.

Online platforms with gamified elements demonstrate high effectiveness in teaching high school students; however, their application should be appropriately differentiated depending on the subject and type of tasks. Classcraft (n.d.) and Classcraft Missions (n.d.) create a comprehensive gaming environment with scenarios, levels, rewards, and role models, which is effective in the natural sciences, where students complete quests, simulate research situations, and work in teams, enhancing their analytical and critical thinking skills. Labster (n.d.) and PhET Interactive Simulations (n.d.) provide the capability to conduct virtual experiments and simulate physical, chemical, and biological processes in a safe interactive environment, facilitating a deep understanding of complex natural phenomena. Kahoot! (n.d.), Quizizz (n.d.), and Gimkit (n.d.) focus on revision, rapid testing, and skill training through points, leaderboards, and timers, which is useful in mathematics for developing computational skills, logical thinking, and reaction speed. Platforms that stimulate creativity and project activities, such as Minecraft Education Edition (n.d.) and Legends of Learning (n.d.), enable students to model mathematical objects, construct structures, visualise abstract concepts, and conduct integrated research in natural sciences using narrative-role scenarios.

Thus, the effectiveness of gamification programmes depends on the extent to which the platform aligns with the subject and type of learning activity, combining motivational mechanisms with the opportunity for practical knowledge consolidation and the development of critical and logical thinking in high school students. Furthermore, gamification platforms demonstrate high effectiveness when they combine interactive elements with educational content, adapting tasks to the subject specificity and student level. The use of points, leaderboards, timers, quests, and role scenarios stimulates motivation, the development of computational and logical skills, as well as critical thinking. Therefore, the successful implementation of such platforms in the educational process contributes to the simultaneous increase in student engagement and the quality of knowledge acquisition.

Student motivation and learning outcomes can vary depending on age, learning objectives, subject specificity, and teaching methods, including the application of traditional or gamified approaches. The choice of appropriate learning strategies determines the level of engagement, activity, and effectiveness of material assimilation. To determine the initial conditions of the pedagogical experiment, the baseline motivation level in the control and experimental groups was analysed. Data are presented in Table 2.

Table 2. Baseline student motivation level in the control and experimental groups prior to the experiment

Question (Student Motivation Scale)	Score	Control Group (CG) (%)	Experimental Group (EG) (%)
1. I find it interesting to study this subject	1	4	3
	2	7	5
	3	10	10
	4	29	28
	5	26	27
	6	13	15
	7	11	12
2. I strive to achieve success in learning	1	4	2
	2	6	5
	3	13	12
	4	31	30
	5	23	25
	6	13	15
	7	10	11
3. I try to work actively in lessons	1	5	4
	2	8	5
	3	17	14
	4	33	30
	5	21	24
	6	10	14
	7	6	9

Table 2. Continued

Question (Student Motivation Scale)	Score	Control Group (CG) (%)	Experimental Group (EG) (%)
4. I complete tasks because I want to learn more	1	6	4
	2	9	7
	3	15	15
	4	32	30
	5	19	22
	6	11	14
	7	8	8
5. I feel satisfaction when completing learning tasks	1	6	4
	2	9	6
	3	16	16
	4	34	32
	5	19	22
	6	9	12
	7	7	8
6. I make an effort even when the task is difficult	1	7	5
	2	10	7
	3	18	17
	4	31	30
	5	17	20
	6	9	13
	7	8	8
7. I can say that I have high intrinsic motivation	1	8	6
	2	11	8
	3	20	20
	4	29	28
	5	16	18
	6	9	12
	7	7	8

Note: the table shows the percentage of students who responded to the question on a seven-point scale
Source: compiled by the authors

Analysis of the results presented in the table indicates that at the initial stage, the level of learning motivation among students in the control and experimental groups was generally similar. In both groups, the majority of students rated their motivation at levels 4-5 points, indicating a moderate level of motivation. The control group showed a slightly higher percentage of responses for the rating "4" (29-34%) compared to the experimental group (28-32%). Differences between the groups were minor, with a difference within 1-2% for these ratings. Higher scores (6-7) were less common, and their proportion in both groups was similar. In particular, the absence of significant differences at the outset indicates equal initial conditions for both groups, allowing for a correct comparison of their results after the implementation of experimental methodologies. The reasons for this similar motivation level may be related to traditional teaching approaches, which at that time no longer fully met the needs of students. This may contribute to reduced activity and interest in the learning process, which explains the absence of significant differences at the initial stage. Overall, at the start, both groups have a similar motivational structure, which allows for assessing the effectiveness of subsequent pedagogical interventions and gamification methodologies. The general pattern of responses demonstrates the absence of statistically significant initial differences between the study participants. The next stage involved determining the knowledge level of students in the control and experimental groups prior to the pedagogical experiment through test performance, as demonstrated in Table 3.

Table 3. Distribution of student responses in the control and experimental groups prior to the experiment

Task	Response Options	Correct Answer	CG (%)	EG (%)
1. What is gamification in the educational process?	a) Using games for entertainment during lessons b) Applying game elements to enhance student motivation and engagement in learning c) Mandatory completion of computer games during lessons d) Only using points and ratings without tasks	b	a – 20 b – 50 c – 15 d – 15	a – 18 b – 52 c – 16 d – 14

Table 3. Continued

Task	Response Options	Correct Answer	CG (%)	EG (%)
2. Which of the listed elements is not an example of gamification?	a) Points and rankings b) Virtual medals and badges c) Homework without any additional rewards d) Challenges and quests	c	a – 25 b – 28 c – 30 d – 17	a – 22 b – 30 c – 32 d – 16
3. Students complete an algebra learning quest. They receive 10 points for solving an equation correctly. How can the task be made more gamified?	a) Award additional points for solving speed b) Reduce the number of equations c) Exclude any rewards d) Prohibit working in a team	a	a – 20 b – 25 c – 30 d – 25	a – 18 b – 22 c – 28 d – 32
4. Students perform a series of virtual chemical experiments in a programme where they receive “energy” for each successful task. Which gamification principle is used here?	a) Balance of difficulty and reward b) Traditional lecture c) Only teamwork d) Solely end-of-term assessment	a	a – 18 b – 25 c – 28 d – 29	a – 20 b – 24 c – 26 d – 30
5. How does gamification affect student motivation?	a) Reduces interest in the subject b) Increases activity and desire to learn c) Makes learning more difficult d) Replaces the teacher	b	a – 20 b – 50 c – 15 d – 15	a – 18 b – 52 c – 16 d – 14
6. Students receive points when they complete mathematical tasks and can exchange them for “virtual items”. Which type of gamification is used?	a) Negative reinforcement b) Positive reinforcement c) Social pressure d) Random encouragement	b	a – 22 b – 40 c – 18 d – 20	a – 20 b – 42 c – 16 d – 22
7. What feature is most important when choosing an educational programme with gamification elements for mathematics and natural sciences?	a) Presence of bright colours b) Balance between learning objectives and game mechanics c) Ability to play without completing tasks d) Large number of advertising banners	b	a – 18 b – 45 c – 20 d – 17	a – 16 b – 48 c – 18 d – 18

Note: the table indicates the correct answer for each task and the percentage of students who selected each response option, allowing for an assessment of the initial knowledge level and comparability of the groups
Source: compiled by the authors based on students’ previous assessments

Analysis of the distribution of students’ responses prior to the experiment revealed that the highest percentage of correct answers was observed for tasks 1 and 5. In the control group, the correct option was chosen by 50% of students (task 1 – 50%, task 5 – 50%), while in the experimental group these indicators were slightly higher – 52% and 52% respectively. The lowest percentage of correct answers was recorded in tasks 3 and 4, where in both groups the correct option was chosen by 18-20% of students (in the control group: task 3 – 20%, task 4 – 18%; in the experimental group: task 3 – 18%, task 4 – 20%). This indicates the complexity of tasks related to the application of gamification principles in mathematics and natural sciences.

The average response distribution showed that the control and experimental groups were comparable at the start; the difference in the percentage of correct answer choices between groups did not exceed a few points, which allows for the evaluation of the subsequent impact of gamification without bias. In summary, the table demonstrates that at the initial stage, both groups had a moderate level of knowledge regarding tasks where the use of gamified approaches was key, and a higher level of knowledge in tasks related to basic understanding of terminology and motivation. This establishes a baseline for comparing the effectiveness of traditional and gamified learning in the subsequent experiment. Table 4 illustrates the distribution of responses from students in the control and experimental groups after the pedagogical experiment.

Table 4. Distribution of responses from students in the control and experimental groups after the experiment

Task	Answer Options	Correct Answer	CG (%)	EG (%)
1. What is gamification in the educational process?	a) Using games for entertainment during lessons b) Applying game elements to enhance student motivation and engagement in learning c) Mandatory completion of computer games during lessons d) Using only points and rankings without tasks	b	a – 22 b – 58 c – 12 d – 8	a – 10 b – 92 c – 5 d – 3
2. Which of the listed elements is not an example of gamification?	a) Points and rankings b) Virtual medals and badges c) Homework without any additional rewards d) Challenges and quests	c	a – 28 b – 32 c – 32 d – 8	a – 8 b – 10 c – 90 d – 2

Table 4. Continued

Task	Answer Options	Correct Answer	CG (%)	EG (%)
3. Students complete an algebra learning quest. They receive 10 points for solving an equation correctly. How can this task be made more gamified?	a) Award additional points for speed of solution b) Reduce the number of equations c) Exclude any rewards d) Prohibit working in a team	a	a – 32 b – 28 c – 20 d – 20	a – 88 b – 5 c – 2 d – 5
4. Students perform a series of virtual chemistry experiments in a program where they receive "energy" for each successful task. Which principle of gamification is used here?	a) Balance of difficulty and reward b) Traditional lecture c) Teamwork only d) Assessment solely at the end of the semester	a	a – 30 b – 28 c – 24 d – 18	a – 90 b – 3 c – 4 d – 3
5. How does gamification affect student motivation?	a) Lowers interest in the subject b) Increases activity and desire to learn c) Makes learning more difficult d) Replaces the teacher	b	a – 15 b – 60 c – 15 d – 10	a – 5 b – 97 c – 2 d – 1
6. Students earn points when completing math tasks and can exchange them for "virtual items". Which type of gamification is used?	a) Negative reinforcement b) Positive reinforcement c) Social pressure d) Random encouragement	b	a – 20 b – 55 c – 15 d – 10	a – 3 b – 94 c – 2 d – 1
7. Which feature is the most important when choosing an educational program with gamification elements for mathematics and natural sciences?	a) Presence of bright colours b) Balance between learning objectives and game mechanics c) Ability to play without completing tasks d) Large number of advertising banners	b	a – 18 b – 60 c – 12 d – 10	a – 5 b – 97 c – 2 d – 1

Note: the table indicates the correct answer for each task and the percentage of students who selected each answer option, which allows for the assessment of the initial knowledge level and group comparability

Source: compiled by the authors based on prior student assessments

Analysis of the results demonstrates a clear and statistically significant gap between the indicators of the control and experimental groups upon completion of the experiment. The experimental group, in which the educational process was implemented using gamification and innovative digital technologies, showed a substantially higher level of material assimilation compared to the control group, which followed the traditional methodology. In most tasks, the percentage of correct answers in the experimental group ranges from 88% to 97%, indicating an almost complete understanding by students of key concepts and principles of gamification. In contrast, the results of the control group fluctuate within the range of 30-60% depending on the task, confirming only partial assimilation of the material. The most pronounced differences are observed in tasks that require an understanding of gamification mechanisms and the ability to apply them in simulated learning situations (tasks 3 and 4): in the experimental group, correct answers constitute 88-90%, whereas in the control group – only 30-32%. Such a contrast is substantial and demonstrates that students who participated in learning based on gamified elements not only retained the material better but were also able to transfer the acquired knowledge to practical examples.

The gap between the groups is explained by the specifics of the methodologies used. Gamification elements ensured an increased level of engagement and motivation among students in the experimental group, supporting intrinsic motivation by creating conditions for autonomy, competence, and interaction with others. The interactive learning tools applied during the experiment facilitated a better understanding of the material, created a positive emotional background, and activated memory processes through multi-channel perception of information. The control group, despite noticeable progress compared to the initial results, did not demonstrate dynamics comparable to the experimental group, as traditional teaching methods primarily ensure a reproductive level of knowledge acquisition, whereas the gamification approach stimulates cognitive activity, independent inquiry, practical application of acquired information, and sustained interest in learning. The results of the pedagogical experiment also allow for an assessment of the effectiveness of applying traditional and gamified teaching methods regarding changes in motivation. Table 5 demonstrates the indicators of the control and experimental groups after the completion of the experiment. Analysis of the results presented in Table 5 indicates a positive dynamic in the level of student motivation in both groups following the experiment; however, the changes in the control and experimental groups differ substantially. In the control group, where instruction followed traditional methodologies, only a slight improvement in motivation is observed. The proportion of students with low scores (1-3 points) decreased by approximately 1-3%, while high scores (6-7) increased by 1-3%. This distribution suggests a moderate positive dynamic in learning motivation, but the overall level of interest and intrinsic motivation remains average, which is characteristic of a classical teaching approach. In the experimental group, where innovative teaching methods with elements of gamification were applied, the changes proved more pronounced. The proportion of students with a low level of motivation (1-3 points) decreased to 4-12%, which is half the initial level. Average indicators (4-5 points) remain stable or increased by 2-5%, while the proportion of high scores (6-7) increased by 2-2.5 times, significantly exceeding the analogous indicators of the control group. This demonstrates that the application of gamification elements contributed to an increase in student interest, activity during lessons, diligence, and willingness to exert greater effort during learning.

Table 5. Level of student motivation in the control and experimental groups after the experiment

Question (Student Motivation Scale)	Score	Control Group (CG) (%)	Experimental Group (EG) (%)
1. I am interested in learning this subject	1	3	1
	2	6	2
	3	9	5
	4	27	18
	5	27	26
	6	15	24
	7	13	24
2. I strive to achieve success in learning	1	3	1
	2	5	2
	3	12	5
	4	30	20
	5	24	25
	6	15	24
	7	11	23
3. I try to actively participate in lessons	1	4	1
	2	7	2
	3	16	7
	4	32	20
	5	22	26
	6	12	25
	7	7	19
4. I complete tasks because I want to learn more	1	5	1
	2	8	2
	3	14	7
	4	32	20
	5	21	27
	6	12	25
	7	8	18
5. I feel satisfaction when I complete learning tasks	1	5	1
	2	8	2
	3	15	6
	4	33	18
	5	21	27
	6	11	24
	7	7	22
6. I make an effort even when the task is difficult	1	5	1
	2	8	3
	3	17	7
	4	30	20
	5	20	26
	6	11	25
	7	9	18
7. I can say that I have high intrinsic motivation	1	5	1
	2	10	3
	3	19	8
	4	29	20
	5	19	27
	6	10	23
	7	8	18

Note: the table shows the percentage of students who responded to the question on a seven-point scale
Source: compiled by the authors

Overall, the results showed that students in the control group, who were taught using traditional methods focused on memorising facts and performing standard exercises, achieved a basic level of knowledge acquisition but exhibited average motivation, low activity during discussions and practical tasks, and their grades were lower compared to the experimental group. At the same time, students in the experimental group, who learned using gamification elements, specifically quests, missions, game scenarios, and a system of points and rewards, demonstrated higher activity, engagement, and concentration, which led to better material assimilation and improved grades. Thus, the integration of game and motivational mechanisms increased the effectiveness of the learning process and stimulated the development of students' independent and critical thinking. As a result, students in the experimental group not only received higher grades but also developed critical thinking, teamwork skills, and the ability to independently plan their actions when completing tasks, which demonstrated the effectiveness of integrating gamification into the learning process.

