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DEVELOPING AN ADAPTIVE EDUCATIONAL ENVIRONMENT MODEL TO MEET THE NEEDS OF GENERATION ALPHA LEARNERS IN GENERAL SECONDARY EDUCATION: A CASE STUDY OF A PRIVATE LYCEUM

РОЗРОБКА МОДЕЛІ АДАПТИВНОГО ОСВІТЬОГО СЕРЕДОВИЩА ЗАКЛАДУ ЗАГАЛЬНОЇ СЕРЕДНЬОЇ ОСВІТИ ДО ПОТРЕБ ЗДОБУВАЧІВ ОСВІТИ ПОКОЛІННЯ ALPHA: НА ПРИКЛАДІ ПРИВАТНОГО ЛІЦЕЮ

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ABSTRACT

Aim. The aim of this article is to identify and substantiate approaches to adapting the educational process of a private lyceum to the Generation Alpha learners' needs, through the systematisation of current theoretical and

Мета. Метою цієї статті є визначення та обґрунтування напрямів адаптації освітнього процесу приватного ліцею до потреб здобувачів освіти покоління Alpha на основі систематизації сучасних теоретико-

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methodological approaches to the digital transformation of education and the analysis and synthesis of the results of learners' survey.

Methodology. The study employed theoretical analysis of the relevant scholarly literature, questionnaire-based surveying, quantitative and qualitative interpretation of the survey findings, synthesis of pedagogical experience, and pedagogical modelling. The empirical basis of the study consisted of a survey of 64 learners in Years 9–10 at the Private Lyceum 'Kharkiv Collegium', Kharkiv, Ukraine. The questionnaire addressed high school students' perceptions of the educational process, digital learning practices, academic workload, attention and concentration, communication, psychological well-being, learner autonomy, critical thinking and career orientation. The interpretation of the findings was based on theoretical and methodological approaches to digital learning, multimedia learning, self-regulated learning, formative assessment, social-emotional learning, Artificial Intelligence (AI) literacy and career guidance discussed in the literature review. Particular attention was paid to the school context of the private lyceum, characterised by greater potential for flexible organisation of learning, individualised support and the integration of digital and supplementary educational practices. The findings are therefore interpreted primarily as evidence of the specific educational needs and adaptation priorities of learners in the lyceum under study, rather than as representative of general secondary school education as a whole.

Findings. The findings indicate that learners generally perceive the lyceum's educational environment positively, particularly in terms of learning comfort, teachers' explanations and communication with teachers. At the same time, several priorities for adaptation were identified. These include establishing a more coherent digital learning environment and providing structured online revision materials; optimising academic workload; developing learner's autonomy and self-regulated learning; strengthening social-emotional support and formative feedback; increasing the practical orientation of learning; expanding career guidance; and developing critical thinking and responsible use of generative AI. The findings demonstrate that adaptation to Generation Alpha learners should not be limited to increasing the use of digital technologies, but should involve the coordinated development of digital, cognitive, self-regulatory, social-emotional, assessment,

методичних підходів до цифрової трансформації освіти, а також аналізу й узагальнення результатів анкетування учнів.

Методологія. У дослідженні використано теоретичний аналіз наукової літератури, анкетування, кількісну та якісну інтерпретацію результатів опитування, узагальнення педагогічного досвіду та педагогічне моделювання. Емпіричною базою стало анкетування 64 учнів 9-10 класів Приватного ліцею «Харківський Колегіум», Харків, Україна. Анкета охоплювала питання щодо сприйняття учнями освітнього процесу, цифрових практик навчання, навчального навантаження, уваги й концентрації, комунікації, психологічного благополуччя, навчальної самостійності, критичного мислення та професійної орієнтації. Інтерпретація результатів ґрунтувалася на теоретико-методичних підходах до цифрового навчання, мультимедійного навчання, саморегульованого навчання, формульованого оцінювання, соціально-емоційного навчання, грамотності штучного інтелекту (ШІ) та профорієнтації, розглянутих у теоретичному огляді. Особливу увагу приділено шкільному контексту приватного ліцею, який характеризується більшим потенціалом для гнучкої організації навчання, індивідуалізованої підтримки та інтеграції цифрових і додаткових освітніх практик. Тому результати інтерпретуються передусім як свідчення специфічних освітніх потреб і пріоритетів адаптації учнів досліджуваного ліцею, а не як репрезентативні для закладів загальної середньої освіти загалом.

