Digitalization of Education: Possibilities of VR-Based Educational Resources and Their Impact on the Development of Analytical Thinking of Students

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***Abstract*—This research aims to assess how virtual reality technology influences the analytical thinking skills of students. The study sample consists of 436 third-year students from the Philological Faculty enrolled in the full-time program. The sample was divided into two groups. Group 1 (228 participants) consisted of students who studied “Philosophy of Social Sciences and Humanities” using traditional teaching methods, without the use of virtual reality. Group 2 (208 students) utilized virtual reality in their learning process. Research methods included an online survey of students and content analysis of the collected data. The study found that students in the group utilizing virtual reality reported a statistically significant change in the level of analytical thinking: it increased by 5%. There was also a 7.81% increase in the average score of this group. The results of this study demonstrate the positive impact of educational digitalization.**

***Keywords*—analytical skills, digital learning technology, higher education, student achievement, Virtual Reality (VR) technology**

I. Introduction

The concept of global development in the era of globalization provides the proactive incorporation of contemporary digital technologies. Software, email, chats, distance learning platforms, virtual educational resources, cloud-based services, and applications have become part of not only daily life, but also education. The digitalization of space and innovative technologies have the potential to enhance the quality of life and drive socio-economic progress [1]. Digital information technologies play a vital role in the functioning of economies, cultures, and educational systems. They are ubiquitous in households, schools, hospitals, and universities, as well as within various enterprises. Their numbers continually expand and proliferate. In the field of education, digitalization facilitates continuous learning processes, creating conditions for seamless information exchange among educational stakeholders to enhance the quality of higher education [2, 3].

The digitization of the education system also improves educational programs and increases academic mobility. An indication of the growth in academic mobility is the number of prospective students who choose to pursue their studies at foreign universities. The proportion of Russian students studying at foreign universities stands at 1.5%. However, between 2012 and 2016, this figure increased by 12%, and from 2014 to 2018, it ranged from 12,000 to 16,000 students. The digitization and globalization of education lead to competition among universities for prospective students and a reduction in educational boundaries [4]. Contemporary research demonstrates a direct correlation between the level of educational development and socio-economic progress [4]. The modernization of higher education is also influenced by factors such as funding, labor market demand and supply, the evolution of IT technologies, globalization of education, overall demographic conditions, disparities between the education level of graduates and employer expectations, and the imbalance in the number of young professionals relative to the economy’s needs [4, 5].

In 2018, the European Commission initiated a plan for the digitization of education. The plan was aimed at digitally transforming the educational process to meet the needs of modern users and modernize it [6]. The principles of the plan encompass the following: 1) the provision of educational services in digital format (streamlined services focused solely on essential information) and conditions for inclusive education; 2) the availability, confidentiality, authenticity, and integrity of data in education, as well as cybersecurity and personal data protection; 3) convenient data and information exchange among universities, institutions, and European Union agencies; 4) digital solutions that enable seamless operations in organizations and make digital government services accessible across borders; 5) education tailored to individual needs, incorporating innovations, user interfaces, data visualization, and information accessibility. The implementation of the education digitization plan faces several limitations: insufficient government support; the need to develop a digital strategy and a coordinated action plan; and the requirement to establish committees, institutions, technologies, and cybersecurity provisions [6].

To enhance the quality of education, a priority has been placed on the effective utilization of digital technologies (such as Google Meet, Twitter, SELFIE (Self-Reflection on Effective Learning by Fostering the use of Innovative Educational Technologies), Work Tasks Motivation Scale for Teachers (WTMST)) in teaching and learning. However, studies have also demonstrated that educators lack digital skills [7]. Furthermore, the COVID-19 pandemic necessitated

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an abrupt shift to remote learning. This event exacerbated the situation even further and highlighted the urgent need for the development of digital competencies among teachers [8].

The Digital Education Action Plan (EC, 2020) calls for intensified efforts to enhance digital skills and competencies to support the digital transformation of education. For instance, the SELFIE tool (Self-reflection on Effective Learning by Fostering the Use of Innovative Educational Technologies) reveals a digital divide among participants in the education system. There is a shortage of technical resources and technical support [9].

Modern research demonstrates that the essential practical skills in the contemporary sphere include adaptability and rapid task-switching [10]. In education, it is essential to cultivate and develop 1) analytical thinking and innovation skills; 2) active learning strategies; 3) creativity, originality, and initiative; 4) planning and programming abilities; 5) critical thinking and analysis; 6) holistic problem-solving capabilities; 7) leadership qualities and social interaction; 8) emotional intelligence; 9) understanding and unconventional problem-solving aptitude; 10) systems analysis and evaluation [10]. To foster and enhance the mentioned contemporary adaptive skills, it is necessary to 1) employ digital technologies, products, and services; 2) establish an innovative learning environment; 3) engage qualified personnel in the realm of digital innovations; 4) create technological infrastructure accessible to consumers; 5) attract private and government investments in innovations and technologies [8]. Limitations are 1) low institutional assimilation in digital development; 2) low infrastructure levels; 3) an outdated education system with a lack of focus on STEM education and soft skills formation; 4) a shortage of highly qualified personnel; 5) low levels of automation and digitization of government services [10].