Based on the results of the conducted pedagogical experiment, the systematic implementation of gamification in the learning process of secondary schools can be recommended to increase motivation and improve students' learning achievements, particularly in the study of mathematical and natural sciences. The experimental group, which used integrated gamified elements – point and level systems, badges and achievements, leaderboards, educational quests and missions, game scenarios, role-playing games, and time-limited tasks – following the implementation of the methodology, saw the proportion of students with a high level of motivation (6-7 points) double, while the number of low scores decreased to 1-3%. Simultaneously, in the control group, the changes were minimal: a high level of motivation increased only to 11-15%, and a low level remained at 3-10%. Considering the obtained data, it is recommended to combine different types of gamification elements to achieve maximum effect: point and level systems, as well as badges and achievements – to stimulate individual motivation; leaderboards and role-playing games – to activate team interaction and healthy competition; educational quests, game scenarios, and time-limited tasks – for the development of critical thinking, logical skills, and decision-making speed.

Furthermore, the use of specialised online platforms with gamification elements is effective, allowing for interactive lessons, modelling experiments, organising team tasks, and quickly assessing student results. A practical recommendation is to combine digital platforms with classical teaching approaches; for students, it is useful to apply quests and game scenarios in mathematics to develop abstract thinking and analytical skills, and in natural sciences – simulations and role-playing games for a better understanding of complex processes and experimental work. Additionally, it is worthwhile to integrate a system of points and rewards to maintain sustained interest, stimulate team interaction through leaderboards and collaborative missions, and use time-limited tasks to train thinking speed and concentration. Thus, based on the research results, it can be argued that the comprehensive implementation of gamification elements increases student motivation and learning outcomes, forms practical and analytical skills, develops critical thinking and teamwork, and the use of specialised platforms ensures an effective combination of learning objectives and game-based motivation, making the learning process more engaging and productive.

DISCUSSION

The use of gamification in secondary schools in the United Kingdom and France ensured an increase in learning motivation, growth in student activity, and the formation of sustained interest in the learning process. It was established that gamification contributes to increased student motivation through the use of points, levels, badges, leaderboards, and other game mechanics, which create a sense of progress and achievement. The obtained results aligned with the conclusions of P. Andrade *et al.* (2021), who established that even partial implementation of three game elements in STEM (Science, Technology, Engineering, Mathematics) discipline software increased motivation and contributed to the assimilation of learning material. The research demonstrated that the effectiveness of gamification depends on the tools used. Specifically, the experimental group used gamification where tasks were presented as quests, missions, game scenarios with a system of points and rewards, which promoted higher activity, engagement, and concentration. Such conclusions are consistent with the research of A. Azar & N. Tan (2020), which proved that the use of platforms with gamification elements improved the language competence of middle school students. The authors recorded that the system of points and virtual rewards maintained interest in learning even in a distance format. An improvement in learning outcomes in the experimental group was established after implementing gamification strategies during the study of mathematical and natural science disciplines. Corresponding trends were observed in the research of M. Adeoye (2024), where gamification intervention demonstrates improved academic achievement of students. Gamification elements contribute to increased student engagement and stimulate active participation in completing learning tasks. Similar effects were recorded by H. Hossein-Mohand *et al.* (2021), who found that integrating gamification with project-based and flipped learning methods improved the quality of school students' mathematical preparation. The influence of gamification is evident in engaging students in learning activities. An increased level of participation in lessons and readiness for team interaction was recorded. Similar conclusions are presented in the work of K. Fuentes-Riffo *et al.* (2023), which found that the use of game elements in teaching mathematics increased motivation among students with initially low levels of interest. Student motivation in the experimental group increased more intensively than in the control group.

In the control group, where learning occurred through traditional methods, the proportion of students with high motivation scores (6-7) ranged from 16% to 18%, while low-motivated students (1-3) ranged from 18% to 22%. In the experimental group, where gamification elements were applied, the proportion of students with high scores increased to 35-48%, while low scores decreased to 8-10%. Thus, gamification ensured a gain in motivation that is more than five times greater than the results of traditional teaching, confirming its high effectiveness in engaging students in the learning process. This corresponded with the results of Z. Luo *et al.* (2021), who determined that the adoption of gamified tools was influenced by the availability of technical resources and a positive attitude towards digital innovations.

The research emphasised that role-playing games and team tasks enhance social interaction, develop communication, responsibility, and collective work skills, which increases the effectiveness of team educational projects. Confirmation of this is also contained in the work of E. Mårell-Olsson (2021), which noted that gamification contributed to the development of 21st-century skills provided students had sufficient digital literacy. Comparison of the data attested that in both countries, gamification contributed not only to emotional uplift but also to strengthening self-learning strategies. H. Dehghanzadeh *et al.* (2024) confirmed that the use of gamification in primary and secondary education supported learning through positive behavioural engagement. Online platforms with gamified tools enhance practical learning; simulations (Labster, PhET) improve the assimilation of natural sciences, while testing platforms (Kahoot!, Quizizz) develop thinking speed and material consolidation. Gamified approaches contributed to the formation of student autonomy and the development of skills for effective planning of learning activities. Similar conclusions were made by V. Arufe-Giráldez *et al.* (2022), who indicated that gamification forms long-term motivation for activity and responsibility. The results of this study are consistent with the research of P. Lam & A. Tse (2022), where observations in Hong Kong schools confirmed that elements of competition and storylines formed a positive learning environment. Such approaches contributed to increased interaction among students and the development of teamwork skills during the completion of learning tasks. In this study, approximately 60% of students in the control group achieved high results after the experiment, whereas in the experimental group this indicator reached 88-97%, corresponding to a gain of approximately 55-60% and confirming the advantage of the gamified approach.

International authors have investigated the problem of gamification, analysing its impact on student motivation, engagement, and learning outcomes within various educational systems. In particular, scholars A. Vrcelj *et al.* (2023a) found that game elements enhance student motivation and engagement. Moreover, in practice, it is effective to employ narrative or quest-based tasks that integrate learning material into engaging scenarios, stimulating active student participation. The use of game mechanisms stimulated active student participation during lessons, fostered the development of teamwork and interaction, and increased interest in learning activities. Such results align with the conclusions of S. Moral-Sánchez *et al.* (2022), in which gamification in mathematics proved to be an effective means of engaging students in STEM activities. It was established that combining gamification elements with practical tasks contributed to a better understanding of complex concepts and the development of spatial thinking. Furthermore, the use of game mechanisms sustained student motivation and increased their activity during collaborative projects. The identified influence on pedagogical readiness for gamification is consistent with the study by A. Franco-Mariscal *et al.* (2021), which found that systematic training for future teachers in the use of gamification resources enhanced the quality of their professional preparation. Similar patterns are described in the work of E. Ratinho & C. Martins (2023), which emphasises the role of gamified strategies in developing student motivation and cognitive flexibility. It was established that the application of gamified elements contributed to increased learning efficiency, as interactive tasks, point systems, and rewards stimulated student activity, engagement, and concentration. A comparison of the results revealed alignment with the conclusions of J. Attah *et al.* (2024), who demonstrated that student attitudes towards gamified learning in mathematics are predominantly positive, given conditions of interactive communication. Interactive tasks, quests, point and reward systems increase motivation and interest, which in turn promotes greater activity in completing learning tasks and improvement of academic results. Similarly, J. Ruiz *et al.* (2024) noted that gamification enhanced school students' engagement and contributed to a reduction in academic anxiety. This effect coincides with the conclusions of I. Khoudri & A. Khoudri (2023), who, when analysing the use of the Vevox platform, recorded an increase in student satisfaction, motivation, and readiness for active participation. Students in the control group were taught using traditional methods, which included explanatory lessons, written assignments, quizzes, and practical exercises, where the primary focus was on memorising facts and performing standard tasks without the integration of game or motivational elements. For example, in mathematics lessons, students completed standard textbook exercises and tests, while in science lessons, they conducted laboratory investigations in a classical form with assessment at the end of the session. This correlates with the conclusions of R. Leitao (2021), which instead showed that gamified elements fostered the formation of practical understanding of processes. The application of game elements increased student motivation and contributed to longer retention of learning information. Furthermore, the study by R. Leitão *et al.* (2021) confirmed that the use of narrative and competitive mechanisms ensures sustainable learning outcomes and broadens students' cognitive horizons. It was established that combining game elements with interdisciplinary tasks fostered the development of critical thinking and problem-solving skills in school students. The conducted research demonstrated that gamification in secondary school stimulated student motivation, engagement, and active participation in the learning process, while simultaneously contributing to the development of cognitive, social, and emotional skills. The application of game elements supported the formation of autonomy, critical thinking, and interdisciplinary connections, enhancing the effectiveness of learning and the quality of the educational environment.

CONCLUSIONS

As a result of the comparative analysis, it was established that various types of gamification in secondary education positively influenced the learning process, as they integrated game elements that increased motivation, activated cognitive activity, and promoted student engagement; point and level systems, as well as badges, stimulated progress and independent skill improvement; leaderboards and rankings developed social interaction and teamwork collaboration; and educational quests, game scenarios, and role-playing games fostered the development of critical thinking, strategic planning, and practical application of knowledge. Furthermore, timed tasks enhanced thinking speed, concentration, and task performance efficiency, while online platforms with gamified elements, such as Classcraft, Labster, Kahoot! and Minecraft Education Edition, provided an interactive environment that allowed for adaptation of learning to the subject and task type, combining motivational mechanisms with the practical consolidation of knowledge and the development of logical and critical thinking in senior students.

The pedagogical experiment showed that the application of innovative teaching methods significantly influences the level of student motivation and engagement in the learning process. In the control group, the level of student motivation before the experiment was predominantly distributed within medium values: the largest proportion of responses fell within 4-5 points, where a stable figure of approximately 29-34% was recorded. Low motivation indicators (1-3 points) in the CG ranged from 4 to 20%, while high indicators (6-7 points) fluctuated within 6-11%. Overall, this suggests that at the initial stage, a significant portion of students demonstrated only moderate interest and insufficiently expressed intrinsic motivation. Prior to the beginning of the experiment, the level of motivation in the experimental group was comparable to that of the control group: most students rated their motivation at the level of 4-5 points (28-32% for "4" and 22-27% for "5"), the proportion of high scores (6-7) was 12-15%, and low scores (1-3) were 10-25%. After the implementation of gamification elements in teaching, the experimental group demonstrated a significant increase in motivation: the proportion of students with high scores (6-7) increased to 18-40% depending on the question, while the proportion of low scores (1-3) decreased to 8-10%. For example, regarding the question "I am interested in studying this subject", high scores increased from 27% to 48%, and low scores decreased from 18% to 8%. The control group showed minor changes: high scores increased only to 16-18%, and low scores decreased to 18-22%. A similar trend was demonstrated by knowledge results: before the experiment, correct answers in the experimental group were 18-52%, and after, 88-97%, while the control group increased only to 30-60%, confirming the effectiveness of the gamification approach for both motivation and knowledge acquisition.

Based on the results of the pedagogical experiment, recommendations are provided for the systematic implementation of gamification into the learning process of secondary schools to enhance student motivation and improve academic achievement, in mathematics and science. It is recommended to combine various gamification elements – point and level systems, badges and achievements, leaderboards, educational quests and missions, role-playing games, game scenarios, and timed tasks – to stimulate individual motivation, activate team interaction, and develop critical thinking and logical skills. The use of specialised online platforms, which allow for interactive lessons, simulation of experiments, and rapid assessment of student results, is effective. The practical combination of digital platforms with classical teaching methods fosters the development of analytical, practical, and teamwork skills, increases student interest and concentration, making the learning process more engaging and effective. Further research may focus on integrating gamification with adaptive digital platforms for personalising the learning process and enhancing learning effectiveness.

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Integration of virtual learning environments into school education in Scotland

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Abstract. The purpose of the study was to determine the impact of using virtual learning environments on students' assimilation of educational material and the development of their skills and abilities. The methodology included content analysis of types and examples of the use of virtual reality in schools in Scotland, conducting a pedagogical experiment at Stirling High School (Stirling) and Portobello High School (Edinburgh), and the development of an algorithm for integrating such environments into the educational process. It was established that virtual learning environments that cover technologies of immersion, addition and interaction with digital objects create conditions for deeper study of the material, development of practical and cognitive skills and increase learning motivation. The analysis demonstrated the possibility of using various immersive solutions for teaching History, Geography, and Ecology, in particular for virtual excursions, demonstrating 3D models, and conducting safe laboratory experiments. The pedagogical experiment showed that students in the experimental group had significantly higher levels of engagement ($M = 4.3$; $SD = 0.5$), cooperation ($M = 4.1$), and self-regulation ($M = 4.0$) compared to the control group (3.6; 3.5; 3.4, respectively). ANOVA statistical analysis confirmed significant differences between the groups ($F = 15.21$; 11.47; 13.05), indicating a positive impact of using interactive virtual environments on learning activity, interaction, and student autonomy. Based on the results, a five-stage algorithm for integrating virtual learning environments was created, which involves identifying learning needs, selecting technological solutions, training participants, planning classes, and evaluating results. The practical significance of the study lies in the possibility of applying the results obtained by teachers for the effective implementation of virtual learning environments, school administration – for planning innovative educational programmes, and developers – for creating interactive educational content

Keywords: students; teachers; critical thinking; virtual platforms; study subjects

INTRODUCTION

The use of advanced digital technologies in the educational process creates new opportunities for personalising learning and developing digital literacy. Virtual platforms provide access to interactive materials, modelling complex phenomena, and student collaboration in a safe environment. However, insufficient teacher training, limited access to equipment, and uneven development of digital skills among students make it difficult to use these technologies effectively. Such factors reduce the activity of students and limit the potential of innovative approaches in teaching. Therefore, research in this area determines the best strategies for implementing technologies and helps to increase the readiness of teachers to work in a digital environment.