Результати. Результати дослідження засвідчили, що учні загалом позитивно сприймають освітнє середовище ліцею, особливо комфортність навчання, пояснення навчального матеріалу вчителями та комунікацію з педагогами. Водночас було визначено низку пріоритетних напрямів адаптації. До них належать створення більш упорядкованого цифрового освітнього середовища та забезпечення структурованими онлайн-матеріалами для повторення; оптимізація навчального навантаження; розвиток навчальної самостійності та саморегульованого навчання; посилення соціально-емоційної підтримки та формульованого зворотного зв'язку; підвищення практичної спрямованості навчання; розширення профорієнтаційної підтримки; розвиток критичного мислення та відповідального використання генеративного ШІ. Отримані результати свідчать, що адаптація освітнього процесу до потреб покоління Alpha не має обмежуватися розширенням використання цифрових технологій, а має передбачати комплексний розвиток цифрового, когнітивного, саморегуляційного, соціально-

career-guidance and AI-literacy components of the educational environment.

Conclusions. *The study substantiates a practice-oriented model of an adaptive educational environment for a private lyceum, grounded in empirically identified learners' needs and contemporary approaches to educational transformation. Its effectiveness should be assessed through repeated diagnosis of learners' needs, changes in academic stress, satisfaction with the digital learning environment, learner autonomy, and clarity of educational and career trajectories. The proposed approach provides a basis for further empirical validation and adaptation across different educational contexts.*

Keywords: *career guidance, digital learning environment, educational process adaptation, Generation Alpha, learner autonomy, private lyceum, social-emotional support.*

емоційного, оцінювального, профорієнтаційного та ШІ-компонентів освітнього середовища.

Висновки. *У дослідженні обґрунтовано практико-орієнтовану модель адаптивного освітнього середовища приватного ліцею, що ґрунтується на емпірично виявлених потребах учнів і сучасних підходах до трансформації освіти. Її ефективність доцільно оцінювати за результатами повторної діагностики потреб учнів, змінами рівня навчального стресу, задоволеності цифровим освітнім середовищем, сформованості навчальної самостійності та визначеності освітньо-професійних траєкторій. Запропонований підхід створює основу для подальшої емпіричної апробації та адаптації моделі в різних освітніх контекстах.*

Ключові слова: *професійна орієнтація, цифрове освітнє середовище, адаптація освітнього процесу, покоління Alpha, навчальна автономія, приватний ліцей, соціально-емоційна підтримка.*

INTRODUCTION

Contemporary general secondary education is developing against the backdrop of profound digital transformation, changing societal expectations of schooling and increasing demands for the quality of learners' preparation for life in conditions of uncertainty. The educational process can increasingly no longer be viewed merely as a system of transmitting knowledge from teacher to learner. Rather, schools are expected to foster learners' capacity for independent learning, critical thinking, information management, responsible use of digital technologies, communication and collaboration, decision-making and the development of their own educational and career trajectories.

These challenges are particularly relevant to the education of Generation Alpha, commonly described as the first generation to have grown up in an environment in which digital technologies are deeply embedded in everyday life. Their educational experiences are shaped by ubiquitous access to digital information, multimodal communication, online interaction, visual content and a wide range of digital learning and entertainment resources. From a psycho-pedagogical perspective, however, Generation Alpha should not be characterised solely by its familiarity with digital technologies.

A systematic review by Höfrová et al. (2024), encompassing 83 studies, demonstrates that although the literature frequently attributes distinctive educational characteristics to Generation Alpha, empirical evidence for clear generational differences remains limited. Nevertheless, the review identifies several tendencies of direct relevance to education, including intensive engagement with digital technologies, the growing role of online and blended learning, and concerns related to social-emotional development and psychological well-being. Importantly, the authors emphasise the continuing role of teachers as mediators of technology use and the need to combine digital learning opportunities with interpersonal interaction and appropriate pedagogical support.

Accordingly, Generation Alpha learners may be viewed not simply as technologically familiar users, but as learners whose educational experiences require a balance between digital opportunities and structured pedagogical guidance. They may value interactive and

visually rich learning environments, rapid feedback, flexible access to learning resources, personalised support and clear connections between learning and real-life contexts.

At the same time, extensive exposure to digital devices, platforms and online content does not automatically result in developed digital competence, critical thinking, self-regulation, sustained attention or academic integrity. This challenges the simplified notion of Generation Alpha as a generation of inherently competent 'digital natives'. As Kirschner and De Bruyckere (2017) argue, frequent use of digital technologies should not be equated with the ability to use them effectively for learning.

Consequently, adaptation of the educational process to Generation Alpha should be understood as a multidimensional pedagogical task encompassing the purposeful organisation of digital learning, cognitive and motivational support, development of learner autonomy and critical judgement, social-emotional well-being, and meaningful teacher–student interaction. In this context, the key issue is not the extent to which digital technologies are present in the educational environment, but how effectively they are pedagogically integrated to support learners' cognitive, social, emotional and educational-professional development.