The digitization of education not only allows for reform but also enables the effective modernization of the global educational environment. Digitization entails the use of all forms of information (text, sound, imagery, video) in digital format. The phenomenon of digitization lies in its capacity to enhance the knowledge and competencies of students (teamwork, three-dimensional modelling, process visualization), while fostering logical thinking and communication skills [11]. This is driven by the active utilization of digital scholarly literature, educational videos on platforms like YouTube, online courses, and video lectures by contemporary students in their learning processes [11, 12].

Educational technologies elicit students' interest, and awaken their research and creative endeavors, thereby contributing to the development of critical thinking among students. They promote the analysis of practical problems and decision-making, foster collaborative skills, cultivate digital literacy and adaptability [13]. By incorporating an emotional component in students and stimulating their high-level mental processes, the digitization of education forms and develops analytical thinking. Thus, students learn how to rapidly adapt to professional requirements and modern labor market demands. Hence, the primary task of contemporary higher education is to foster and develop analytical thinking. This not only empowers individuals to comprehend theoretical principles and gain practical competencies but also motivates them to reflect upon and understand professional procedures [14, 15].

Analytical thinking is an individual's ability to process and decompose information with a detailed examination of each part. It enables 1) the analysis of large datasets; 2) the development of logical thinking; 3) the selection of new information; 4) the formation of conclusions; 5) attention to detail; 6) the comparison of facts; 7) the separation of the primary from the secondary; 8) the skill of comparing and establishing connections between processes [16, 17].

Innovative technologies substantially impact the development and improvement of analytical thinking. Non-standard approaches enable diverse communication within the educational context and create an environment conducive to student involvement. Students comprehend and reflect upon their knowledge and thoughts. Innovative pedagogy is characterized by a high level of active interaction and emotional synergy among participants. Innovative educational technologies like virtual reality [18, 19], brainstorming [20], and the discussion method [21, 22] serve as tools to capture students' interest, encourage active individual participation, influence students' emotions, facilitate highly effective information absorption, provide feedback, and help students form opinions, attitudes, skills, and behaviors. The challenges faced by educators in integrating innovative technologies include a lack of methodology knowledge, uncertainty about their effective use, and mistrust in the efficacy of modern methods [23].

The feedback from students constitutes a vital component for the successful implementation of innovative educational technologies. Open communication between students and educators is essential for understanding their needs and preferences to create a more effective adaptive curriculum design [24]. This dialogue can identify opportunities for integrating new technologies, such as Virtual Reality (VR). Consequently, the understanding of students' needs and expectations enables the more efficient integration of innovative teaching methods, such as VR, which can provide a more immersive learning experience.

Virtual reality is an effective learning environment that not only expands the physical learning space but also provides students with a richer learning experience and educational resources. Virtual reality allows for (1) immersing students in the learning process, (2) stimulating their imagination, (3) enabling interaction among students, (4) providing situational support for a more in-depth study of agricultural students, and (5) fostering the development of high-level thinking [25]. This study addresses the capabilities of modern digital educational resources and their impact on students' level of analytical thinking. These findings can complement and deepen previous investigations into this issue.

The focus is on the incorporation of modern digital educational resources in higher education to enhance learning and facilitate the integration of practical knowledge, skills, and competencies. The relevance of this research is defined by the choice of the topic - the digitization of education: the possibilities of modern digital educational resources and their impact on students' analytical thinking. The study aims to determine the influence of virtual reality (VR-technology) on the level of students' analytical thinking. The research objectives are 1) to ascertain the level of analytical thinking among students in groups with different learning formats (traditional methods vs. virtual reality); 2) to analyze the presence or absence of a correlation between students' level of analytical thinking and their academic performance.

The scientific novelty lies in analyzing the presence or absence of the influence exerted by modern digital educational resources on the level of analytical thinking. The study also examines the presence of a correlation between the level of analytical thinking and students' academic performance. The application of VR technology in university education allows for its high effectiveness and personalized learning, making it an accessible tool.

II. Literature Review

Sharapova *et al.* [26] have investigated the development of students' analytical thinking. Thus, modern digital interactive educational resources were effective for (1) cultivating analytical thinking skills, (2) achieving set objectives, (3) modeling rational decision-making in professional practical tasks, (4) analyzing processes and events, (5) integrating multifactorial practical tasks, and (6) utilizing group learning. Innovative educational technologies have the potential to strongly motivate students to participate in learning, improve their skills, and shape their behavior. Analytical thinking helps identify relationships among two or more studied variables, with one variable being the dependent variable while the others serve as factors [26].