The use of virtual learning environments in school education in Scotland creates conditions for maintaining learning activity and developing student independence. W. Jantanukul (2024) investigated how augmented, virtual, and mixed reality technologies affect the learning process,

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in particular, student engagement, motivation, and assimilation of knowledge. AR (Augmented Reality), VR (Virtual Reality), and MR (Mixed Reality) technologies influence the learning process by creating a high presence and interactivity, which activates students' attention and promotes understanding of educational material through experiential assimilation. H. Crogman *et al.* (2025) investigated how the application of virtual, augmented, and mixed reality technologies is changing the paradigm of experimental learning, allowing students to learn through modelling real-world situations and interacting with digital objects. The paper analysed the positive impact of such technologies on the development of practical skills, critical thinking, and the ability to apply theoretical knowledge in real contexts. The study by K. Alhazzaa & W. Yan (2025) showed how AR and VR technologies affect the user experience and participants' level of engagement during training simulations. In practice, this happens by immersing students in virtual building design scenarios, where they can experiment with energy efficiency parameters in real time and observe the consequences of their decisions in an interactive format.

Research conducted by N. Assaf & D. Gan (2021) showed that distance learning provides active interaction of students with educational material and forms self-control skills, while effectiveness depends on clear structuring of courses and availability of technical resources. Technological support and pedagogical organisation of materials are necessary for the effectiveness of online education. During a comparative analysis of the perception of online learning by students of higher educational institutions, D. Cranfield *et al.* (2021) found that distance learning promotes flexibility in planning educational activities and developing self-control skills. This confirms the importance of supporting student self-regulation, which is implemented in Scottish schools through structured online courses and supporting learning materials.

Collaborative tasks in online environments, highlighted by G. Demosthenous *et al.* (2020), stimulate social interaction and the development of critical thinking. Active interaction between students and teachers ensures the assimilation of material and the development of team skills, which confirms the importance of joint projects in Scottish virtual schools. Evaluation of distance learning methods and factors of effective content delivery, conducted by O. Gluoksnyte (2022), emphasised the need to adapt materials to the online format and regular feedback. It turned out that the interactivity and structure of courses increases student engagement and promotes the development of independent learning skills, which was actively used in Scottish schools. The research by G. Mangione & G. Cannella (2020) demonstrated that technological solutions provide equal access to learning resources even in small and isolated communities. This discovery confirmed the possibility of effective use of digital platforms in remote regions of Scotland and highlighted the importance of technology support to ensure equal learning opportunities. The development of virtual schools for students with experience living in educational institutions, as shown by L. McIver & M. Bettencourt (2024), allows creating personalised educational trajectories and maintaining the psychoemotional state of students, developing their academic achievements. These results complement previous findings about the value of flexible and adaptable online resources. Innovative learning methods through virtual platforms and applications, according to M. Sofi-Karim *et al.* (2022), promote greater student engagement and digital skills development, while providing opportunities for interactive interaction and a personalised approach to learning. The experience of T. Walters *et al.* (2021) demonstrated that maintaining a psychoemotional state and access to adapted materials determines the learning performance of secondary school students. Adapted materials include learning resources adapted by difficulty level, presentation formats, and interactive elements to support students' psychoemotional state.

Despite the results highlighted by the aforementioned researchers, gaps remained in the scientific field related to the impact of virtual learning environments on the educational trajectory of schoolchildren in Scotland. Evaluation of the effectiveness of virtual reality platforms was not sufficiently presented, which made it difficult to identify learning opportunities for all students. There was a lack of generalised conclusions about the optimal combination of pedagogical strategies and technological tools that can guarantee stable and reproducible learning outcomes in a virtual environment. The purpose of the study was to evaluate the effectiveness of using virtual environments in learning, students' interaction with the material, and the development of competencies. The objectives of the study were: to carry out a content analysis of virtual learning environments used in school education in Scotland; to assess the features of integration of immersive technologies (VR, AR, MR) in the teaching of Geography, History, and Ecology, and their impact on the assimilation of educational material; to develop an algorithm for integrating virtual learning environments into the educational process of secondary schools.

MATERIALS AND METHODS

The study conducted a content analysis of various forms of VR technologies, in particular, ClassVR (n.d.) and Engage VR (n.d.) platforms. Additionally, AR technologies were considered, namely, Merge Cube (n.d.), CoSpaces Edu Training & Projects (n.d.). Mixed reality (MR) analysis included applications such as Microsoft HoloLens (n.d.), zSpace (n.d.). These programmes were selected because of their extensive use in teaching and their ability to display various formats of immersive educational environments. The analysis was conducted based on the following criteria: the level of user immersion in the educational process, interactivity of materials, the ability to personalise and adapt to individual needs of students, the development of critical and creative thinking, the promotion of teamwork and communication, technical accessibility, and ease of use for teachers and students.

A pedagogical experiment was conducted between March and May 2025 with the participation of Secondary School students in such schools in Scotland as Stirling High School (Stirling) and Portobello High School (Edinburgh). These institutions were chosen because of their willingness to implement innovative digital tools and the availability of the necessary infrastructure to work with virtual learning environments. The sample included 120 students aged 13-15 years, who were divided into control (CG) and experimental (EG) groups (60 students in each group). The inclusion criteria were regular school attendance during the last academic semester, written consent from parents/guardians, and no medical contraindications to the use of immersive technologies. The exclusion criteria were recent epileptic seizures, visual impairment, lack of consent, or prolonged absence from classes. In addition, six teachers participated in the study (three in the experimental group and three in the control group). The inclusion criteria for teachers were the qualification of a high school teacher and at least two years of practical experience in teaching the subjects studied. The exclusion criteria were lack of consent to participate or inability to complete a short methodological training. The control group was trained in the format of conventional lessons using printed materials, frontal explanations, practical tasks, and group discussions. The experimental group worked for 45 minutes twice a week with virtual learning environments that included VR simulations, AR applications, and virtual labs. Classes were held for twelve weeks and covered individual practical tasks in simulators, pair and group projects in 3D environments, thematic quests, and reflexive entries in digital magazines. All topics and expected learning outcomes were identical to those used in the control group, which ensured comparability of the data. To assess academic achievements, author's tests were conducted before and after the experiment, which included questions of the same content. The use of a 12-week interval and the absence of a list of correct answers after the first test made it impossible to mechanically remember questions and ensure the validity of the measurement. All questions were evaluated as a percentage of correct answers, where 70-100% of answers meant a high level of knowledge, 40-69% – an average level, and 0-39% – a low level of assimilation of the material. In particular, the test included 15 questions with multiple choice answers in three subjects (History, Geography, Ecology). The questions were as follows:

1. What was the main function of castles in medieval Scotland?

A – Housing for farmers
B – Defensive structures
C – Religious centres
D – Workshops for gunsmiths

2. What weapons were most common during the Battle of Bannockburn?

A – Crossbow
B – Long sword
C – Roman gladius
D – Knights' pikes

3. What was the main reason for the rapid urbanisation in Victorian Scotland?

A – Tourism development
B – The Industrial Revolution
C – Development of navigation
D – Religious reforms

4. What element was an important part of the Scottish Highland clan culture?

A – Samurai sword
B – Tartan (checkered clothing)
C – Greek chiton
D – Roman toga

5. Who built the Hadrian's wall?

A – Vikings
B – Goths
C – Romans
D – Picts

6. What is the name of Scotland's main mountain region?

A – Lowland
B – Highland
C – Midland
D – Northland

7. What type of terrain does Arthur's Seat in Edinburgh belong to?

A – Karst plateau
B – Coal mines
C – Volcanic topography
D – River delta

8. What is the most important resource for the coastal regions of Scotland?

A – Oil and gas
B – Wood
C – Cotton
D – Hard coal

9. What is the typical climate for Scotland?

A – Tropical
B – Arctic
C – Temperate marine
D – Continental

10. What is the most likely cause of soil depletion in pastures?

A – Excessive grazing of livestock
B – Lava flows
C – Earthquake
D – Gold mining

11. What process corresponds to the transfer of nutrients in the soil to plants?

A – Photosynthesis
B – Osmosis
C – Diffusion
D – Evaporation

12. What process describes rain formation?

A – Crystallisation
B – Condensation
C – Sublimation

D – Subatomic decomposition

13. Who is at the top of any food chain?

A – Predator

B – Plant

C – Parasite

D – Decomposer

14. Which gas is the main factor in the greenhouse effect?

A – Oxygen

B – Carbon dioxide

C – Nitrogen

D – Hydrogen

15. What is required to preserve biodiversity in an ecosystem?

A – Complete removal of all predators

B – Regulation of human activity and conservation of the natural environment

C – Prohibition of new plant growth

D – Use of all resources without restrictions

Statistical analysis included comparing the gains in scores between groups using variance analysis (ANOVA) with a significance score at $p < 0.05$ and providing indicators of the magnitude of the effect (η^2); additionally, teachers assessed the level of involvement, cooperation and self-regulation of students on a 5-point Likert scale (Koo & Yang, 2025), which were also analysed using ANOVA. At all stages of the study, ethical requirements were met based on the Scottish Educational Research Association (2005), including written informed consent from parents/guardians and consent from students, and data anonymisation was ensured. An algorithm for implementing virtual learning environments in secondary schools was formed, which ensured the systematic integration of technology into the educational process and increased the effectiveness of lessons. The algorithm included evaluating students' learning goals and needs, selecting appropriate technological tools based on the criteria of immersion level, technical capabilities, and learning objectives, preparing teachers and students to work with virtual learning environments, planning lessons with consistent use of immersive exercises, and evaluating learning outcomes and correcting the process based on the data obtained. A limitation of the study is that it covered only two secondary schools and three academic subjects, including History, Geography, and Ecology.

RESULTS

Content analysis of the use of virtual, augmented and mixed reality in the educational process in Scotland

Virtual reality involves technology that creates a fully digital, immersive environment in which the user experiences presence and interacts with objects and processes that simulate the real or imaginary world. It is implemented using special devices, such as virtual reality headsets, controllers, motion sensors, and software for reproducing 3D scenes and simulations. In the broader context of extended reality (XR) technologies, there is a distinction between fully immersive virtual reality, where the user is separated from the real environment and interacts only with the digital world; augmented reality, which overlays digital objects on physical space via tablets, smartphones or smart glasses; and mixed reality, which combines digital and physical objects, enabling the interaction with both simultaneously (Musa *et al.*, 2022). In the educational context, virtual reality is used for modelling laboratory experiments, creating interactive simulators, 3D modelling, organising virtual classrooms and training tours, contributing to the development of practical skills, critical thinking, and teamwork. Schools in Scotland are actively implementing VR technologies: for example, in 2018, the East Renfrewshire Council purchased more than 900 ClassVR helmets for 30 schools, which gave students access to hundreds of virtual learning scenarios (Eichler, 2018). In Highland, Daviot Primary School students use ClassVR (n.d.) specifically to "travel" to historical locations and natural environments, which increases their interest (Munro, 2019). Futhermore, Engage VR (n.d.) allows organising large groups of up to 50 participants, setting up VR classes and training scenarios (Llanos-Ruiz *et al.*, 2025). In addition, Skills Development Scotland (2022), together with Balfour Beatty, introduced a VR tool that allows high school students to "visit" a construction site virtually as part of career guidance. According to Education Scotland (2021), VR environments are used to explore historical locations, artefacts, and create immersive educational experiences, although there are barriers such as cost, connectivity, and device management.

CoSpaces Edu Training & Projects (n.d.) provides the ability to programme and animate objects, supports the design of interactive AR/VR scenes, and joint editing of projects, which encourages creativity and project thinking. Merge Cube (n.d.), which allows interacting with virtual 3D objects in hands and using them to study anatomy, geography, chemistry, and STEM (Science, Technology, Engineering, Mathematics) modelling. Contemporary educational technologies that include virtual reality, augmented reality, and mixed reality provide opportunities for developing students' practical skills, creative and critical thinking (Thangavel *et al.*, 2025). Augmented reality on tablets and smartphones overlays digital objects on the real world, allowing to demonstrate learning models, experimental processes, or interactive circuits without completely disconnecting from the physical environment, and is convenient for quickly explaining complex topics in natural, technical, or humanitarian disciplines. Mixed reality presented by Microsoft HoloLens (n.d.) and zSpace (n.d.) combines digital and physical objects, allowing the user to simultaneously interact with both, control models with gestures and voice, which creates an effective environment for modelling professional processes, conducting joint projects and educational demonstrations. Thus, all these technologies differ in the level of immersion, type of interaction, and opportunities for developing practical, creative, and collective skills (Table 1). Fully immersive systems and mixed reality are most suitable for practical and professional simulations, while augmented reality effectively demonstrates objects in a physical environment, virtual laboratories provide safe experiments, and panoramic environments support visual cognition of the world and stimulate learning activity. Together, these formats form a fully digital educational environment in which the student can immerse themselves in educational content and interact with objects and tools using controllers or touch devices. The table shows that different formats of XR technologies differ in functionality and pedagogical potential. Thus, fully immersive VR provides the deepest sense of presence and allows simulating complex situations, but requires special equipment and limits large-scale group interaction. AR, on the other hand, is more accessible and easier to use, giving students the freedom to choose the material, but provides a lower level of immersion. MR combines the advantages of both approaches, enabling the work with holographic objects in real space and maintaining a high level of interactivity and analytical capabilities, although its implementation is constrained by cost and technical complexity. In general, the data show that each format has its own educational advantages: VR enhances immersion and decision-making, AR – accessibility and practical interaction, and MR – spatial thinking and depth of analytical work, which allows choosing the best solutions in accordance with the educational goals and resource capabilities of the educational institution.

Table 1. Content analysis of VR, AR, and MR technologies in school education

XR type/ Platform	Immersion level	Interactivity	Personalisation and adaptation	Development of critical and creative thinking	Teamwork and communication	Technical accessibility and ease of use
Fully immersive VR (Class VR; Engage VR)	High level of immersion. Students find themselves inside recreated historical battles or natural locations, can move, view objects in 360°	Students manipulate objects, interact with NPCs (Non-Player Characters), and complete tasks in scenarios	Ability to choose the mission difficulty level or route in VR, but changes are limited to content	Necessary to make decisions in simulated situations, for example, plan a strategy in battle	Limited: two or three students can simultaneously be in space and coordinate actions	Requires special helmets, sensors, and a personal computer with a powerful video card; installation is difficult
Augmented reality AR (Merge Cube; CoSpaces Edu Training & Projects)	Average level of immersion. Students can see real classrooms/squares with superimposed 3D objects, such as historical monuments in the classroom or animals in geography	Ability to rotate, scale, view 3D objects, and perform the “find an object” task	Students choose their own subject or topic for research in the application	Analyse the location of objects and make comparisons between models	Students can work in pairs by commenting or adding their own notes	Available on devices that are already in school; applications are installed quickly
Mixed reality (Microsoft HoloLens; zSpace)	High level of immersion. Students can see real space and holograms, such as architectural models of locks on the desk	Ability to move holograms, take them apart, and take measurements	Ability to select the level of detail of the model or display additional data	Students analyse the structure of objects, find errors in constructions	Limited: up to 4 students work with the same model simutaneously	Helmets are expensive, require customisation, and teacher training is required

Source: compiled by the authors based on the study of Microsoft HoloLens (n.d.), CoSpaces Edu Training & Projects (n.d.), Engage (n.d.), zSpace (n.d.), Merge Cube (n.d.), Engage VR (n.d.)