The digital transformation of education is inherently ambivalent. On the one hand, digital platforms, online resources, multimedia materials, assessment systems and artificial intelligence tools create opportunities for more flexible, accessible and personalised learning. On the other hand, their chaotic or fragmented use may intensify information overload, complicate the organisation of learning, reduce learners' concentration, and increase the risk of superficial knowledge acquisition. The OECD (2023) emphasises that an effective digital education ecosystem should not be built around technology itself, but around the pedagogically purposeful use of digital tools to support learning, assessment, feedback and educational interaction.

A review of the contemporary literature indicates that the adaptation of educational processes to the needs of the new digital generation is an interdisciplinary issue. Höfrová et al. (2024) synthesise the educational characteristics of Generation Alpha and highlight its orientation towards digital interaction, visual forms of information, rapid access to information and personalised modes of learning. At the same time, Kirschner and De Bruyckere (2017) caution against the mythologisation of the concept of the 'digital native', as technological activity does not necessarily correspond to the development of effective learning strategies, critical thinking or digital literacy. Consequently, learners' digital experience should not simply be incorporated into the educational process; rather, it should be purposefully guided and pedagogically mediated.

Within the context of blended learning, the findings of the systematic review by Angawi and Tasir (2024) are particularly relevant. Their findings demonstrate that the effectiveness of blended learning depends not on the mere combination of online and face-to-face formats, but on purposeful pedagogical design, a clear allocation of functions between face-to-face and digital components and appropriate support for learners' independent study. This position is consistent with research on informal online learning, particularly MOOCs, which, in the context of Ukrainian business education, are regarded as a resource for expanding educational opportunities, fostering learner autonomy, and providing flexible access to knowledge (Salun & Zaslavskaya, 2024). In school education, these findings can be applied to the development of digital revision materials, short online modules and curated collections of open-access courses for career guidance.

The issue of cognitive load in digital educational environments has been examined extensively in research on multimedia learning, which emphasises that the combination of text, images, video and interactive elements is effective only when their use is pedagogically purposeful and does not overload working memory (Mayer & Fiorella, 2021).

Ukrainian scholarship likewise highlights the ways in which the digitalisation of education transforms the cognitive conditions of learning, particularly by increasing the role of information noise, multitasking, digital distractions, and the need for pedagogically structured online interaction (Fazan et al., 2025; Tverdokhliebova & Yevtushenko, 2026). Therefore, an adaptive educational environment should not merely provide learners with digital resources; it should also support them in organising, prioritising and effectively using these resources.

A distinct body of research focuses on social and emotional learning, feedback and pupil well-being. Durlak et al. (2011) demonstrate that social and emotional learning programmes have a positive impact on pupils' academic attainment, behaviour and emotional well-being. UNESCO (2024) conceptualises the 'happy school' as an educational environment in which psychological well-being, supportive relationships and a safe atmosphere constitute important preconditions for effective learning. Similarly, the Education Endowment Foundation (2021) and Lui and Andrade (2022) emphasise that feedback should not merely communicate the outcome of learning but should also help pupils identify their next steps, learn from errors and sustain their motivation to learn.

With regard to digital competence, particular importance should be attached to the DigComp 2.2 framework, which encompasses information and data literacy, communication and collaboration in digital environments, digital content creation, safety and problem-solving (Vuorikari et al., 2022). In view of the growing use of generative artificial intelligence, the UNESCO recommendations (2023a), are particularly relevant, emphasising the need for human-centred, ethical and pedagogically guided use of Artificial Intelligence (AI) in education. Studies by Gulich and Chetveryk (2025), and Yurchenko and Nalyvaiko (2025) indicate that generative AI can support motivation, foreign language learning, writing activities and creative processes. At the same time, its use requires clear academic integrity guidelines, critical evaluation of AI-generated outputs and the preservation of the pupil's role as an active agent in the learning process.

Overall, the contemporary scholarly literature allows the adaptation of educational provision to the needs of Generation Alpha to be conceptualised as a multifaceted challenge encompassing the digital organisation of learning, cognitive support, formative assessment, the development of self-regulation, social and emotional well-being, digital competence and career guidance. Nevertheless, insufficient attention has been paid to how these approaches can be systematically integrated into the educational process of a specific private lyceum on the basis of the empirically identified needs and expectations of its pupils.

The relevance of this issue is further heightened by the fact that the digitalisation of education in Ukraine is taking place alongside reforms to the content of general secondary education, the strengthening of the competence-based approach and the transition towards a more flexible model of upper secondary education. The New Ukrainian School (NUS) concept identifies the development of critical thinking, the capacity for lifelong learning, initiative, digital literacy and pupils' responsibility for their own educational trajectories among its key priorities (Kabinet Ministriv Ukrainy, 2016).

At the same time, the reform of upper secondary education, scheduled to commence in 2027, envisages broader opportunities for pupils to choose educational profiles and subjects. This development further highlights the importance of supporting senior pupils' career decision-making and personalising the educational process (Ministerstvo osvity i nauky Ukrainy, 2024).