The utilization of gaming technologies (Bingo games) and mobile applications (Socrative) in education increased motivation, knowledge, and the level of critical thinking among students. Both digital technologies exert a favorable impact on educational results through diverse mechanisms, encompassing concentrated attention, brainstorming, active engagement, interaction, and logical reasoning. Although bingo games have a greater impact on boosting motivation for learning, Socrative contributes more to knowledge exchange and critical thinking. This mobile application offers rapid interaction between students and educators, featuring a user-friendly interface that enhances the enjoyment of mobile learning environments and facilitates efficient knowledge exchange. It also plays a crucial role in the formation and development of critical thinking [27].

Sarı *et al.* [28] examined the impact of virtual reality on students' thinking. The virtual reality technology allows for the integration of three-dimensional animation, interactivity, and text-sound support. Through the augmentation of collateral and semantic connections, virtual reality contributes to (1) the development of thinking, (2) the generation of new non-standard solutions to posed tasks, (3) the stimulation of cognitive processes (forecasting optimal solutions, analysis through synthesis), and (4) the effective influence on the formation and development of figurative, formal-logical, and analytical thinking [28].

Beardsley *et al.* [7] have investigated the role of modern digital technologies among educational resources. The outbreak of COVID-19 and the shift to remote learning compelled the field of education to urgently transition to a new digital format of operation. The perception of digital technologies depends on the motivation of educators, which changed in the quarantine and post-quarantine periods. During the study period, along with an increase in motivation levels, educators improved their confidence in digital teaching competence. Skills related to preparing digital lessons, creating digital content, classroom teaching, assessment, and providing feedback also improved. Communication skills with students and families demonstrated enhancements as well. The increase in educators' digital literacy can be attributed to (1) continuous professional development activities, (2) the utilization of digital technologies in pedagogical practice, and (3) feedback and support from students [7].

Sarı *et al.* [29] investigated the development of algorithmic thinking in the context of digital education. Algorithmic thinking is a key skill in STEM (Science, Technology, Engineering, Mathematics) education and enables the improvement of solutions to practical problems through effective information analysis, causality determination, and planning. Widely used technologies in education include Arduino. Arduino is a modern hardware and software system based on an integrative approach, where disciplines (Biology, Physics, Chemistry, and Mathematics) are taught not in isolation but interconnected with each other. This approach fosters effective solutions to real-world problems: students learn to consider problems as a whole system rather than within the confines of individual scientific disciplines. In practical STEM-oriented lessons with the use of Arduino technology, the holistic perception of posed problems enhances the development of algorithmic thinking skills [29].

Galustyan *et al.* [30] elucidated the application of digital technologies in cultivating analytical competence among future professionals. The digitization of education extends traditional learning by harnessing the expanded capabilities of mobile platforms (such as AppStore, BlackBerry App World, GooglePlay, 1mobile market, Windows Phone Store, and Yandex.store) and learning environments, thereby developing students' analytical competence. Analytical competence rests on 1) seeking new information, 2) analyzing and synthesizing acquired data, and 3) concluding. Analytical competence is an individual's readiness to harness their potential (knowledge, skills, experience, and personal qualities) for successful socialization and adaptation in professional endeavors [30]. This competence comprises the following components: managerial, strategic, informational, and reflexive [30]. The managerial component implies the ability to 1) plan work, coordinate goals, responsibilities, and professional agreements, and 2) make objective managerial decisions. The strategic component involves an individual's readiness and capability to define goals, tasks, resources, and deadlines for their activities, as well as engage in collaborative efforts. The informational component includes skills related to harnessing the potential of information and communication technologies and mobile technologies. The reflexive component encompasses the ability to work in teams and analyze group activities. Current digital technologies are efficient and readily available tools for nurturing students' analytical competence, facilitating not only its development but also significant enhancement [30].

In the realm of interactive education, Perdana *et al.* [31] have investigated the correlation between analytical thinking aptitude and the ability to engage in scientific argumentation. Presently, students demonstrate a deficiency in both analytical thinking and the capacity for scientific argumentation, with the integration of digital technology in education further compounding this issue. The adoption of digital modeling technology introduces fresh problem-solving algorithms to students, consequently elevating their proficiency in scientific argumentation and analytical thinking skills. There is a statistically significant correlation between these two skills. Problem-Based Learning (PBL) is a student-centered methodology that allows students to 1) explore professional issues, 2) engage in small-group sessions, 3) facilitate group learning, and 4) promote self-directed learning. The use of PBL technology with web-based modeling in the digital learning environment effectively improves scientific knowledge, argumentation skills, and analytical thinking through the acquired skill of modeling results and consequences [31].