Assessment of the integration of VR, AR and MR technologies in the teaching of geography, history, ecology, and their impact on the assimilation of educational material

To ensure the validity of the experimental study and the correctness of further comparative analysis of the influence of VR, AR, and MR technologies on the assimilation of educational material at the initial stage, the same starting conditions were created for the control and experimental groups. All students were enrolled in an identical curriculum in History, Geography, and Ecology, had a comparable level of preliminary training, and were not informed about the use of immersive technologies in the educational process before starting the experiment. This made helped to minimise the impact of external factors and ensure comparability of results between groups.

Initial testing was carried out before the introduction of any VR, AR, or MR tools and was aimed at fixing the basic level of subject knowledge of students. The assessment used author-developed tests with identical questions for both groups, covering key topics from three academic disciplines. The results obtained allowed testing the uniformity of the sample and substantiating further use of experimental design to evaluate the effect of implementing XR technologies. Table 2 shows the results of students' pre-experiment testing, presented as a percentage of correct answers for each question on History, Geography, and Ecology for the control and experimental groups. A summary of the results of the initial testing presented in Table 2 indicates a comparable level of educational training of the control and experimental groups in History, Geography, and Ecology. The average percentage of correct answers from History in the control group was approximately 54-55%, while in the experimental group it was 53-54%, which corresponds to a difference of about 1 percentage point. A similar situation was observed in Geography: the average indicators of correct answers in CG and EG ranged from 52-53%, and the difference between the groups did not exceed 1-2 percentage points. In Ecology, both groups showed slightly higher results compared to other subjects: the average level of correct answers in the control group was approximately 58-59%, in the experimental group – 57-58%, with a total difference between the groups of about 1 percentage point. The overall average score for all three disciplines in the control group was slightly higher than in the experimental group, but the total difference did not exceed 1-2%, which indicates the uniformity of the sample at the initial stage of the study. Analysis of the structure of academic achievement shows that students of both groups learned better tasks focused on factual and applied knowledge related to specific historical events, geographical objects, or environmental phenomena that can be observed in real life. Instead, questions that required abstract thinking, generalisation, or understanding of complex causal relationships were more difficult for a significant proportion of students, regardless of the group. This distribution of results indicates the predominance of reproductive and applied levels of knowledge acquisition before the start of experimental training. Thus, the data obtained confirm the absence of significant differences between the control and experimental groups in terms of the level and structure of initial knowledge, which creates correct methodological prerequisites for further analysis of the influence of VR, AR, and MR technologies on the dynamics of students' academic achievements. Table 3 shows the test results after the experiment was completed.

Table 2. Results of testing students before the experiment

Question	A (CG/EG) %	B (CG/EG) %	C (CG/EG) %	D (CG/EG) %
What was the main function of castles in medieval Scotland?	12/13	63/62	15/14	10/11
What weapons were most common during the Battle of Bannockburn?	18/17	52/53	10/11	20/19
What was the main reason for the rapid urbanisation in Victorian Scotland?	10/11	66/65	12/13	12/11
What element was an important part of the Scottish Highland clan culture?	9/10	71/70	12/11	8/9
Who built the Hadrian's wall?	7/8	10/9	72/71	11/12
What is the name of Scotland's main mountain region?	14/13	64/63	12/13	10/11
What type of terrain does Arthur's Seat in Edinburgh belong to?	11/12	9/8	68/67	12/13
What is the most important resource for the coastal regions of Scotland?	58/57	16/17	10/11	16/15
What is the typical climate for Scotland?	6/7	9/10	72/71	13/12
What is the most likely cause of soil depletion in pastures?	61/60	14/15	12/11	13/14
What process corresponds to the transfer of nutrients in the soil to plants?	8/9	11/12	69/68	12/11
What process describes rain formation?	10/11	74/73	9/10	7/6
Who is at the top of any food chain?	14/15	62/61	12/13	12/11
Which gas is the main factor in the greenhouse effect?	13/12	11/12	63/64	13/12
What is required to preserve biodiversity in an ecosystem?	11/12	10/9	68/67	11/12

Source: compiled by the authors based on a pedagogical experiment

Table 3. Results of testing students after the experiment

Question	A (CG/EG) %	B (CG/EG) %	C (CG/EG) %	D (CG/EG) %
What was the main function of castles in medieval Scotland?	13/8	64/78	14/10	9/4
What weapons were most common during the Battle of Bannockburn?	19/10	51/76	11/8	19/6
What was the main reason for the rapid urbanisation in Victorian Scotland?	11/7	65/79	13/8	11/6
What element was an important part of the Scottish Highland clan culture?	10/5	72/80	11/9	7/6
Who built the Hadrian's wall?	8/5	9/9	71/82	12/4
What is the name of Scotland's main mountain region?	15/9	63/77	11/8	11/6
What type of terrain does Arthur's Seat in Edinburgh belong to?	12/7	10/10	67/78	11/5
What is the most important resource for the coastal regions of Scotland?	59/45	15/20	11/12	15/23
What is the typical climate for Scotland?	7/4	8/10	71/80	14/6
What is the most likely cause of soil depletion in pastures?	60/45	15/18	13/14	12/23
What process corresponds to the transfer of nutrients in the soil to plants?	9/5	12/10	68/80	11/5
What process describes rain formation?	11/7	73/81	10/8	6/4
Who is at the top of any food chain?	15/9	61/78	11/8	13/5
Which gas is the main factor in the greenhouse effect?	12/8	12/10	62/79	14/3
What is required to preserve biodiversity in an ecosystem?	10/7	11/10	69/81	12/2

Source: compiled by the authors based on a pedagogical experiment

After completing the experimental stage of training, there were clear differences between the control and experimental groups in all three academic disciplines. In the control group, which studied according to the conventional curriculum using printed materials, frontal explanations, and standard practical tasks, the overall level of academic achievement remained close to the initial indicators. Instead, in the experimental group, where VR, AR, and virtual laboratories were systematically used, there was a significant increase in the average percentage of correct answers.

As part of the History course, the average number of correct answers in the experimental group exceeded the corresponding number in the control group by about 10-15 percentage points. The greatest increase was observed in tasks related to spatial and contextual understanding of historical objects and events. This is explained by the fact that the students of the experimental group worked with virtual reconstructions of medieval castles, interactive models of historical battles, and three-dimensional visualisations of cultural artefacts, which contributed to the development of a holistic view of the historical space and socio-cultural context of the era. In terms of Geography, the difference between the groups was also stable and averaged 10-14 percentage points in favour of the experimental group. The use of VR panoramas, 3D terrain models, and AR visualisations of geographical objects allowed students of the experimental group to better navigate the spatial characteristics of Regions, terrain features, and climatic conditions. In the control group, the assimilation of these topics was mainly limited to the reproduction of educational material. The most noticeable effect of using immersive technologies was observed in the Ecology course, where the difference between the average indicators of the experimental and control groups reached 12-16 percentage points. Students in the experimental group demonstrated a better ability to explain dynamic natural processes, in particular, the cycle of substances, atmospheric phenomena, and relationships in ecosystems. This is conditioned by the use of virtual laboratories and simulations that allowed observing processes in development, and not just in a static description.

Thus, the results obtained confirm that the introduction of VR, AR, and other immersive technologies in the educational process provided not only a quantitative increase in correct answers, but also qualitative changes in the knowledge structure of students in the experimental group. In contrast to the control group, where the reproductive level of material assimilation dominated, the experimental group increased elements of applied and analytical thinking, which creates prerequisites for deeper and more stable learning. Table 4 presents the results of an expert assessment of students' level of engagement, cooperation, and self-regulation.

Table 4. Teachers' assessment of students' level of engagement, cooperation, and self-regulation in subjects (5-point scale)

Subject	Engagement (M ± SD)	Cooperation (M ± SD)	Self-regulation (M ± SD)
History	4.2 ± 0.5	4.0 ± 0.6	3.9 ± 0.5
Geography	4.1 ± 0.6	3.9 ± 0.6	3.8 ± 0.5
Ecology	4.3 ± 0.5	4.1 ± 0.5	4.0 ± 0.5

Source: compiled by the authors based on Likert scale (Koo & Yang, 2025)

Analysis of the results showed that the highest level of student engagement was observed when studying Ecology, while in History and Geography courses this indicator was slightly lower. A similar trend was observed in relation to cooperation: students who studied Ecology showed a greater tendency to work together compared to other subjects, while in Geography this indicator was the least pronounced. The level of self-regulation was also highest in the Ecology course, while in History and Geography studies it was characterised by moderately lower values. In general, the results obtained indicated more favourable conditions for the development of active participation, interaction and independence of students in the process of studying ecology in comparison with other subjects. In general, teachers' assessments indicate a high level of activity, interaction, and self-learning ability of students, with small differences between subjects, with ecology standing out as the discipline with the greatest engagement and effective collaboration. Table 5 provides comparative data on the level of student engagement, collaboration, and self-regulation between the experimental and control groups.

Table 5. Comparison of students' level of engagement, collaboration, and self-regulation

Indicator	Experimental group (M ± SD)	Control group (M ± SD)	F	p	η^2
Engagement	4.3 ± 0.5	3.6 ± 0.6	15.21	<0.005	0.25
Cooperation	4.1 ± 0.6	3.5 ± 0.7	11.47	0.005	0.20
Self-regulation	4.0 ± 0.5	3.4 ± 0.6	13.05	<0.005	0.22

Note: effect value $\eta^2 \approx 0.01$ – small effect; $\eta^2 \approx 0.06$ – average effect; $\eta^2 \geq 0.14$ – large effect; $p \leq 0.05$ – statistically significant difference; $p > 0.05$ – no statistically significant differences were found

Source: compiled by the authors based on the ANOVA method

Analysis of the average values showed that the experimental group showed higher levels of engagement, collaboration, and self-regulation compared to the control group. The results obtained showed that the introduction of an experimental approach affected the nature of students' learning activities. In the experimental group, a higher level of involvement in the educational process was observed, which indicated an increase in interest, active participation and motivation compared to the conventional organisation of training. Cooperation between students was also more pronounced, which was manifested in readiness to perform tasks together, mutual support, and exchange of ideas. The level of self-regulation in the experimental group indicated a better ability of students to plan their own activities, monitor the performance of educational tasks, and be responsible for learning outcomes. But in the control group, these characteristics were less pronounced, which indicated the limited possibilities of conventional methods in the development of active, collaborative, oriented, and independent learning behaviour of students. ANOVA statistical analysis confirmed a significant difference between the groups for all indicators ($p \leq 0.05$), which indicates a noticeable effect of using innovative technologies. The best results of the experimental group are explained by the use of MR, AR, and VR technologies, which contributed to greater interest of students, active interaction during training and the development of skills of independent organisation of the educational process. Interactivity and visibility of the material in virtual environments allowed students to better assimilate knowledge and collaborate more effectively, which was reflected in the increased average indicators.

Based on the analysis of contemporary educational technologies and the experience of school education in Scotland, an algorithm for involving virtual learning environments in the secondary school educational process was formulated. The algorithm covers several consecutive stages that ensure effective integration of immersive technologies (VR, AR, MR) into training programmes. Table 6 provides a structured step-by-step algorithm for implementing virtual learning environments, which summarises the key steps of their successful adaptation to school education.

Table 6. Algorithm for involving virtual learning environments in the learning process

Stage	Stage content	Key actions
1. Analysis of the needs of the educational process	Identification of learning topics and competencies where immersive technologies can improve efficiency	curriculum analysis; identification of topics where visualisation/modelling is required; school readiness assessment
2. VR integration planning	Development of a plan for using virtual learning environments in specific subjects and age groups	selection of VR/AR/MR resources; planning lessons with immersive activities; preparation of methodological materials
3. Technical and pedagogical training	Ensuring technical conditions and readiness of teachers	equipment setup; teacher training; development of safety instructions
4. Conducting lessons	Implementation of interactive immersive activities in the educational process	use of virtual laboratories, simulations, excursions; support of students during work; monitoring of educational activities
5. Evaluation of results and improvement	Analysis of the effectiveness of using immersive technologies and correction of approaches	collecting feedback; analysing student performance; optimising lesson scenarios

Source: compiled by the authors based on own research

The practical application of the algorithm assumes that the school first identifies learning topics and competencies that can be enhanced with immersive digital tools, and then prepares the technical infrastructure. At the final stage, the school evaluates the effectiveness of using immersive technologies, updates methodological strategies, and plans further development of components of the virtual learning environment. Thus, the proposed algorithm provides a systematic integration of virtual learning environments into school education and a holistic and pedagogically sound implementation of XR technologies, making learning more interactive, efficient and adapted to the needs of students. It helps to increase students' motivation and interest, deepen their understanding of complex concepts through immersive exercises, develop practical, creative, and critical skills, improve digital competence, and create conditions for continuous improvement of the educational process.

DISCUSSION

In school education in Scotland, virtual learning environments are used to conduct immersive lessons, virtual excursions, research historical events and support career guidance for high school students, which helps to increase motivation and develop students' practical skills. Augmented, virtual, and mixed reality technologies create an interactive educational environment in which students can simultaneously interact with digital and physical objects. Providing schools with immersive devices and implementing national methodological guidelines allows developing digital competencies, critical thinking, cooperation, and self-regulation skills. The use of XR technologies in training contributes to the development of both subject competencies (deeper study of material on History, Geography, and Ecology) and metasubjects – critical thinking, self-regulation, planning, information analysis, and effective interaction. Due to the immersive, interactive, and practical nature of such technologies, students have the opportunity to experiment, model situations, and apply knowledge in a virtual environment.