For private general secondary education institutions, the adaptation of educational provision to the needs of pupils belonging to the new digital generation is of particular significance. Such institutions operate in a competitive educational services environment, where key factors determining their development include the quality of education, comfort and safety, digital readiness, educational specialisation, individualised support, psychological provision, and the capacity to respond effectively to the current needs and expectations of pupils and their parents. Consequently, the adaptation of educational provision cannot be reduced to the declarative introduction of digital tools or the modernisation of material and technical resources. Rather, it should be grounded in a systematic analysis of pupils' educational experiences, needs, difficulties and expectations.

Recent research indicates that contemporary educational science offers a range of approaches relevant to adapting educational provision to the needs of Generation Alpha. Among these, Universal Design for Learning (UDL) occupies an important position, as it provides for multiple means of engaging learners, representing information and demonstrating learning outcomes (CAST, 2024). Equally significant is the competence-based approach, which focuses education on learners' ability to apply knowledge in authentic situations.

Research on blended learning further demonstrates that the effective integration of face-to-face and online components can enhance the flexibility and accessibility of educational provision (Angawi & Tasir, 2024). Within the context of digital education, particular importance should be attached to self-regulated learning, which encompasses goal setting, planning, monitoring, reflection and the adjustment of one's own learning activities (Faza & Lestari, 2025). Assessment and high-quality feedback are likewise regarded as important conditions for supporting pupils' learning progress (Education Endowment Foundation, 2021; Lui & Andrade, 2022).

The social and emotional dimension of educational adaptation is of particular importance. The meta-analysis conducted by Durlak et al. (2011) demonstrates that social and emotional learning programmes have a positive effect not only on pupils' behaviour and emotional well-being but also on their academic attainment. Similarly, UNESCO (2024) through its concept of 'happy schools', emphasises that psychological well-being, supportive relationships, a safe environment and positive pedagogical interaction constitute important conditions for effective learning.

This is particularly relevant to upper-secondary pupils, who simultaneously experience considerable academic demands, prepare for entrance examinations and face uncertainty concerning their future educational and career choices. Therefore, adapting the educational environment to their needs requires not only appropriate digital and pedagogical solutions but also systematic psychological and motivational support.

Despite the substantial body of theoretical research in this field, the transition from general concepts of the digital transformation of education to context-specific solutions at the level of an individual educational institution remains an important research problem. It is particularly important that such solutions should be grounded in empirical

evidence concerning pupils' actual needs rather than solely in general assumptions about Generation Alpha. Accordingly, the present study focuses on the results of a survey of Year 9 and Year 10 pupils at the Private Lyceum 'Kharkiv Collegium'.

The aim of this article is to identify and substantiate approaches to adapting the educational process of a private lyceum to the Generation Alpha learners' needs, through the systematisation of current theoretical and methodological approaches to the digital transformation of education and the analysis and synthesis of the results of learners' survey.

To achieve this aim, the following research objectives were defined: to analyse pupils' perceptions of the educational process at the private lyceum; to identify the digital platforms used by pupils and the difficulties associated with their use; to examine the pupils' cognitive, socio-psychological, communicative and value-related characteristics; and to substantiate practical directions for developing an adaptive educational environment aimed at fostering motivation, learner autonomy, critical thinking and career self-determination.

METHODOLOGY

– Study Participants

The empirical study was conducted at the Private Lyceum 'Kharkiv Collegium' (2026). A total of 64 Year 9 and Year 10 pupils participated in the survey (Tab. 1).

Table 1

Characteristics of the Study Sample

Year group	Number of respondents	Percentage of the total, %
Year 9	37	57,8
Year 10	27	42,2
Total	64	100,0

Note. Compiled by the authors based on the survey findings.

In selecting the empirical setting, consideration was given not only to the age characteristics of the respondents but also to the institutional context in which the lyceum operates. The Private Lyceum 'Kharkiv Collegium' of Kharkiv Region is a private general secondary education institution whose activities are documented in publicly accessible state educational registers (Yedyna derzhavna elektronna ..., n.d.). This made it possible to interpret the survey findings alongside an analysis of the institution's organisational characteristics, educational specialisation, digital readiness and position within the regional educational environment.

The selection of Year 9 and Year 10 pupils as the target group was determined by the importance of this educational stage for the development of learning autonomy, critical thinking, career interests and readiness to make subsequent decisions concerning an educational trajectory. Pupils at this stage have already acquired substantial experience of engaging with different learning formats, digital platforms, online materials and tools for independent study. At the same time, they are entering a period of increased academic demands associated with preparation for upper-secondary specialised education, the National Multi-Subject Test (NMT) and subsequent admission to higher education.