Researchers from Germany and Sweden have examined the role of digital technologies in professional education and training [32]. Contemporary digitization stimulates adaptation not only in business models but also in education. The integration of digitization necessitates specific skills and competencies for modern professions that are relevant in the labor market, including management competencies, problem-solving skills, social competencies, scientific literacy, digital competencies, and media. In professional education, there is a demand for information literacy among employees in the workplace, particularly in the execution of job tasks and decision-making processes. All employers concur on the necessity of 1) future professionals possessing practical competencies, 2) understanding the production process when working with modern technical means, machinery, and equipment, and 3) organizing logical/analytical production and product packaging. Such competence can be acquired in education through the integration of virtual modeling and digital capabilities [32].

Researchers from Malta, UK, have studied contemporary digital educational resources [1]. The methodology of "the pace of technological innovativeness" and the "technology acceptance model" enables the determination of the rationale for the application of digital capabilities in education, as well as an assessment of their costs and benefits. Educators are inclined toward the use of digital technologies in line with "the pace of technological innovativeness" and the "technology acceptance model". Additionally, younger mentors are more actively engaged in modern digital educational resources. Digital educational technologies, including gamification and electronic methodologies, actively engage students in the learning process, thus garnering significant positive reception among students and positively influencing their motivation. Such technologies facilitate the creation and analysis of various educational content in terms of complexity levels [1].

Scientists from the UK have examined the impact of digital technologies on the development of professional analytical skills [33]. Digital technologies, Big Data, and analytical skills significantly influence the formation of professional competencies (team-building, planning, computer literacy, critical thinking) among students at individual, organizational, national, and international levels. Contemporary digital educational resources allow for the acquisition of new skills related to responsibility and professional decision-making. The cultivation of professionalism (professional education) among students is effectively realized through its entanglement with digital technologies. As a result, students can 1) transform their knowledge about labor, divisions of labor, and labor identity, and 2) employ simple technical non-standard solutions to complex professional tasks and issues [33].

The development of analytical competence in the educational environment of case-based learning has been studied by Zottmann *et al.* [34]. Analytical competence is considered an important aspect of forming professional competence. The educational format and multiple support mechanisms, including authentic comments made by teachers and learners, enable participants to consider various aspects of assigned tasks, analyze them, and forecast outcomes, thereby fostering cognitive flexibility and analytical thinking. The formation of analytical competence also depends on educational environment technologies, such as audio and video content, which teach individuals to "sense," remember, and utilize information. The level of analytical competence (the ability to apply conceptual knowledge) is higher in student groups using the audio format compared to those using the audio and video format [34]. This study addresses the capabilities of contemporary digital educational resources and their impact on students' level of analytical thinking. These findings can complement and enhance previous research on this issue.

III. Methods and Materials

A. Study Design and Sampling

The scientific study was conducted at the Elabuga Institute of Kazan Federal University (KFU) in the Russian Federation. The research experiment took place during the study of the course "Philosophy of Social Sciences and Humanities" because the course's curriculum has the highest level of independent work (73%). To facilitate the acquisition of the course material, immersive VR technology was integrated into the educational process. This technology enabled the following: 1) integration of auditory and visual components into practical scenarios and tasks; 2) formation and acquisition of more meaningful knowledge; 3) enhanced information retention; 4) presentation of information in multiple ways; 5) provision of an authentic context; 6) realism in learning; 7) active engagement in the educational process; and 8) increased student motivation [35].

This study involved a sample of 436 third-year students from the Faculty of Philology, who were enrolled in full-time programs. The curriculum for third-year students involves a self-study workload of over 60%. Therefore, the choice of this cohort was reasonable.

The study employed an experimental method, as it allowed for establishing causal relationships between the implementation of VR technology and changes in the level of analytical thinking [36]. The experiment enabled the control of other factors that might influence the research outcomes and established a direct link between the introduction of VR technology and changes in analytical thinking [36]. This approach contributed to objective and reliable data regarding the impact of the intervention. To compare the impact of VR technology on students' levels of analytical thinking, the sample was divided into two groups. Group 1 (228 participants) consisted of students who studied the course "Philosophy of Social Sciences and Humanities" using traditional teaching methods (lecture, explanation, classroom discussion, illustrative material, and demonstration) without the use of VR technology. Group 2 (208 students) included students who studied the same course but with the inclusion of VR technology. The average age of the students was 21.43 ± 0.55 (Group 1) and 21.79 ± 0.23 (Group 2). The gender distribution was 56% female and 44% male for Group 1 and 58% female and 42% male for Group 2, with no significant differences ($p > 0.05$). The selection criteria for the sample were in line with the contemporary demands of the labor market. Future professionals are expected to 1) develop and integrate new models of societal processes and 2) apply interactive technologies for rational and effective professional decision-making. The course comprises a total of 60 hours of study, which are allocated as follows: 6 hours for Lectures (L), 10 hours for Practical Classes (PC), and 44 hours for Self-Study (SS). The breakdown of the course workload shows that classroom-based instruction constitutes 27%, while student self-study makes up the remaining 73% (Table 1).