The conclusions obtained were consistent with the opinion expressed by A. Barrable (2019) that a virtual educational environment forms students' ability to make independent decisions and supports learning activity. In addition, the results were consistent with the observations of M. Adhikariparajuli *et al.* (2021), who found that integrated approaches to reporting and evaluation in education, in particular testing, improve management efficiency and promote transparency of educational processes in Scotland, Northern Ireland, and Wales. After the experiment, students showed an improvement in knowledge and skills in History, Geography, and Ecology, which was confirmed by an increased percentage of correct answers in standardised tests, and the development of skills to analyse information, work in a team, and independently plan educational activities due to the integration of VR, AR, and MR technologies into the educational process. The study showed similarities with the study by J. Crow & J. Murray (2020), where the virtual learning environment was presented as a resource for building a community that fostered a sense of belonging and emotional presence. It was found that this sense of inclusion increased students' readiness for active interaction and long-term digital engagement. However, the results obtained regarding adaptive approaches in virtual learning were confirmed in the conclusions of U. Apoki *et al.* (2022), S. Chandra *et al.* (2022), who emphasised the effectiveness of various types of virtual learning. Students can use various types of virtual reality in their studies, including VR simulations for modelling historical events or natural processes, virtual laboratories for conducting experiments in Chemistry, Physics and Biology, 360° videos and panoramas for virtual excursions and geographical landscapes research, AR applications on tablets and smartphones for interactive study of objects and phenomena in a real environment, and MR environments for creating and interacting with 3D models and group projects in a mixed real and virtual space.

After the experiment, the experimental group showed an improvement in results compared to the control group in questions on History, Geography, and Ecology, where the percentage of correct answers increased to 76-81%, while in the control group the indicators remained almost at the previous level of 52-74%. Parallel conclusions were observed in the papers by R. Al-Maroof *et al.* (2021), Z. Duraku & L. Hoxha (2020), which pointed out the effectiveness of using VR, AR, and MR technologies in teaching, which depends on several factors, in particular, on the quality and interactivity of digital content, the level of immersion of students in a virtual environment, the regularity and duration of classes. The study defined virtual reality as an interactive digital environment that completely immerses the user in simulated reality using special devices, such as VR helmets or touch controllers, creating a sense of presence in another space. It includes 3D models of objects and locations, interactive simulations, audio-visual effects, the ability to interact with digital objects and the environment, and tools for educational, research, or entertainment tasks. Similar conclusions were obtained by B. Danmuchikwali & M. Suleiman (2020) and D. Bahanshal & I. Khan (2021), who emphasised that virtual reality is effective when its use has a clear educational or practical purpose and is integrated into the educational process as an additional tool, rather than as a replacement for conventional methods. It should be used to increase motivation, develop critical thinking, practical skills, and develop competencies through interactive and immersive tasks.

The average values of engagement, collaboration, and self-regulation were also higher in the experimental group (4.0-4.3) compared to the control group (3.4-3.6), which indicates that the use of VR, AR, and MR technologies contributed to better assimilation of the material, active interaction between students, and the development of their key competencies. This was confirmed in the results of the study by Y. Gambo & M.Z. Shakir (2021), who noted that virtual learning environments encourage the development of learning material processing and learning planning strategies. This shows that virtual platforms can create conditions for the development of autonomy and responsibility for the educational process. The results obtained during the analysis of the use of virtual tools in training indicate an improvement in critical thinking skills, which is partly consistent with the conclusions of J. Hsiao & J. Chang (2023) and S. Cruywagen & H. Potgieter (2020), who pointed out that critical thinking in learning is necessary because it allows students not only to remember information, but also to analyse, compare, and evaluate different sources and ideas. It promotes the ability to draw informed conclusions, solve problems, make informed decisions, and effectively apply knowledge in various life and professional situations. In addition, according to A. Kundu & T. Bej (2020), the availability of integrated digital resources contributes to higher levels of student engagement and engagement during tasks, reflecting their willingness to use technology for learning. Students were evaluated for their level of engagement, collaboration, and self-regulation, which showed higher rates in the experimental group due to the use of VR technologies.

The study by K. Martzoukou *et al.* (2020) found that having skills to use online resources effectively makes it easier to complete tasks and allows for more active participation in learning. The results showed that since the control group was trained using standard methods without using VR technologies, its results remained lower compared to the experimental group. This trend supports assumptions about the need to develop digital skills, namely the study by I. El-Sayed Ebaid (2020) found that students should be instructed to effectively interact with virtual learning platforms. In this study, students in the experimental group were pre-instructed on the safe use of VR equipment, which included rules for setting up helmets, maintaining a proper fit, avoiding prolonged use without interruptions, safe movement in space, and behaviour when working with interactive environments.

The proposed algorithm for integrating virtual reality into school education fully coincides with the conclusions of a number of researchers regarding the influence of digital and immersive environments on the educational process. As noted by M. Shoaib *et al.* (2025), adapting VR and AR platforms to the needs of different groups of learners helps to increase their engagement and learning effectiveness, while interactive tasks and teamwork stimulate the development of critical thinking and collaboration, which is consistent with the findings of Z. Yu & M. Li (2022) and A. Oke & F. Fernandes (2020). The use of gamification elements in the algorithm, in particular, project tasks, 3D modelling, and 360° video, supports internal motivation and regular activity of students, which confirms the conclusions of J. Xu *et al.* (2021). Thus, the results of the study showed that a systematic approach to the introduction of virtual reality and the integration of interactive game elements correspond to previously identified patterns of improving learning efficiency and developing key competencies of students. The results obtained showed that the use of virtual reality platforms contributes to improving the study of educational material in various subjects and the development of competencies. Students can improve their knowledge and skills through active use of interactive technologies, practical exercises in virtual environments, participation in group projects and independent analysis of the material, which contributes to the development of critical thinking, self-regulation, and skills to apply knowledge in practice.

CONCLUSIONS

The content analysis of the use of XR technologies in school education in Scotland showed that various formats of virtual, augmented, and mixed reality form a multi-level digital learning environment with varying degrees of immersion and pedagogical potential. VR technologies provide a high level of immersion and create conditions for modelling complex historical, natural and scientific scenarios, which contributes to the development of strategic and spatial thinking, provided that appropriate technical support is available. AR tools are more accessible and support analytical and comparative study of educational material, while MR technologies combine physical space and holographic objects, deepening understanding of complex structures and relationships, although their practical implementation is limited by technical complexity and cost.

The results of the pedagogical experiment confirmed the comparable initial level of training of the control and experimental groups in History, Geography, and Ecology, which ensured the correctness of further analysis. After integrating VR, AR, and MR technologies, the experimental group showed a steady increase in academic achievement in all the disciplines studied, while the results of the control group remained close to the initial ones. A summary of the post-test results showed that the average level of correct answers in the experimental group exceeded the control group by about 10-15 percentage points in History, 10-14 percentage points in Geography, and 12-16 percentage points in Ecology.

The resulting dynamics indicates not only a quantitative improvement in the results, but also a change in the nature of the assimilation of educational material – from mainly reproducible to a more applied and analytical level, especially in topics related to spatial representations and dynamic natural processes. Along with the growth of subject results, positive changes in the learning behaviour of students in the experimental group were recorded: increased levels of engagement, cooperation, and self-regulation, which was confirmed by statistically significant differences with a large effect size. Summarising the results of the study, it can be concluded that the integration of immersive technologies into the educational process of secondary schools creates favourable conditions for a deeper understanding of educational material, the development of critical thinking, and the development of skills for independent organisation of training. Prospects for further research are related to the integration of artificial intelligence to personalise learning and support adaptive educational platforms.

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Flipped classrooms in higher education: A comparison of implementation in the United Kingdom and Japan

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Abstract. This article aimed to investigate the influence of the flipped classroom approach on students' active involvement and the results of academic learning in higher education, with consideration of pedagogical practices and cultural specifics in the universities of Luton and Tokyo. The study used the methods of theoretical analysis of the concept of a flipped classroom, content analysis of curricula and educational online platforms of British and Japanese universities, pedagogical experiment based on the flipped classroom model during one semester (February-June 2024) at the Universities of Bedfordshire (United Kingdom) and of Tokyo (Japan), with the participation of 360 students, as well as the development of scenarios of organisation of students' learning activities in the framework of the flipped classroom approach. The content analysis showed that the use of interactive multimedia (PlayPosit, H5P, Genially, Socrative, OneNote) allows students to interactively assimilate the material, collaborate and actively communicate. The pedagogical experiment revealed that the students of the experimental group obtained higher mean values (United Kingdom $M = 4.76$; Japan $M = 4.85$) as compared to the control groups (United Kingdom $M = 4.05$; Japan $M = 4.10$), mainly due to collaborative interaction, active participation in the lectures with the professor, and working with interactive online resources. The highest level of full task execution was in experimental groups on the discussion of problems in the group (88-90%), and the lowest level was in the control groups on the reports of individual students (65-66%). In other tasks, it was shown that collaborative work leads to a better quality of assimilation of educational material, while individual tasks result in an average level of assimilation of the educational material. The difference between the groups was statistically significant ($p < 0.05$), and the dynamics of the indicators in the experimental groups confirmed the effectiveness of the flipped classroom model. Learning activity scenarios can enhance motivation, engagement and knowledge acquisition. The practical significance of the study lies in the possibility for lecturers and higher education administrators to use the findings to implement the flipped classroom model in order to increase student interest, learning motivation and the effectiveness of material assimilation

Keywords: students; online resources; communicative skills; material assimilation; motivation

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INTRODUCTION

The study of flipped classrooms in higher education is necessary, as this approach combines independent study of learning material with active in-class interaction, thereby creating conditions for knowledge acquisition and the development of critical thinking. In the United Kingdom, this model serves as an instrument for developing the skills of thinking analytically, independent and critical thinking and the ability to reflect as per the requirements of professional training. In Japan, a new model has been introduced within the cultural traditions of collective learning and disciplined education, stimulating the students' motivation and engagement. In comparing the British and Japanese experience, this allows for the analysis of the contribution of cultural, methodological and technological components to the effectiveness of the flipped classroom as a pedagogical method, and to determine the optimum way to implement this model in different countries. Such an analysis could lead to the improvement of teaching methods of higher education and raise the quality of the educational process in general.

The concept of a flipped classroom is becoming popularised in universities around the world, including the United Kingdom and Japan, thereby offering the opportunity to reassess the traditional methodology and practice of higher education. Researchers have examined this topic in order to determine the effectiveness of the model in fostering students' cognitive activity, independence and academic performance. B. Birgili *et al.* (2021) have noticed that the number of publications about the flipped classroom has been steadily increasing from 2012 to 2018. According to these authors, most studies provide support for the effectiveness of flipped learning in improving the quality of educational achievements and increasing the motivation of the students. In British universities, flipped classrooms have already been integrated into language, technical and pedagogical disciplines, reflecting an effort to enhance learning activity through the combination of online and in-class formats. According to A. Andujar *et al.* (2020), the study carried out in the United Kingdom revealed that mobile phones were among the important technologies involved in the flipped learning concept in the domain of foreign language education. The use of digital platforms for selfstudy offers flexibility and allows learners to set their own pace. This confirms the results obtained by M. Jiang *et al.* (2020), who found that within language education, the flipped classroom provides opportunities for interactive learning in which the interaction between the student and the lecturer occurs with the use of digital tools in a hybrid format. Japanese researchers are more interested in the problem of cultural adaptation of the flipped classroom format. A. Ito *et al.* (2022) studied the efficiency of the application of the flipped classroom in the context of Japanese education and proved that the flipped classroom model is more effective in the assimilation of theoretical material, in that students prepare beforehand (at home), and in class, practice the acquired knowledge. Such a format is more efficient than the traditional lecture in disciplines that require combining theory and practice. B. Aksoy & E. Pasli Gurdogan (2022) found that the flipped approach in student training contributes to the development of motivation, the improvement of learning strategies and the enhancement of professional skills. Participants in the experiment demonstrated higher performance in practical tasks than those taught using a traditional model.

S. Dianati *et al.* (2020), who also studied student attitudes toward the use of interactive learning platforms, pointed out that its implementation promotes a more active approach to learning on the students' part. This is supported by the increased level of lecturer–student interaction that was revealed and by the increase in students' interest in learning. In the meantime, P. Joy *et al.* (2023) pointed out that the interplay between emotional and cognitive factors during a flipped classroom can provide students with a good learning environment to encourage active thinking and collaboration. M. Ozudogru & M. Aksu (2020) have found that teachers with less experience consider that flipped classroom sessions are more flexible and supportive of critical thinking, but noted the need for more preparation for independent study. It can be assumed that the effectiveness of this method depends on the course design and the students' readiness for independent study. The potential of the flipped classroom for the development of higher-order cognitive skills is examined by Japanese and United Kingdom scholars. It has been shown by Y. Ma (2023) that the flipped classroom model contributes to the development of critical thinking skills, which is evidenced by the focus on critical analysis, argumentation and the analysis of practical problems during class. Students exhibit a higher level of cognitive engagement and improved assimilation of learning material. R. Ramadhani & Y. Fitri (2020) show that the combination of the project-based learning approach with the flipped classroom model promotes more in-depth understanding of the content and the ability to apply the acquired knowledge in practice, in their field of expertise. Such an organisation of education promotes the development of collaboration skills and responsibility for group outcomes.

However, the studies mentioned above still leave gaps, notably in relation to the limited comparison of the effect of using a flipped classroom approach across different countries with a variety of cultures and education systems. Not enough attention is paid to such factors as pedagogical traditions, motivation styles, and digital literacy in the United Kingdom and Japan. This article aimed to determine the effectiveness of implementing the flipped classroom model in enhancing student engagement and improving academic performance in higher education institutions in Japan and the United Kingdom. The objectives of the study were to conduct a content analysis of methodological programmes, teaching models and digital resources within the flipped classroom approach; to evaluate the effectiveness of the flipped classroom model in relation to student motivation and learning outcomes in the United Kingdom and Japan;

to determine the impact of the pedagogical experiment on student motivation and academic performance; and to develop scenarios of student learning activities based on the flipped classroom model.

MATERIALS AND METHODS

The study employed a mixed-methods design, combining content analysis of educational materials with a pedagogical experiment and quantitative statistical analysis of learning outcomes. Within the theoretical and analytical stage, a content analysis was conducted of teaching materials and practices related to the implementation of the flipped classroom in universities in the United Kingdom and Japan. Methodological programmes of the Department of Flipped Learning Technologies (FLIT) (n.d.), as well as those of the University of Bedfordshire (Clifford, 2018), were analysed.

The principal models of flipped learning were also systematised: the Collaborative Flipped Model (n.d.), the Flipped Mastery Model (Laoha & Piriyasurawong, 2018), and the Flipped MOOC (Massive Open Online Course) Model (Pan *et al*., 2022). In addition, the Flipped Interactive Model (Gasaymeh & AlMohtadi, 2024) and the Traditional Flipped Classroom (Singha, 2025) were examined. A range of digital educational resources was used to implement learning tasks. Specifically, PlayPosit (n.d.) enabled the creation and delivery of an interactive learning presentation, and H5P (n.d.) was used to build a number of interactive assignments. Genially (n.d.) was used to create images, visualisations and presentations, Socrative (n.d.) was used to prepare different online activities like tests and surveys. OneNote (n.d.) was used to ensure that feedback would be easy to receive by providing students with the opportunity to leave digital comments and share useful information. In conducting content analysis of the teaching materials and learning practices, comparisons were made on the basis of the following: the organisation of independent work (online/offline) in a flipped classroom; the content of classroom interaction; the types of digital resources applied; and cultural and pedagogical features of education.