The survey was conceived as a diagnostic instrument aimed not at identifying individual characteristics of particular pupils but at establishing the aggregated educational needs

of the group. Accordingly, the data were analysed primarily using descriptive statistics, while the resulting percentages were interpreted as indicators of educational needs, difficulties and potential directions for adapting the educational process. This approach is consistent with the principles of evidence-informed education, whereby pedagogical decisions are expected to be grounded in evidence derived from a specific educational context rather than solely from general assumptions about a particular generation of learners.

– Research Procedure

The survey was designed to determine the extent to which the existing organisation of the educational process corresponds to the needs and expectations of contemporary upper-secondary pupils in the context of digitalisation. The survey had a diagnostic purpose and comprised several thematic blocks: overall perceptions of the educational process; the digitalisation of learning and the use of educational platforms; blended learning; academic workload; communication with teachers and peers; psychological well-being; motivation; learner autonomy; critical thinking; value orientations; and career self-determination.

The questionnaire included closed, semi-closed and open-ended items. Some questions required responses on an agreement scale, while others involved selecting one or more response options. The results were processed in an aggregated form. The data were interpreted as indicators of pupils' educational expectations, needs and areas of difficulty within the educational process.

Importantly, the study was not intended to rank pupils according to their academic performance or to conduct individual psychological or pedagogical assessment. Rather, its purpose was to identify general directions for adapting the educational process at the institutional level. Consequently, the primary units of analysis were not individual responses but the proportions of respondents who endorsed particular statements, reported specific difficulties or expressed a need for particular forms of educational support.

– Methods of Analysis

The study employed theoretical analysis of the relevant scholarly literature, a comparative-analytical method, questionnaire-based surveying, quantitative and qualitative analysis of the survey findings, synthesis of pedagogical experience, and pedagogical modelling. Quantitative data processing was conducted using descriptive statistics. The principal findings are presented as percentages of the total number of respondents.

The interpretation of the empirical findings was informed by contemporary theoretical and methodological approaches, including Universal Design for Learning, blended learning, self-regulated learning, formative assessment, multimedia learning, digital competence, social and emotional learning, and career guidance and support. This methodological framework made it possible to establish meaningful links between the empirical findings and specific pedagogical solutions for adapting the educational process.

RESULTS

– Pupils' Overall Perceptions of the Educational Process

The survey findings indicate that the majority of pupils generally perceive the educational process at the lyceum positively (Tab. 2).

Table 2*Students' Assessment of Selected Aspects of the Educational Process*

Indicator	Proportion of positive responses, %	Analytical interpretation
Comfort of learning at the lyceum	76.8	The overall educational environment is perceived positively by the majority of students
Clarity of teachers' explanations of learning material	71.4	Teacher–student interaction is perceived as sufficiently effective
Adequacy of the academic workload	48.2	There is a need to reconsider the balance between task complexity, workload and rest
Alignment of the timetable with students' levels of fatigue	52.7	Greater flexibility in organising the school day is required
Practical orientation of learning	55.4	Students expect stronger links between school subjects, real-life contexts and future careers
Support for preparation for the NMT / university admission	68.7	Subject-specific and examination preparation represents a notable strength of the lyceum
Comfort of communication with teachers	73.2	Most students feel able to approach teachers for assistance
Need for additional career guidance and support	64.3	Career orientation and educational–professional decision-making are among the key concerns of senior students

Note. Compiled by the authors based on the results of the student survey.

In particular, 76.8% of respondents reported that they felt comfortable studying at the lyceum, while 71.4% positively assessed the clarity of teachers' explanations of the learning material. Communication with teachers was also evaluated favourably: 73.2% of pupils indicated that they felt comfortable asking a teacher questions when they did not understand the material.

At the same time, the findings reveal several areas requiring further attention. Only 48.2% of pupils considered their academic workload to be optimal, while 52.7% positively assessed the extent to which the timetable corresponded to their level of fatigue throughout the school day. The practical orientation of learning was positively evaluated by 55.4% of respondents. Although 68.7% of pupils positively assessed the support provided for preparation for the National Multi-Subject Test (NMT) or admission to higher education, 64.3% simultaneously reported a need for additional career guidance and support.

Taken together, these findings suggest that the existing educational environment provides a generally positive basis for learning, while also indicating a need for greater

attention to workload management, the practical relevance of learning, and systematic support for pupils' educational and career planning.

The findings indicate that the lyceum's educational process has a strong foundation in the form of a supportive learning environment and sufficiently effective teacher–student interaction. At the same time, students expect greater digital organisation, practical relevance, flexibility and career guidance and support.

– Use of Digital Platforms

A separate section of the questionnaire addressed the digitalisation of the educational process. The results indicate that digital tools have already become an integral part of students' learning experience (Tab. 3). Respondents most frequently reported using Zoom; messaging applications such as Telegram, Viber and WhatsApp; Google Docs and Google Drive; YouTube; online tests for NMT preparation; Google Classroom; interactive services such as Kahoot, Quizlet and Learning Apps; as well as ChatGPT and other artificial intelligence tools.