The course aims to develop the following Generic Competencies (GCs):

GC-1: Analytical Thinking Skills – The ability to perceive information, analyze it, and make effective, rational decisions.

GC-2: Planning and Conducting Complex Research—The ability to plan and conduct comprehensive research.

GC-3: Application of Knowledge in Practical Situations—The ability to apply knowledge in practical situations.

GC-4: Quality Management System Development and Integration—The ability to develop and integrate a quality management system for provided services and products.

GC-5: Integration of Knowledge and Clear Communication—The ability to integrate knowledge, formulate judgments based on insufficient or limited information, and communicate one's conclusions and knowledge clearly and unambiguously, reasonably justifying them to both professional and non-professional audiences.

The course was conducted in real-time online mode; practical sessions were held through Microsoft Teams; educational materials were available the whole time; lectures were also accessible as recorded video/audio content; communication with instructors occurred via modern digital services (Microsoft Teams chat, Skype, Telegram, email); the sessions were conducted by the pedagogical team of the Elabuga Institute at Kazan Federal University.

This research had three stages: 1) preparation for research and questionnaire development; 2) surveying of students; and 3) compilation and analysis of the gathered information.

Table 1. Curriculum of "philosophy of social and humanities sciences"

No.	Topics	Hours			Formed Competencies
		L	PC	SSR	
1	Philosophy as a System of Knowledge, Activity, and Social Institution.	2	2	4	GC-1, GC-2, GC-5
2	The Place and Role of Philosophy in the Development of Culture and Civilization.	-	-	4	GC-1, GC-3, GC-4,
3	The Emergence of Philosophy, Stages of Its Historical Evolution, and Its Connection with Social and Humanities Sciences.	-	2	4	GC-2, GC-3, GC-4, GC-5
4	1. Key Concepts in Contemporary Philosophy. The Alternatives Between Dialectics and Metaphysics in Philosophy.	-	2	4	GC-1, GC-4, GC-5
5	2. The Laws of Dialectics and Their Application in Social and Humanities Sciences.	-	-	4	GC-2, GC-4
6	Socio-Cultural Aspects of Philosophy.	2	-	4	GC-4, GC-5
7	The Structure of Scientific Knowledge: Its Methods and Forms. The Role of Methodology in Scientific Cognition.	-	-	4	GC-2, GC-3, GC-5
8	The Dynamics of Science as a Process of Generating New Knowledge.	-	2	4	GC-1, GC-4, GC-5
9	Traditions and Innovations in the Development of Science. Scientific Revolutions.	-	-	4	GC-1, GC -5
10	Characteristics of the Contemporary Stage of Science Development.	2	-	4	GC-2, GC-3, GC-4
11	3. Philosophy of Science. Models of Scientific Cognition.	-	-	4	GC-1, GC-5
12	Final Assessment.	-	2	-	GC-1, GC-2 GC-3, GC-4 GC-5
	Total	6	10	44	

Stage 1 involved the preparation and development of the questionnaire at the Elabuga Institute of Kazan Federal University (KFU), where the authors conducted a series of preparatory activities. The procedures at this stage included selecting the students included in the research (all students from the Faculty of Philology were included in the study), compiling and discussing questionnaire questions, and developing criteria for assessing responses. In the process of developing the questionnaire, 10 questions were selected to assess individual respondent abilities, including the ability to break down large sets of information into smaller components, establish correlations between processes, factors, and facts, make non-standard rational decisions for professional tasks, analyze and compare data, and forecast the effectiveness of assigned tasks. To assess the validity and reliability of the questionnaire, Cronbach's alpha coefficient and factor analysis using principal component analysis were employed. Cronbach's alpha coefficient yielded a value of 0.85, indicating high internal consistency among the questionnaire items. Furthermore, the factor analysis confirmed the appropriate grouping of questions by factors. Eigenvalues greater than one indicated an adequate number of factors to account for the variability in the data. Thus, the obtained results corroborate the validity and reliability of the questionnaire.

Stage 2 involved conducting student surveys using the online service Google Forms where respondents entered their answers. The questionnaire consisted of 10 open-ended questions. The authors distributed the questionnaire link to students, and the link remained active for one month (January 2022). Respondents had the option to complete the survey via a computer or smartphone.