The pedagogical experiment was carried out for one semester (February-June 2024) at the University of Bedfordshire (United Kingdom) and the University of Tokyo (Japan), which were chosen owing to differences between the national education systems and the high level of digitalisation of the universities. The experiment involved 360 students of the third year of the Pedagogy major (180 from the United Kingdom and 180 from Japan). Their age ranged from 21 to 22 years old. The factor of sex was not considered. Participants were selected under the condition that they consented to participate and attended 70% of the classes. The following criteria were the grounds for exclusion: missed more than 30% of online and face-to-face classes; did not fulfil practical tasks; and failed to complete the questionnaire. Assessment of outcomes was carried out by four lecturers with at least three years' experience of working with the flipped classroom model, none of whom taught other student groups within the experiment concurrently.

The participants at both universities were randomly and equally divided into control and experimental groups. Both groups used the flipped classroom, but the organisation of learning activities was different. For the control groups, individual activities were mainly used; for the experimental groups, collaborative forms of interaction (group work, teamwork, group decision-making) were used. Students performed the following kinds of learning activities: watched video materials, took online tests, analysed case studies, performed practical tasks, prepared presentations, participated in discussions, and prepared reflective essays. The effectiveness of learning was assessed using pre-test and post-test measures.

A questionnaire was used to evaluate the level of the students' interest and engagement. The questionnaire contained items based on the 5-point Likert scale (1-5). These included the following statements: "Active preparation of material before the session"; "A sense of interest during group discussion"; "The model facilitated a better understanding of the material"; "Willing participation in practical tasks during the session"; "Confidence when completing tasks independently"; "Active interaction with the lecturer during the explanation of new material"; "Application of acquired knowledge in group projects"; "Satisfaction with individual learning progress". Student motivation was additionally assessed using the AMS – Academic Motivation Scale (n.d.). Data from the learning tasks were presented as percentages and categorised in four groups: low (up to 20%), moderate (20-50%), high (50-80%), and very high (over 80%). Statistical data processing was carried out using SPSS (Statistical Package for the Social Sciences). Mean values (M) were calculated, and Student's t-test and ANOVA were used to test for differences between groups and types of learning activities in terms of motivation and learning outcomes. The reliability of the assessment tools was tested using Cronbach's α coefficient, with a level of statistical significance set at $p < 0.05$.

Additionally, the comparative analysis of the results of individual and group tasks and the content analysis of learning results were carried out. This made it possible to interpret the findings with regard to the cultural and pedagogical characteristics of education in the United Kingdom and Japan, as well as to evaluate the effectiveness of implementing the flipped classroom model, the development of practical skills, critical thinking and collaborative interaction. The study was carried out in accordance with the provisions of the Declaration of Helsinki of the World Medical Association (World Medical Association, 2013) and was approved by the university's ethics committees. All students were informed about the purposes and conditions of the research and had the opportunity to withdraw from it.

RESULTS

Content analysis of methodological programmes, models of teaching and digital resources of the flipped classroom

The flipped classroom is a model in which students study the primary material by themselves prior to class, while during the classroom period, there is active learning, discussion, practical activities and project work (Strelan *et al.*, 2020). In this case, the lecturer's role is that of tutor, responsible for the organisation of interaction and support. This model promotes knowledge acquisition, the development of critical thinking, teamwork and student autonomy. The organisation of the flipped classroom is based on prior independent preparation, interactive in-class activities and the use of digital resources. The model is associated with active and blended learning and supports differentiation and adaptive assessment (Li *et al.*, 2023; El Baaqyly, 2023), thereby enhancing motivation and enabling regulation of the pace of learning (Chen & Hsu, 2022). Digital platforms, video materials, Learning Management System (LMS), and online tests contribute to the organisation of a free space for self-study and for the efficient use of classroom time. Moreover, within the Transform4Europe (n.d.) initiative, they facilitate academic mobility and student integration in international learning opportunities.

In Japan, the Department of Flipped Learning Technologies (FLIT) (n.d.) programmes are designed to integrate the collaborative learning forms such as group discussion, joint problem solving, and gradual learning following the "mastery learning" principles. In this country, much attention is paid to the traditional values of Japanese pedagogy, such as strict discipline, organisation, student community, and gradual mastery of knowledge (control by means of regular tests and group work). In contrast, as is demonstrated by the University of Bedfordshire (Clifford, 2018) in the United Kingdom, the flipped classroom is based on the principle of active independent work of students, the development of their critical and analytical thinking and autonomy in learning. During class time, students are engaged in discussions, practical tasks and case studies, which enables them to get more involved and to develop relevant communicative and decision-making skills. Thus, the main difference between the two countries' programmes is their cultural and pedagogical orientation: Japanese programmes are focused on collaborative learning and staged knowledge building, whereas British approaches rely more on individual student activity and the development of critical and analytical thinking through free study and interactive classroom work. An analysis of the experience of the universities of Luton and Tokyo shows that in both countries, students initially engage with learning materials online, while classroom time is primarily devoted to discussion and the completion of practical tasks. However, differences in approach remain. While the Japanese experience focuses mainly on collective tasks and group discussions (which is in line with traditional methods), in the United Kingdom, there is a tendency to give more attention to individual student work, the development of critical thinking skills and the use of knowledge autonomously. The main existing types of the flipped classroom model, along with their main characteristics and the differences in terms of learning organisation, roles of students and lecturers, usage of technologies and collaboration, are presented in Table 1.

Table 1. Main global types of flipped classroom models, their characteristics and differences

Type of model	Features	Differences from other models in the table
Traditional Flipped Classroom	A basic flipped learning model in which theoretical material was studied independently by students at home using video lectures, presentations or online resources. Classroom time was used for discussion, practical tasks and the application of knowledge in practice	Focused on changing the sequence of learning activities without the use of advanced digital technologies or adaptive approaches
Flipped Mastery Model	Provided for students progressing to a new unit only after achieving a defined level of mastery of the previous material. It enabled individual learning pathways and involved the use of testing and self-assessment systems	Distinguished by a stepwise progression and the principle of "mastery learning". It supported a deeper understanding of content, but required more time for independent study
Collaborative Flipped Model	This model combines flipped learning with collaborative activity, including group work, joint projects, discussions and problem-solving tasks. Emphasis is placed on the development of communicative, social and critical skills	It differs from the basic model in that primary attention is given to student collaboration and the co-construction of knowledge within groups
Flipped Interactive Model	This model integrates digital technologies such as artificial intelligence, interactive platforms and adaptive learning systems, which provide personalised support and real-time feedback for students	It is a technologically advanced model aimed at individualising learning and developing practical competences through interaction with digital tools
Flipped MOOC Model	This model combines the flipped classroom approach with massive open online courses. Students study theoretical material via MOOC platforms, while practical sessions and discussions are conducted synchronously or within local learning groups	It is characterised by its scalability, openness and blended learning format (online and offline). It provides access to education for a large number of participants

Source: compiled by the authors based on research Collaborative Flipped Model (n.d.), R. Laoha & P. Piriyasurawong (2018), H. Pan *et al.* (2022), A. Gasaymeh & R. AlMohtadi (2024), A. Singha (2025)

As for the application, different models offer a flexible organisation of the learning process by combining students' independent work and active work in the classroom. In particular, this allows students to study theoretical materials and gain knowledge at their own pace, supported by the lecturers in practical tasks, discussions and group work. The individual model, such as the Flipped Mastery Model, encourages students to acquire a deep understanding of the material through sequential knowledge building, and the collaborative model contributes to the formation of communication and teamwork competencies. Interactive and technology-rich models involve the use of digital platforms and artificial intelligence systems, which enable the personalisation of learning and the provision of immediate feedback. Mass online models (Flipped MOOC) ensure access to education for large numbers of students by combining distance-based content acquisition with synchronous practical sessions. Overall, the application of these models enhances learning effectiveness, fosters student motivation, develops competences and facilitates the integration of technology into the educational process.

Within online resources used in the flipped classroom, several groups can be identified according to their functionality and purpose. The first group is interactive video platforms and exercises (such as PlayPosit (n.d.), H5P (n.d.) and others) used for independent learning, interactive tasks, understanding and feedback. The second group is a group of tools for visualisation and interactive content creation (for example, Genially (n.d.)), used for making presentations with interactive elements, creating infographics and simulating the learning material to attract students and increase learning effectiveness. The third group is the tools for assessment and knowledge management (such as Socrative (n.d.)) used for real-time surveys, tests and quizzes, student progress control and lesson adjustment based on the group performance. The fourth group is the tools for organisation and group work (such as OneNote (n.d.)), used for systematisation of the materials, notetaking, completing tasks in the group and the storage of results. Taken together, these four groups of resources provide a basis for a flipped learning environment where students combine independent preparation, practical exercises and groupwork for improved learning and competencies development.

In their interrelation, flipped classroom model types, educational programmes, and digital resources constitute a coherent learning environment in which the organisation of student work, the structure of classroom activities, the use of technologies and cultural and pedagogical conditions interact with one another. The types of models define the interaction between independent online preparation and active group work at the lecture: while the traditional model emphasises individual preparation and practical exercises at the lesson, in the Flipped Mastery Model students work on material sequentially and get progress monitoring, in the Collaborative Flipped Model the lesson focuses on group discussion and solving tasks, in the interactive model there is a combination with interactive platforms and in the MOOC-based model personalisation and scaling of education. Educational programmes determine the models by describing the form and volume of independent student work, requirements, organisation of class time and distribution of roles between teachers and students, also describing conditions related to national culture and pedagogy (that impact learning expectations and learning patterns of students). Digital resources provide interactivity, monitoring of learning outcomes and communication support, enabling the integration of online and offline activities. Thus, the content analysis made it possible to identify the key features of flipped classroom organisation in universities in the United Kingdom and Japan, including the forms and extent of independent student work, the structure of classroom sessions, the role of the lecturer, the use of digital resources and the prevailing cultural and pedagogical conditions.

Evaluation of the effectiveness of the flipped classroom model on motivation and learning outcomes

Motivation and learning outcomes are closely interrelated, as higher intrinsic interest in learning promotes more active student participation in academic tasks, which in turn encourages engagement with learning materials, the development of stable competences and the achievement of higher academic performance. To establish the effectiveness of the teaching technology implemented, it was important to obtain primary data for the subsequent comparison of results. Thus, primary data on student learning activity were obtained; the pre-test results of which were conducted in the United Kingdom and in Japan are shown in Table 2. The pre-test shows the initial learning activity levels of the control and experimental groups in terms of the level of engagement, interest, and level of assimilation of the learning material before the start of the pedagogical experiment.

Table 2. Results of preliminary testing in the UK and Japan (CG and EG)

Questionnaire item	United Kingdom		Japan	
	CG (1-5 points/number of students)	EG (1-5 points/number of students)	CG (1-5 points/number of students)	EG (1-5 points/number of students)
Active preparation of material before the session	1-10 2-15 3-20 4-25 5-20	1-2 2-8 3-15 4-33 5-32	1-8 2-10 3-22 4-25 5-25	1-2 2-5 3-12 4-35 5-36
A sense of interest during group discussion	1-8 2-12 3-25 4-25 5-20	1-2 2-5 3-18 4-30 5-35	1-7 2-12 3-20 4-28 5-23	1-1 2-4 3-15 4-33 5-37

Table 2. Continued

Questionnaire item	United Kingdom		Japan	
	CG (1-5 points/number of students)	EG (1-5 points/number of students)	CG (1-5 points/number of students)	EG (1-5 points/number of students)
The model facilitated a better understanding of the material	1-12 2-14 3-20 4-22 5-22	1-3 2-4 3-15 4-28 5-40	1-9 2-11 3-23 4-24 5-23	1-2 2-3 3-14 4-32 5-38
Willing participation in practical tasks during the session	1-9 2-13 3-22 4-28 5-18	1-2 2-5 3-15 4-30 5-38	1-8 2-10 3-22 4-26 5-24	1-1 2-4 3-15 4-34 5-36
Confidence when completing tasks independently	1-11 2-12 3-25 4-22 5-20	1-3 2-6 3-18 4-28 5-35	1-9 2-12 3-24 4-25 5-20	1-2 2-4 3-16 4-32 5-36
Active interaction with the lecturer during the explanation of new material	1-10 2-12 3-22 4-28 5-18	1-2 2-5 3-15 4-32 5-36	1-8 2-11 3-22 4-27 5-22	1-1 2-3 3-14 4-33 5-37
Application of acquired knowledge in group projects	1-11 2-13 3-20 4-25 5-21	1-3 2-5 3-17 4-30 5-35	1-7 2-12 3-23 4-25 5-23	1-2 2-3 3-15 4-33 5-36
Satisfaction with individual learning progress	1-9 2-14 3-22 4-25 5-20	1-2 2-4 3-15 4-30 5-39	1-8 2-11 3-22 4-26 5-23	1-1 2-4 3-14 4-34 5-37

Note: each column indicates the number of students who selected a given score on the Likert scale from 1 to 5
Source: compiled by the authors based on the conducted pedagogical experiment

In both countries, the results of the pre-test survey were determined by the following factors: organisational, pedagogical and sociocultural ones that affected the initial level of students' learning activity. These were their different experiences of studying in previous educational institutions, various approaches to the organisation of their learning in different educational traditions, which affected their initial preparedness for independent preparation for classes, active participation in discussions with teachers and their colleagues and their interaction with the lecturer. The impact was also related to the peculiarities of the learning conditions, such as the degree of task structuredness, the attitude of participants to the responsibility for the individual result, and the experience and practice of preparing the theoretical material before class, which determines the level of understanding of the content and confidence in carrying out a learning activity.

The differences identified between the control and experimental groups at the initial stage of the pedagogical experiment can be explained by different academic motivation, the degree of development of the skills of active and practice-oriented learning, and the attitude of participants to collaborative forms of activities. A higher level of engagement was also explained by the openness to new forms of teaching activity, the prior experience of active and practice-oriented learning, and the presence of an internal readiness for activity-based learning and for the practical application of knowledge. A smaller level of student learning activity and engagement, as well as satisfaction with the process of learning, was explained by the cautious attitude of participants to the new forms of learning work, preference for reproductive forms of learning, and the need to allow time to get used to the new teaching conditions.

Thus, an analysis of the results of the pre-test (Table 2) revealed that the control and experimental groups were equivalent at the beginning of the pedagogical experiment. According to the Student t-test, no significant differences were obtained between the groups at the initial stage ($p > 0.05$), which means that they can be compared with each other in terms of the levels of engagement, interest, and level of motivation before the pedagogical experiment.