Table 3

Digital Platforms and Online Services Used by Students

Digital platform / online service	Proportion of students reporting use, %	Main purpose of use	Analytical significance for the educational process
Zoom	92.2	Participation in online lessons, consultations and remote learning	Enables continuity of learning for students studying remotely or temporarily unable to attend lessons in person
Telegram / Viber / WhatsApp	81.3	Educational communication with teachers and classmates	Facilitates rapid interaction but requires better organisation of information flows
Google Docs / Google Drive	68.8	Working with documents, storing materials and collaborative work	Supports the organisation of learning materials and the development of digital collaboration skills
YouTube	65.6	Watching video explanations and reviewing challenging topics	Supports visual processing of information and independent revision
Online tests for NMT preparation	57.8	Self-assessment and practising test-taking skills	Supports individual preparation for entrance examinations
Google Classroom	42.2	Accessing assignments and learning materials and communicating with teachers	Can provide a basis for systematising the digital organisation of learning

Kahoot, Quizlet, Learning Apps	34.4	Interactive exercises, revision and game-based activities	Enhances student engagement and can be used for formative assessment
ChatGPT and other artificial intelligence tools	31.3	Explaining challenging topics, generating ideas and preparing learning materials	Require pedagogical guidance, clear academic integrity rules and the development of critical thinking

Note. Compiled by the authors based on the results of the student survey.

The findings concerning the use of digital platforms demonstrate the dual nature of digitalisation within the educational process. On the one hand, the high proportion of students using Zoom, messaging applications, Google Docs/Google Drive, YouTube and online tests confirms that digital tools have already become integrated into students' everyday learning practices.

On the other hand, difficulties associated with the excessive number of platforms and the challenges of locating relevant learning materials indicate that the digital environment has not yet acquired sufficient coherence and systematic organisation. In this context, the conclusions of UNESCO (2023a) emphasise that technology should be used as a means of enhancing the quality of education rather than as an end in itself, are directly supported by the empirical findings of the present study.

Furthermore, the finding that 31.3% of respondents use ChatGPT and other AI tools requires particular pedagogical consideration. On the one hand, this indicates students' openness to emerging digital tools for explaining complex topics, generating ideas and preparing learning materials. On the other hand, this proportion reinforces the need to develop AI literacy, academic integrity and the critical evaluation of AI-generated content. This is consistent with UNESCO's position (2023b) on the need for ethical and human-centred use of generative AI, as well as with the findings of Gulich and Chetveryk (2025), which highlight the potential of AI as a tool for psychological and motivational support when accompanied by appropriate pedagogical guidance.

The findings indicate that students' digital environment is highly multi-component. Students use different services for different educational purposes, including video conferencing, communication, document management, viewing video explanations, test preparation, interactive revision and accessing artificial intelligence tools. However, such diversity does not necessarily constitute an advantage. Rather, it may contribute to the fragmentation of the educational environment.

This interpretation is supported by students' responses concerning difficulties associated with the use of digital platforms (Fig. 1).

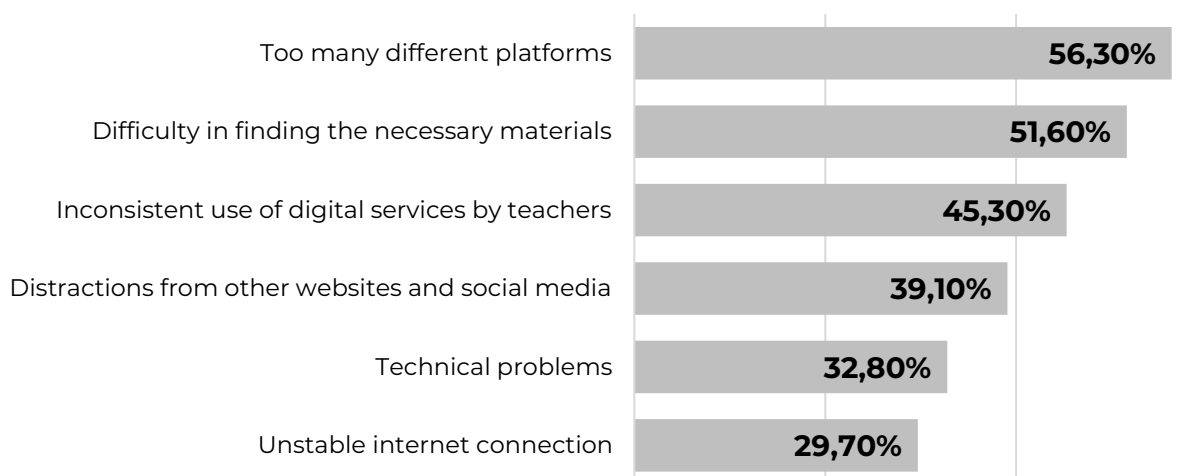
A total of 56.3% of students reported that there were too many platforms, 51.6% indicated difficulties in locating the required learning materials, 45.3% identified inconsistencies in teachers' approaches to the use of digital services and 39.1% reported being distracted by other websites and social media.