Stage 3 encompassed the synthesis and analysis of the collected data, carried out by an expert team consisting of 2 candidates and 3 doctorates in Psychological and Philosophical Sciences. The level of analytical thinking ranged from 0 to 10 points and was categorized into three intervals: low level (0 to 3 points), intermediate level (4 to 7 points), and high level (8 to 10 points).

To assess analytical thinking, the authors developed a questionnaire titled “Analytical Thinking of Students”. The assessment of academic performance was conducted on a five-point scale, where “1” indicated weak performance, “2”: fair, “3”: satisfactory, “4”: good, and “5”: excellent.

B. Statistical Data Analysis

Statistical analysis of the research results involved the Microsoft Office Excel software package and occurred in two stages:

Analysis of quantitative parameters; calculations performed according to the formula (M ± SD), where M is the mean arithmetic value, and SD is the standard deviation. In all statistical analysis calculations, the significance level (p) was set to 0.05.

Correlation analysis conducted to determine the presence/absence of a relationship/correlation between the level of thinking and the academic performance of students. The Pearson coefficient (r) was used, with values of r (in absolute terms) up to 0.2 indicating a very weak correlation, up to 0.5 indicating a weak correlation, up to 0.7 indicating a moderate correlation, up to 0.9 indicating a high correlation, and above 0.9 indicating a very high correlation.

C. Ethical Issues (Compliance with Ethical Standards)

This non-therapeutic research observed the Helsinki Declaration on Ethical Principles for Medical Research Involving Human Subjects. All research participants were informed about the purposes and methods of the study, and they provided informed consent. Additionally, conditions of complete anonymity were maintained, and there were no conflicts of interest. The university’s Bioethics Committee approved the conduct of the research in the 2021/2022 academic year.

IV. Results

The research findings revealed that, when comparing groups utilizing traditional teaching methods and VR technology, the level of analytical thinking was significantly higher by 9.97% in the VR group ($p < 0.05$). The level of analytical thinking in the studied groups was 7.32±0.36 (average level) and 8.05 ± 0.11 (high level), respectively (Table 2). These results indicate that the integration of modern digital VR technology enables an increase in the level of analytical thinking by 9.97%.

Table 2. Learning outcomes of the students

Participants	Group 1 (228 participants), traditional learning	Group 2 (208 students), VR technology	*p*-value
	M ± SD	M ± SD	
Analytical Thinking	7.32 ± 0.36	8.05 ± 0.11	0.042**
Academic Results	3.84 ± 0.69	4.14 ± 0.49	0.058*

Note: * $p > 0.05$, not significantly different; ** $p < 0.05$, significantly different

In self-assessing their analytical thinking abilities, respondents in the traditional learning and VR groups believed they possessed such thinking (82% and 87%, respectively); probably had it (7% and 10%, respectively); did not have it (11% and 3%, respectively) ($p < 0.05$). In VR group, there were 5% more students who considered themselves to have analytical thinking skills. This may be associated with the formation and development of neural connections, and an increase in collaterals and semantic connections during the development of analytical thinking. The number of experiment participants using trigonometry and statistics in the investigated groups was 81% and 87%, respectively ($p < 0.05$). The VR group used trigonometry and statistics 6% more frequently, probably due to their ability to solve geometric problems with elements of trigonometry, thereby developing their intelligence, logic, and the ability to draw conclusions and find simple non-standard solutions.

Computer technologies were used by 77% (traditional learning) and 81% (VR) for solving various tasks, problems, and situations ($p > 0.05$). There are no significant differences between the investigated groups in the use of computer technologies, but the VR-technology group used computer technologies 4% more frequently. Computer technologies (modeling, synergy) might have contributed to the development of systemic-analytical thinking among students. Indecisiveness was observed in both the traditional education group and the VR group, at rates of 13% and 8%, respectively ($p < 0.05$). Students from the VR group were 5% significantly less indecisive, which may be linked to a lower level of ability to predict the outcomes of their decisions.

Fast decision-making was observed in 88% and 94% of respondents in the investigated groups ($p < 0.05$). Students from the VR group made decisions 6% faster. The possible reason is a higher level of knowledge that enabled those students to make efficient and non-standard decisions more quickly. There were positive dynamics in planning skills in 71% of the traditional learning group and 77% of the VR group ($p < 0.05$). Students from the VR group developed their planning skills 6% better, probably due to their ability to separate tasks into parts and establish cause-and-effect relationships.

Students in both groups made errors, with percentages of 24% (traditional learning) and 22% (VR) ($p > 0.05$). Students from the VR group made 2% fewer errors, which may be associated with their more attentive and detailed examination of the problem or task at hand. There were no hopeless situations for 22% of students in the VR group and 14% of students in the traditional learning group ($p < 0.05$); they sought alternative solutions in 78% and 86% of cases, respectively ($p < 0.05$). Students from the VR group were 8% more effective at finding solutions to hopeless situations. This may be attributed to their ability to actively search for non-standard and simple solutions and effective thinking skills.