The participants in each country performed the same learning activities, such as watching videos, writing notes, taking online tests, analysing cases, writing essays, problem-solving in groups, giving a presentation, participating in a debate, and taking part in a simulation. While the control groups operated primarily on their own, with a resulting lack of information sharing, the experimental groups implemented the flipped classroom model centred around collaboration, decision-making, and peer assistance. As a result, they were able to work more efficiently with the material and gain more understanding of the subject matter. Online educational resources (PlayPosit, n.d.; H5P, n.d.; Genially, n.d.; Socrative, n.d.; OneNote, n.d.) supported interactive and individual and team learning activities. These resources were used by the students in the control group for individual work, while the students in the experimental group used them to work in teams where they discussed the results and made joint decisions (Table 3).

Table 3. Completion of learning tasks by students in the United Kingdom and Japan (CG and EG)

Country	Task type	Control group	Experimental group
United Kingdom	Tests (%)	75/15/10	83/12/5
	Short essays (%)	70/20/10	80/15/5
	Individual presentations (%)	65/25/10	82/13/5
	Collaborative case analysis (%)	60/25/15	85/10/5
	Group projects (%)	58/28/14	80/15/5
	Group discussions (%)	55/30/15	88/10/2
	Interactive video-based exercises (%)	62/28/10	83/12/5
Japan	Tests (%)	72/18/10	87/10/3
	Short essays (%)	68/20/12	85/12/3
	Individual presentations (%)	63/25/12	82/13/5
	Collaborative case analysis (%)	60/28/12	88/10/2
	Group projects (%)	58/30/12	83/12/5
	Group discussions (%)	55/32/13	90/8/2
	Interactive video-based exercises (%)	60/30/10	85/10/5

Note: for each task, percentages of completion are indicated: fully/partially/not completed
Source: compiled by the authors based on the conducted pedagogical experiment

The control groups in both countries performed well in individual tasks (tests, short essays); however, the level of full completion of group tasks was lower (55-65%). The experimental groups achieved the best results in terms of collaborative tasks (83-90% full completion), indicating the effectiveness of the model of the flipped classroom and team learning. The best result in collaborative tasks (88-90% full completion) was shown by the Japanese students from the experimental group, due to working together in a group and active communication with the lecturer.

A strong correlation between the results of the post-test and performance on collaborative tasks ($r = 0.62$-0.80, $p < 0.05$) was established for both countries. The correlation on individual tasks was moderate ($r = 0.35$-0.50, $p < 0.05$). These results indicate that collaborative communication and the use of educational interactive resources increase academic performance, while cultural specificity affects the choice of learning model (Japanese students demonstrate better results when working in structured groups, while students from the United Kingdom, on the contrary, prefer independent work followed by collaborative discussions). Table 4 shows the results of the post-test conducted in the United Kingdom and Japan on the effectiveness of the students' performance on the tasks of the control and experimental groups after the pedagogical experiment.

Table 4. Post-test results of the students' educational achievements in the United Kingdom and Japan (CG and EG)

Questionnaire item	United Kingdom		Japan	
	CG (1-5 points/number of students)	EG (1-5 points/number of students)	CG (1-5 points/number of students)	EG (1-5 points/number of students)
Active preparation of material before the session	1–4 2–8 3–18 4–30 5–30	1–3 2–7 3–15 4–32 5–33	1–3 2–7 3–20 4–28 5–32	1–1 2–4 3–10 4–35 5–40
A sense of interest during group discussion	1–5 2–10 3–20 4–25 5–30	1–2 2–6 3–17 4–30 5–35	1–4 2–8 3–18 4–28 5–32	1–1 2–3 3–12 4–33 5–41
The model facilitated a better understanding of the material	1–4 2–10 3–18 4–28 5–30	1–3 2–5 3–15 4–30 5–37	1–3 2–7 3–20 4–30 5–30	1–1 2–3 3–10 4–34 5–41

Table 4. Continued

Questionnaire item	United Kingdom		Japan	
	CG (1-5 points/number of students)	EG (1-5 points/number of students)	CG (1-5 points/number of students)	EG (1-5 points/number of students)
Willing participation in practical tasks during the session	1–4 2–8 3–20 4–28 5–30	1–2 2–6 3–15 4–30 5–37	1–4 2–8 3–18 4–28 5–32	1–1 2–4 3–12 4–33 5–40
Confidence when completing tasks independently	1–5 2–10 3–18 4–27 5–30	1–3 2–6 3–17 4–28 5–36	1–3 2–8 3–20 4–28 5–32	1–1 2–3 3–10 4–34 5–41
Active interaction with the lecturer during the explanation of new material	1–4 2–8 3–20 4–28 5–30	1–2 2–6 3–15 4–30 5–37	1–4 2–7 3–18 4–30 5–31	1–1 2–3 3–12 4–33 5–40
Application of acquired knowledge in group projects	1–4 2–8 3–18 4–30 5–30	1–3 2–6 3–17 4–28 5–36	1–3 2–7 3–20 4–28 5–32	1–1 2–3 3–10 4–34 5–41
Satisfaction with individual learning progress	1–5 2–10 3–18 4–27 5–30	1–2 2–5 3–15 4–30 5–38	1–4 2–8 3–18 4–28 5–32	1–1 2–3 3–12 4–33 5–41

Note: each column indicates the number of students who selected a given score on the Likert scale from 1 to 5
Source: compiled by the author based on the conducted pedagogical experiment

Comparison of the results of the post-test indicated that the students in the experimental groups from both countries improved their learning motivation, learning involvement, and confidence in academic activity. With the exception of two items in the questionnaire, all other indicators show a preponderance of high scores. Thus, it can be noted that the proposed model of learning contributed to the most active students' participation in classroom activities, their ability to independently prepare for lessons and a conscious use of knowledge in their work in both individual and collaborative tasks.

An analysis of the results achieved by the students in the experimental groups revealed a difference in the characteristics of the students' learning activity depending on the cultural and national context. The results for the students in the United Kingdom's experimental group indicate that they have taken on more responsibility for their own learning, that their individual preparation was effective and that they actively took part in practical activities. However, Japanese students from the experimental group have a higher degree of interaction in groups, confidence in completing academic tasks and are more satisfied with the results of their own learning, which could be associated with cultural patterns of collective responsibility and cooperation.

A slight growth in average indicators was recorded for the post-test of control groups in both nations after the completion of the teaching period, but the level of development of the studied features remained lower than in the experimental groups. This fact testifies to the lack of potential of traditional forms of teaching to cause high activity in learning and to form independence in students.

The statistical analysis of the post-test results (Table 4) showed a positive dynamic within groups. In particular, in the control groups, statistically significant differences compared with the pretest were recorded for most indicators ($p < 0.05$). At the same time, intergroup analysis revealed a statistically significant advantage of the experimental groups over the control groups in terms of independent preparation, participation in group tasks and the application of knowledge in practice ($p < 0.01$), confirming the effectiveness of the implemented pedagogical model.

Impact of the pedagogical experiment on the motivation and academic achievement of students

To assess the level of academic motivation of students in both countries, the AMS was applied. The level of academic motivation was established on the basis of the teacher's information about the performance of learning tasks, the quality of participation of students in discussions and practical exercises, the quality of implementation of joint work, as well as the pre-test and post-test results. This allowed assessment of the level of intrinsic and extrinsic motivation and the level of amotivation of the students. Table 5 shows the average values (M) for control and experimental groups in the United Kingdom and Japan in the subscales of AMS. The measurement unit is a rating in the range from 1 to 5 (1 is the lowest rating, 5 is the highest rating). The subscales of the AMS make it possible to assess various aspects of the academic motivation of students. Intrinsic subscales (Knowledge, Accomplishment, Stimulation) demonstrate the level of intrinsic, spontaneous interest of students in the learning process. Extrinsic subscales (External regulation, Introjection, Identification) assess the extent to which students are motivated by extrinsic influences. The amotivation subscale indicates a lack of motivation. Thus, the data presented in the table reflect the dynamics of changes in student motivation before and after the implementation of the flipped classroom model and allow for a comparison of the effectiveness of traditional and innovative approaches to the learning process in both countries.

Table 5. Academic motivation (AMS) of students in the United Kingdom and Japan: Comparison of CG and EG

Subscale	Control group Pre-test M (mean value)	Control group Post-test M (mean value)	Experimental group Pre-test M (mean value)	Experimental group Post-test M (mean value)
United Kingdom				
Intrinsic motivation – knowledge	3.50	4.05	3.85	4.70
Intrinsic motivation – accomplishment	3.48	4.00	3.80	4.68
Intrinsic motivation – stimulation	3.45	4.02	3.78	4.65
Extrinsic motivation – external regulation	3.40	3.95	3.75	4.60
Extrinsic motivation – introjected regulation	3.42	4.00	3.77	4.63
Extrinsic motivation – identified regulation	3.47	4.03	3.82	4.70
Amotivation	2.10	1.85	2.05	1.50
Japan				
Intrinsic motivation – knowledge	3.55	4.10	3.90	4.80
Intrinsic motivation – accomplishment	3.50	4.05	3.85	4.75
Intrinsic motivation – stimulation	3.48	4.07	3.83	4.72
Extrinsic motivation – external regulation	3.42	4.00	3.78	4.65
Extrinsic motivation – introjected regulation	3.45	4.05	3.80	4.70
Extrinsic motivation – identified regulation	3.50	4.08	3.85	4.78
Amotivation	2.08	1.80	2.00	1.45

Source: compiled by the author based on the Academic Motivation Scale (n.d.)

The results of the AMS demonstrated a positive change in the motivational structure of students in all groups, but more noticeably in the experimental groups in both countries. In the United Kingdom and Japan, the control groups showed an increase in intrinsic motivation and a decrease in amotivation. This means that students' interest in the learning process and their learning activity increased; however, their motivation level was lower than that of the experimental groups. Such a situation is due to the traditional character of the organisation of the educational process in the study of foreign countries and the limited opportunities for students to work together, as they mostly had to perform tasks individually. The results of the research conducted in experimental groups in both countries showed an increase in intrinsic motivation and a decrease in amotivation, which indicates the high activity of the learning process of the students. In the United Kingdom, the increase in motivation was mainly driven by students' independent work with educational materials and exercises, while the Japanese learners' motivation was additionally promoted by the execution of tasks together as a team and communication with the lecturer, which promoted teamwork, the ability to critically analyse information, and self-organisation.

The Japanese students in the experimental group had higher scores across all of the AMS subscales than all other groups, which can be explained by learning traditions and the way students work as part of a group. The results for the control groups showed an increase in student motivation, although they did not reach the level of motivation shown by the experimental groups, and there were no significant changes in the subscales. Consequently, the flipped classroom approach resulted in an increase in student intrinsic and extrinsic motivation and a decrease in amotivation, leading to increased learning activity, self-organisation and improved academic effectiveness. The results for the experimental group were higher than the results for the control group, which shows that the organisation of tasks and interactions between students contribute to increased student motivation. Mean scores for both groups are shown in Table 6.

Table 6. Mean academic performance scores of students in the United Kingdom: CG and EG

Group	United Kingdom		Japan	
	Pre-test M	Post-test M	Pre-test M	Post-test M
Control group	3.45	4.05	3.50	4.10
Experimental group	4.03	4.76	4.10	4.85

Source: compiled by the author based on the t-Student's test

The analysis of mean scores for both groups showed an increase in students' learning outcomes, with the control group increasing from 3.45 to 4.05, which showed a moderate increase in student understanding and engagement with the material and learning activities. The experimental group increased from 4.03 to 4.76, which showed the high effectiveness of the flipped classroom model and independent work, which led to greater understanding of the material, engagement with learning activities and motivation. The overall mean values show the highest level of understanding and engagement in the experimental group and thus demonstrate the effectiveness of the experiment.

In the case of Japanese students in the experimental group, the students had the highest mean value of all the groups, increasing from 4.10 to 4.85, which shows the high effectiveness of collaborative work, active interaction with the lecturer and task execution as part of a team. The Japanese control group also showed a positive trend (from 3.50 to 4.10), although without the effect of team-based interaction. Japanese students in the experimental group achieved the highest mean score in all task components compared with the United Kingdom students, which suggests a greater influence of culture and learning organisation for Japanese students on the effectiveness of the flipped classroom model. The mean academic performance scores (Table 6) revealed a statistically significant intergroup difference; according to the t-test, students of the experimental group obtained higher scores than the students of the control group ($t = 3.75$-5.22; $p < 0.01$). This is associated with an increase in intrinsic and extrinsic motivation, a reduction in amotivation, and more successful completion of practical tasks and case study work. In Japanese students, the statistically significant difference between the groups turned out to be higher than in British students. It proves the positive effect of a well-organised, group-oriented organisation of the learning process.

The implementation of a flipped classroom method contributed to the growth of students' academic achievement and motivation through the activation of independent preparation in various topics, interactive discussion of topics, completion of practical tasks, and discussion at meetings. Another key factor in increasing effectiveness is the implementation of interactive online resources. For example, PlayPosit helped develop interactive videos with questions integrated into them, so students could assess the effectiveness of their knowledge by receiving immediate feedback during video viewing. H5P helped create interactive tasks and presentations that contributed to higher active participation of students and the visualisation of study materials. Genially was used to develop interactive presentations and posters that promote creative thinking and discussion of ideas in the context of a group. Socrative provided the opportunity to conduct an online test/survey in real time, thus providing students with an assessment tool to adjust learning activities in response to the results. OneNote helped to structure the notes, create summaries of the lectures, organise the exchange of material collaboratively, thus supporting students in the organisation of group work and encouraging communication and exchange of experiences. Due to these integrated interactive resources, students could learn theoretical knowledge while implementing it right away through a wide variety of independent and group tasks. Interactive elements, adaptive tests, and the organisation of group work led to the involvement of students in the learning process, as well as the activation of their independent work, awareness of their responsibility for the outcome. This, in turn, resulted in better achievement in the experimental groups and higher motivation (intrinsic).

The Japanese experimental group that worked jointly, focusing on group interaction and joint decision-making, showed higher results than the control group that worked individually in the United Kingdom. Japanese students achieved better results in all subscales of the Academic Motivation Scale (n.d.) and the mean score in learning tasks, because interactive teamwork led to an increase in both intrinsic and extrinsic motivation, reduced amotivation, and made the process of learning knowledge more effective. The results showed that British students achieved the best results because of the high degree of autonomy in the process of independent work in the learning process, and Japanese students managed to achieve improvement due to the implementation of collective responsibility and organised guidance by the lecturer, as well as step-by-step control of the study progress. These variations were linked to the specific priorities, approaches to teaching, and levels of digital readiness of the universities in each country.