Particularly noteworthy is the fact that 78.1% of respondents supported the idea of establishing a single digital platform for the lyceum, bringing together the timetable, homework assignments, learning materials, online tests, announcements, assessment results, teachers' comments and materials for NMT preparation. Furthermore, 81.3% of students expressed a desire for more online materials to support revision of previously studied topics. Thus, the key demand is not simply for an increase in the number of

digital services, but rather for the development of a coherent and well-organised digital educational ecosystem.

Figure 1

Main difficulties experienced by students when using digital platforms



Note. Compiled by the authors based on the results of the student survey.

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Particularly noteworthy is the fact that 78.1% of respondents supported the idea of establishing a single digital platform for the lyceum, bringing together the timetable, homework assignments, learning materials, online tests, announcements, assessment results, teachers' comments and materials for NMT preparation. Furthermore, 81.3% of students expressed a desire for more online materials to support revision of previously studied topics. Thus, the key demand is not simply for an increase in the number of digital services, but rather for the development of a coherent and well-organised digital educational ecosystem.

– Cognitive and Learning Characteristics of Students

The cognitive component of the survey indicated that students benefit from diverse modes of presenting learning material (Tab. 4).

Table 4

Cognitive and Learning Characteristics of Students

Indicator	Proportion of responses, %	Analytical interpretation
It is important to understand the practical relevance of a subject	78.6	Students need to understand the practical significance of the learning material
Digital materials help students understand a topic more effectively	69.6	Digital resources are an important tool for supporting cognitive activity

Video explanations are useful for revising learning material	65.6	Visual formats are perceived as effective for independent learning
Interactive learning formats are effective	62.5	Students respond positively to active forms of learning
It is easy to concentrate during lessons	41.1	A considerable proportion of students experience difficulties in sustaining attention
Students are able to plan their own learning independently	46.4	Learning self-regulation requires further development
It is easy to complete tasks requiring sustained concentration	39.1	Students need gradual development of skills for sustained and focused learning

Note. Compiled by the authors based on the results of the student survey.

Visualisation, practical examples, video explanations, digital materials for revision, interactive activities and opportunities for self-assessment were identified as particularly important. A total of 78.6% of students reported that understanding the practical relevance of a subject was important to them. Furthermore, 69.6% indicated that digital materials helped them to understand a topic more effectively, while 65.6% considered video explanations a useful means of revising previously studied material. Interactive learning formats were positively evaluated by 62.5% of respondents.

At the same time, the indicators of students' learning autonomy were comparatively lower. Only 46.4% of students rated their ability to plan their own learning highly, while 39.1% reported that they found it easy to complete tasks requiring sustained concentration.

The factors affecting students' concentration are complex in nature. A total of 59.4% of students identified fatigue as a major factor, 53.1% mentioned their mobile phone, 48.4% referred to the difficulty of the learning material, 43.8% indicated an unengaged lesson format, 39.1% pointed to the excessive amount of information, and 34.4% identified anxiety.

Thus, difficulties with concentration cannot be attributed solely to the influence of digital devices. They are also associated with fatigue, academic workload, lesson design, the complexity of the learning material and students' emotional state.

– Social, Psychological and Communicative Characteristics

The social and psychological component of the survey indicated that the majority of students perceive the lyceum's educational environment as supportive (Tab. 5).

Table 5

Social and Psychological Indicators of Students

Indicator	Proportion of responses, %	Analytical interpretation
Perceive support from teachers	72.3	Teacher–student interaction is perceived as supportive
Perceive support from classmates	68.8	The classroom environment is generally perceived as socially supportive

Experience academic stress periodically or frequently	61.6	Psychological strain is a significant factor in the educational process
Would like to receive greater psychological support	46.9	Some students require additional support
Consider fear of making mistakes to be a source of stress	43.8	There is a need to foster a safe attitude towards mistakes
Identify the NMT as a source of stress	57.8	Entrance examinations have a substantial impact on students' emotional well-being

Note. Compiled by the authors based on the results of the student survey.

The communicative component revealed that students generally feel comfortable interacting with teachers; however, group work requires greater pedagogical organisation. Specifically, 73.2% of respondents reported that they feel comfortable asking a teacher questions when they do not understand something. At the same time, only 57.1% positively assessed their comfort when working in pairs or groups. 60.9% would like to have more discussions and debates during lessons, while 62.5% expressed a preference for individual consultations. Furthermore, 81.3% of respondents reported using messaging applications for educational communication.