Students managed to predict the effectiveness of the tasks they set in 83% (traditional learning) and 89% (VR) ($p < 0.05$). Students from the VR group predicted the effectiveness of their tasks 6% more often, which may be linked to their more frequent, thorough, and effective analysis of past processes, trends, and events. Both groups of students used tables: 53% and 56%, respectively ($p > 0.05$). Students from the VR group used tables 3% more frequently, possibly due to their mathematical skills.

The study found that when comparing groups using traditional teaching methods and VR technology, academic results did not differ ($p > 0.05$). The average score was 3.84 ± 0.69 and 4.14 ± 0.49, respectively, with a 7.81% increase in the average score in the VR group (Fig. 1). These results indicate that the integration of modern digital VR technology allows for an increase in academic results by 7.81%. Students taught using traditional teaching methods demonstrated a lower average score compared to students who used VR technology.

The study used a correlation analysis to detect the presence or absence of a correlation between students' level of analytical thinking and their academic performance. The results of the correlation analysis revealed a moderate positive correlation in the studied groups: the Pearson correlation coefficient was r1 = 0.761 (traditional learning) and r2 = 0.846 (VR technology), respectively. The research findings indicate that students in the VR group showed a statistically significant change in the level of analytical thinking: it increased by 5%. They also used trigonometry and statistics 6% more frequently, computer technologies 4% more frequently, exhibited 5% less indecisiveness, made decisions 6% faster, developed planning skills 6% better, made 2% fewer errors and found solutions to seemingly insurmountable situations 8% more effectively compared to their counterparts in the traditional education group. This enhancement in analytical thinking could potentially be attributed to a 9.97% increase.

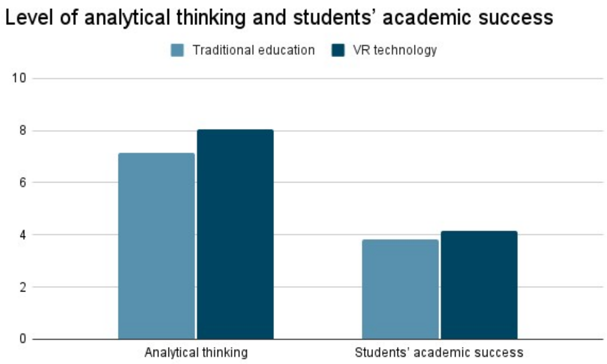

Fig. 1. Level of analytical thinking and students' academic success.

The research found a moderate positive correlation between the level of analytical thinking and academic performance among students. To put it differently, improved academic outcomes are linked to elevated levels of analytical thinking, and the utilization of VR technology fosters the development of advanced analytical thinking abilities in students.

Thus, this study examined the capabilities of modern digital educational resources and their impact on students' analytical thinking levels. The results showed that the application of VR technology leads to 1) an increase of 9.97% in the level of analytical thinking and 2) a 7.81% increase in the average grade. These findings suggest that digital educational opportunities foster the growth, comprehension, and grasp of professional tasks, processes, and situations. Furthermore, there is a moderate positive correlation between the degree of analytical thinking and the academic accomplishments of students.

V. Discussion

Researchers in the USA [37] investigated the application of modern digital virtual reality tools in student education. Their study revealed several advantages of 360 VR-technology simulation in education: (1) It effectively enables students to absorb large volumes of information; (2) It supports novice students in acquainting themselves with new contexts and communities; (3) It facilitates macro and micro practice. Furthermore, immersive VR technology environments activate the emotional component, the formation of semantic connections, and the holistic perception of assigned tasks. These aspects, in turn, form the basis for the development of analytical thinking. The results of our study also demonstrate the positive impact of VR technology on the level of analytical thinking among students. The use of VR technology for education resulted in a 9.97% increase in the level of analytical thinking compared to the traditional education group.

The impact of virtual reality technologies on the development of students' thinking was investigated by researchers in China [38]. They conducted a study among medical students, focusing on clinical thinking, which forms the foundation for making profession-oriented decisions. The application of educational VR technology allows for the following outcomes: (1) Effective development of students' visual-spatial abilities and comprehension of the material; (2) Provision of a realistic clinical learning environment for students; (3) Reduction of the gap between theoretical knowledge and practical competencies; (4) Conservation of educational resources; (5) Formation and enhancement of critical thinking skills. In our study, the use of VR technology enabled an increase in the level of analytical thinking by 9.97% and raised the average score by 7.81%.