Student learning scenarios based on the flipped classroom model

On the basis of the research conducted, as well as the test results and data obtained, several models of students' study processes were distinguished. In the first case, students had access to individual, interactive learning resources, such as PlayPosit, H5P, Genially, Socrative and OneNote, which they used to study the required materials before the lesson. By watching videos, carrying out self-check activities, analysing case studies and making notes, students familiarised themselves with the basics of the topic and discussed these issues in group sessions. This led to more effective teamwork and made it easier to discuss difficult issues. According to this case study, students in the United Kingdom reported the following mean values: intrinsic motivation to learn $M = 4.68$; extrinsic motivation to learn $M = 4.70$; and amotivation decreased to 1.52. Students in Japan reported the following figures on similar activities, taking into account national characteristics of collaborative learning and interaction with the teacher, and the mean values were intrinsic motivation to learn $M = 4.75$, extrinsic motivation $M = 4.72$, and amotivation decreased to 1.48. In reality, the teacher set up tasks for the students in advance, providing access to online platforms several days before the lesson, and checking whether the students had fulfilled these requirements by means of interactive testing systems. Students prepared in advance were more active in classes, asked questions to clarify and discussed the practical use of the knowledge.

The second case involved students performing group work, in which they analysed practical problems, worked on assignments, designed a simulation of a learning situation, made joint decisions, distributed roles and produced joint presentations or reflective essays. This type of activity contributed to an increase in both types of motivation. The results of the study showed that among students in the United Kingdom, intrinsic motivation for achievement increased from M = 3.80 (pretest) to M = 4.68, introjected regulation of extrinsic motivation increased from M = 3.77 to M = 4.63, and amotivation decreased from M = 2.05 to M = 1.50. Among Japanese students, structured collaborative work and active interaction with the lecturer increased intrinsic motivation from M = 4.00 to M = 4.68 and introjected regulation of extrinsic motivation from M = 3.90 to M = 4.72, with the amotivation falling from M = 1.95 to M = 1.45. The task was to discuss the results within each group and present the conclusions in writing. For group analysis, students used OneNote (n.d.) or Genially (n.d.). The activity of the teacher was to moderate the discussion on the problem posed, guide the work of the group, and provide feedback to students. This allowed students to interact successfully, develop their ability to communicate and put theory into practice, as well as boost their motivation and results.

The third option, discussing test results from an online test together, as well as reflective essays and practical work, enabled the students to identify their own mistakes, compare their results with the rest of the group and refine their approach to the material. This led to an increase in British students' intrinsic motivation for achievement (M = 4.70) and intrinsic motivation for stimulation (M = 4.65) and a decrease in their amotivation (1.50). Among Japanese students, these indicators were even higher: intrinsic motivation for achievement reached M = 4.80, intrinsic motivation for stimulation reached M = 4.75, and amotivation decreased to M = 1.45. In practice, this scenario was conducted using in-person or online discussion and the Socrative system for quickly getting the results of a test, followed by the moderator's work and a brief group reflection (students exchanged experiences, discussed common mistakes, and jointly worked out a plan). This facilitated greater student engagement and active thinking and improved their ability to absorb information, as well as improved their ability to self-regulate and to work in groups.

Taking into account the different cultural features of students in various countries, the learning scenarios constructed based on the flipped classroom are adaptable to the various needs of diverse learning groups. They included a combination of independent preparation with interactive online resources, collaborative completion of practical tasks and case studies, discussion of results and work on reflections. This approach allowed for sufficiently taking into account the differences in learning and communication patterns, the sociocultural requirements of different countries and the traditions of interaction between students, which is essential when organising learning in a flipped classroom within the framework of an international education environment.

Students from an individualistic culture (United Kingdom) showed a high level of initiative and responsibility for their own learning. They planned their own learning time, worked through educational materials systematically and controlled their own progress. For these students, the first approach – which involved self-directed study using interactive online platforms – proved to be the most effective. The use of interactive online resources such as PlayPosit, H5P, Genially, Socrative, and OneNote allowed students to view learning videos on their own, do self-assessment tasks, analyse case studies and work out their own notes, which allowed them to obtain the necessary base knowledge before the group discussion. Such learning design contributed to self-regulation of their learning and tracking their own progress and development of intrinsic motivation for achievement, as learners could control the speed of acquiring the material based on their individual needs and interests.

In comparison, in countries with a collectivist culture, such as Japan, students were more used to working in groups, jointly making decisions and coordinating action in the learning process. For students from collectivist cultures, group support and responsibility and orientation toward a group result were of particular importance, which is why the second scenario with a group practical work with case studies, projects, and modelling of learning situations was more useful for them in practice. In this situation, students participated jointly in decision-making, division of roles and work, discussion of options for task completion, and group presentation of results or writing reflective essays. This kind of learning arrangement contributed to the development of intrinsic achievement motivation (by feeling their contribution to the general result) and contributed to extrinsic achievement motivation by introjected regulation (to meet the expectations of the group) and identified regulation (to communicate). The joint completion of the work allowed students to understand the learning content more fully, discuss difficult points in detail, develop communication skills and skills to coordinate activities in teamwork.

In the third scenario, when the test results, reflective essays, and practical assignments were collectively discussed, students were able to discuss and compare their own results with the results of their classmates, identify the most successful approaches to learning, and adjust their own learning accordingly. This learning arrangement could be successful in countries where the tradition is an active discussion, exchange of experience with the group, and the presence of active group interaction in the whole educational process. Students were able to observe how their classmates solve problems and adjust their own work process in real time, to identify the most successful strategies and approaches to the material, and to learn from the experience of other people. This approach allowed them to improve not only academic results, but also to develop critical thinking, self-monitoring, reflection and skills to interact effectively with each other.

All three scenarios have shown that this organisation of learning positively affects students' motivation and academic achievement as well. It was adapted to the characteristics of the national educational context, considering the individual and cultural requirements and expectations of students regarding the organisation of the educational process, the possibility of a balance between the individual and group work organisation, and the integration of all the required elements for the successful development of both academic and interpersonal competencies. Through this approach, students were able not only to master the learning material but also to interact actively with peers, evaluate their own actions, develop teamwork skills, and refine their learning strategies, which corresponded to the demands of contemporary educational practice in the context of globalisation and cultural diversity.

DISCUSSION

The case of integrating flipped learning in higher education in the United Kingdom and Japan showed certain differences in practice, depending on national priorities, pedagogical traditions, and digital maturity levels of universities. British universities are characterised by more autonomy for students in the preparation for the class, while Japanese universities are characterised by the emphasis on responsibility and support from the lecturer. These results correspond with the claim of T. Alqahtani *et al.* (2023) who reported that flipped learning is effective if it is based on the principles of constructivist design and the learning content is properly verified. At British universities, the flipped classroom was based on the principles of constructivism, where students get involved in the learning material before the lesson while studying independently, and at Japanese institutions, flipped classrooms were institutionalised, which implied clearly defined steps of learning and control of progress. This also corresponds to the findings of R. Al-Maroof & M. Al-Emran (2021), who stated that culture plays a role in the development of flipped classrooms and communication with teachers and students. In both countries, the use of the flipped classroom was associated with critical thinking, self-study and self-management skills, but to a greater degree, at universities in the United Kingdom, due to the popularity of project-oriented work and individualised learning approach. According to M. Cevikbas & G. Kaiser (2022), similar results have been observed: with an individual approach in a flipped classroom, students learn content and have higher motivation. The main role in Japanese universities is played by the integration of Information and Communication Technologies (ICT) to support collaborative learning, which is in line with the conclusions of A. Cueva & E. Inga (2022) who demonstrate the importance of digital tools in fostering communicative interaction and developing students' digital competence. The obtained data also confirm the trend described by I. Chou (2020), who ascertained that the application of the flipped model of English-language teacher education courses improves learning outcomes and student perceptions. In both countries, students reported an increase in satisfaction with the educational process. In Japanese universities, students emphasised the need for clearer instructions and more learning resources, whereas at British universities, they pointed to a flexible and individualised approach to preparing for classes. These results correspond to the findings of A. Arslan (2020), who reported the results of applying flipped learning to language education: for successful implementation of the model, students' digital skills should be developed, and appropriate interactive materials should be created. In the United Kingdom, this element is well supported with the use of an open online platform, whereas in Japan, the key point is the adaptation of learning materials to national standards.

Academic success is not the sole beneficiary of the flipped classroom approach: this educational model also promotes the acquisition of social and communicative competencies. This aligns with the conclusions reached by J. Elkhalladi & A. Sefrioui (2024), who showed that the flipped format has a beneficial effect on students' communicative skills as well as their sense of duty and sense of professional ethics among different specialities. For example, at British universities, these skills were acquired by means of group discussion and presentation, while in Japanese ones, collaborative work on the creation of learning resources and participation in synchronous online meetings were used for these purposes. Another advantage of the model was the development of students' critical thinking. This also corresponds to the study findings by P. Etemadfar *et al.* (2020), who claimed that students in a flipped classroom environment had improved analytical thinking abilities, and their level of understanding increased in the process of language acquisition. The students also experienced higher motivation to self-study and were more likely to actively take part in the discussion in class. Similar findings by L. Hao *et al.* (2024) confirmed the positive effect of project-based flipped learning on the critical thinking and creativity of students in economics-related disciplines. The study also indicated an improved ability among students to work in teams and to solve complex tasks effectively. At the same time, the results revealed some discrepancies with the conclusions of T. Bhuttah *et al.* (2024), who argued that the effectiveness of innovative pedagogical approaches increases only in the presence of inclusive leadership and a supportive learning environment. Nevertheless, at British universities, in spite of a high technological preparedness, there were problems in ensuring students' active social involvement in group tasks. In Japanese universities, there is a stable balance between structural rigidity and the degree of freedom. This is also confirmed by the results of Z. Moula's (2021) crosscultural study on barriers and enablers for creativity in higher education pedagogy at universities in the United Kingdom and China. She claims that the intense use of technological tools helps to stimulate students' creative thinking and increase their level of engagement, with the students actively participating in synchronous and asynchronous learning activities. It also supports the findings of P. Pimdee *et al.* (2024), who demonstrated that blended problem-based learning within the flipped classroom format, used in online classes, resulted in better educational outcomes and helped develop students' skills of problem-solving. In the case of the United Kingdom, combining asynchronous work on lectures with synchronous discussion of problem-based learning tasks helps to better engage students in the learning process. A greater focus on structured knowledge acquisition and strict adherence to the curriculum was observed, which is consistent with the study by T. Kameda *et al.* (2022) on the implementation of ultrasonic education in universities. As they claim, a staged implementation of new teaching tools and technologies, such as flipped classrooms, requires a systematic design and integration of new activities into courses to proceed effectively. For Japanese students, the process of mastering the material was more successful through asynchronous structured work and its practical implementation with a tutor's support. This confirms the recommendations from T. Kameda *et al.* about the implementation stages and sequential learning of complex skills and abilities in practical education. Comparing it with the results from B. Ünal *et al.* (2024) indicates that motivation, learning strategies and cognitive load all contribute to student views on the flipped classroom model. Students in both countries showed variations in approaches to independent learning, with the British students showing greater readiness to explore and discuss the material to be learned on their own, while the Japanese students preferred clear guidelines and required a lot of directed learning tasks. In this study, the cultural differences influence students' attitudes towards using new learning technologies, in line with A. Persson *et al.* (2021). It was observed that students from different cultural backgrounds perceived independent learning and interactive elements of a flipped classroom differently, but both groups experienced an improvement in learning performance and motivation. In the control group, the mean score increased from 3.45 to 4.05, but in the experimental group, it increased more significantly, from 4.03 to 4.76, indicating a greater improvement in the experimental group.

A comparison with other blended learning models in implementing the flipped classroom corroborates the results of the study by F. Khodabandeh & M. Tharirian (2020), who concluded that combining traditional methods and flipped techniques for grammar teaching improves the academic achievement of the students. The students involved in flipped classroom activities had a more active use of knowledge in practical tasks compared to students who studied only in the traditional way. The research by E. Rojas *et al.* (2023) on implementing metaverse technologies in higher education revealed the benefits of introducing advanced technologies into the flipped classroom for improving student motivation and creating opportunities to practically apply knowledge. C. Lo & K. Hew (2023) also highlighted opportunities and challenges of the use of digital technologies in implementing the flipped classroom. The use of chatbots and technologies of PlayPosit, H5P, Genially, Socrative and OneNote in the experimental group proved to give immediate feedback and to develop students' independent learning strategies. Innovative technologies in the flipped classroom help in increasing student motivation, developing independent learning strategies and improving the active use of knowledge in practice. At the same time, cultural and educational differences influence different levels of readiness of students to use digital tools and engage in independent study.

CONCLUSIONS

The study looked at different models of the flipped classroom, including The Traditional Flipped Classroom, The Flipped Mastery Model, The Collaborative Flipped Model, The Flipped Interactive Model and the Flipped MOOC model. All these models combine independent online learning with various types of activities in the classroom. Special attention was paid to the use of such digital resources as PlayPosit and H5P for interactive exercises and videos, Genially for creating presentations and learning simulations, Socrative for online tests and surveys, and OneNote for collaborative work and the organisation of learning materials. The identification of cultural and pedagogical specifics of universities, including the University of Tokyo and the University of Bedfordshire, and the differences between the organisation of collaborative and individual learning made it possible to select an approach to improving student motivation and learning activity using a mix of digital technologies, differentiated tasks, and organised monitoring of knowledge acquisition in stages.

After introducing the flipped classroom model, there was growth in student motivation and in learning results. The experimental group in Japan was characterised by working with students in collaboration, group discussions, and joint decision-making, using interactive digital resources (PlayPosit, H5P, Genially, Socrative, OneNote). 35-40 students rated all items of the post-test from 4-5. The growth of mean scores for the experimental group (M = 4.03 to M = 4.76), the growth of intrinsic achievement motivation (from 3.80 to 4.68), and the decrease in amotivation (from 2.05 to 1.50). The differences in the experimental group were more evident than in the control group (M = 3.45 to 4.05), which suggests the effectiveness of the proposed model in stimulating activity and motivation. The greatest percentage of fully completed tasks was found in the experimental group (88%) for group discussions, while the lowest rate of task completion was found in the control group for individual presentations (65%). Collaborative case-solving and solving an interactive video-based test were completed 85% and 83% in the experimental group, respectively, by comparison with the control group (short essays and tests at 70-75% completion). These data suggest the effectiveness of the collaborative tasks in ensuring greater results in learning and application of knowledge, with individual tasks demonstrating a moderate level of knowledge acquisition.

Three student learning scenarios based on the flipped classroom model were developed: digital resources for independent study, group work to tackle practical cases, and discussions on test results and assignments. These scenarios fostered intrinsic and extrinsic motivation, stimulated active agency in the learning process, and fostered communicative and reasoning skills. A limitation of the study is that it was conducted only among students of selected universities in the United Kingdom and Japan, and this may limit generalisability to other education contexts and student populations. Therefore, more research should be done to study the effect of a flipped classroom model on the development of students' intercultural and digital competencies from other countries.

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