A team of researchers from Russia [39] examined the development of thinking skills using modern digital educational resources. The authors assert that a key competence in higher education is critical thinking, which needs to be cultivated and enhanced. The researchers investigated the development of critical thinking in an online learning environment by increasing student engagement in the educational process. This study revealed a correlation between preferred learning styles and levels of critical thinking. The research findings demonstrate that 54.8% of respondents positively perceived reflective learning, which involves critical assessment and analysis of the received information. In our study, the level of analytical thinking, involving the analysis of information, in the examined groups was 7.32 points (73.20%) and 8.05 points (80.50%), respectively.

Khalifaeva *et al.* [40] have described the impact of digital virtual reality technology on systemic thinking skills. Their results indicate that virtual reality technology is an effective tool for stimulating high-level systemic thinking skills, enabling the development of effective decision-making skills, conducting analysis, and increasing the level of thinking. These findings align synchronously with our results, as the application of VR technology allowed for an increase in the level of analytical thinking by 9.97%. Furthermore, the authors from the USA confirmed that virtual reality technology is positively perceived by students. They also concluded that the level of education is an important factor in shaping thinking—individuals with higher education tend to have a higher level of thinking. In addition, the researchers found that gender does not influence the systems thinking skills of students.

Goel *et al.* [41] examined the relationship between thinking styles and the academic success of students. The researchers identified a significant correlation between managerial and practical thinking styles and academic performance. Our study found a positive correlation between analytical thinking and academic achievements. Respondents in the Russian study demonstrated above-average success, which aligns with the results of our study.

Goel [42] have studied the development of analytical thinking in digital education. Analytical thinking skills require students not only to memorize and understand the material but also to apply it in their professional activities. The authors also emphasize that analytical thinking skills in students need to be cultivated, developed, and practiced through the interpretation of information and the identification of similarities and differences in the presented data. The research found that the level of analytical thinking among Indonesian respondents was 41.89%. In our study, the level of analytical thinking in the investigated groups was determined to be 7.32 points (73.20%) and 8.05 points (80.50%), respectively. The integration of modern digital educational resources into the higher education system contributes to the digitization and modernization of educational processes. This leads to improvements not only in the academic success of students but also in their level of analytical thinking.

The study did not include students from the following faculties: engineering and technology, mathematics and natural sciences, economics and management, and law. This exclusion was due to differences in their educational programs and curriculum requirements.

VI. Conclusions

Digitization of education ensures the continuity of the learning process and provides a high level of theoretical knowledge and practical competencies. Research methods included an online survey of students and content analysis of the obtained results.

The research findings revealed that students in the VR group demonstrated a statistically significant increase in their analytical thinking skills by 5%. Furthermore, they exhibited a 6% higher propensity to utilize trigonometry and statistics, a 4% greater inclination toward using computer technologies, a 5% reduction in indecisiveness, a 6% improvement in decision-making speed, a 6% enhancement in their planning skills, a 2% decrease in errors, an 8% improvement in finding solutions in challenging situations, and a 3% higher frequency of utilizing tables. These findings were attributed to the development and cultivation of a higher (9.97%) level of analytical thinking. It is noteworthy that the academic achievements of students in the examined groups did not exhibit any significant differences ($p > 0.05$). The mean score for the VR group was 4.14 ± 0.49, indicating a 7.81% increase in average scores compared to the group without VR-based integration.

The results of this study demonstrate the positive impact of educational digitalization: the integration of contemporary digital educational resources such as VR technology not only enhances the academic performance of students but also significantly increases their level of analytical thinking. In the future, there are plans to introduce a live webinar titled "Development of Analytical Thinking in Digital Learning Environments" for higher education. This webinar, facilitated through web technologies in a live streaming mode, will incorporate innovative educational techniques (immersive immersion, brainstorming, dialogues, exercises, situational problems) aimed at improving theoretical knowledge and practical skills.

Appendix

Questionnaire of "Analytical Thinking of Students":

1) Do you possess analytical thinking? Please justify your answer.
2) Describe a task for which you needed to use trigonometry or statistics to solve.
3) Describe a problem for which you utilized computer technologies to find a solution.
4) Share a situation in which you experienced indecision
5) Describe a scenario in which you had to make a quick decision.
6) In your opinion, how much have you improved your planning skills over the last few years?
7) Under what circumstances do you usually make mistakes?
8) What actions do you take in seemingly impossible situations?
9) Based on what factors do you typically predict the effectiveness of set tasks?
10) How often do you use tables?

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, Z.L. and E.G.; Methodology, Z.L.; Software, E.G.; Validation, Z.L., L.M. and I.S. and E.G.; Formal Analysis, L.M. and I.S.; Investigation, E.G.;

Resources, L.M. and I.S.; Data Curation, E.G.; Writing – Original Draft Preparation, Z.L.; Writing – Review & Editing, L.M. and I.S.; Visualization, Z.L.; Supervision, E.G.; Project Administration, Z.L.; Funding Acquisition, E.G. All authors had approved the final version.

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