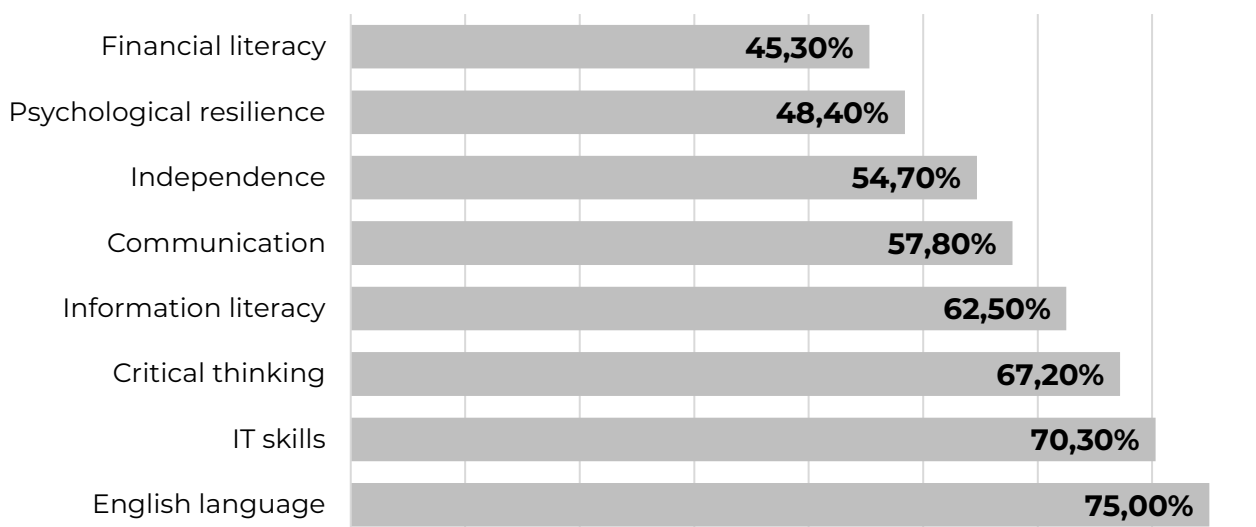
These findings indicate the mixed nature of the communicative behaviour of Generation Alpha students. On the one hand, they actively use digital communication channels, exchange messages rapidly and expect prompt feedback. On the other hand, not all students feel equally comfortable in situations involving public discussion, collaborative work or the shared allocation of responsibility within a team.

– Value Orientations and Career Self-Determination

The values-oriented component of the questionnaire revealed that students associate school education with their future self-realisation (Fig. 2). The skills they consider most important for their future include English language proficiency, IT skills, critical thinking, the ability to work with information, communication skills, independence, psychological resilience and financial literacy.

Figure 2

Skills Considered Most Important by Students for Their Future



Note. Compiled by the authors based on the results of the student questionnaire.

Career self-determination remains incomplete for a substantial proportion of students. 34.8% reported having a clear idea of their future profession or field of activity, 41.1% had a general idea but were still uncertain, while 24.1% had not yet made a decision. At the same time, 64.3% of respondents indicated a need for additional career guidance and counselling support.

– Synthesis of the Identified Student Needs

Based on the questionnaire results, it is possible to identify the key educational needs and problematic areas that should underpin the development of an adaptive educational environment (Tab. 6).

Table 6

Students' Educational Needs and Directions for Adapting the Educational Process

Survey result	Interpretation as a need or problem	Direction of adaptation
81.3% would like more online learning materials	There is a shortage of structured resources for revision	Development of a digital repository of learning materials
78.1% support the introduction of a single digital platform	The digital learning environment is fragmented	Establishment of a unified digital ecosystem
56.3% report an excessive number of platforms	Students experience difficulties navigating between different digital channels	Unification and rationalisation of digital services
59.4% identify fatigue as a factor contributing to reduced concentration	The organisation of the school day requires greater balance	Optimisation of students' learning load
46.4% report being able to plan their learning independently	Learning autonomy and self-regulation remain insufficiently developed	Development of self-regulated learning skills
61.6% experience academic stress	Psychological strain represents a significant challenge	Strengthening social and emotional support
64.3% require career guidance	Students' understanding of their future educational and career pathways remains insufficiently defined	Development of a systematic career guidance and counselling framework
78.6% would like subjects to have greater practical relevance	Learning needs to be more closely connected with real-life contexts	Promotion of practice-oriented learning

Note. Compiled by the authors based on the results of the student questionnaire.

DISCUSSION

The findings of the study confirm that Generation Alpha students cannot be characterised solely in terms of their digital activity. Although they make extensive use of digital platforms, online resources, messaging applications, video content and, increasingly, artificial intelligence tools, they simultaneously require clear learning

structures, pedagogical guidance, psychological safety, support for the development of self-regulation, and systematic career guidance.

The first important finding concerns the digital learning environment. Students actively use a wide range of digital tools; however, the very diversity of platforms becomes problematic when their use is not governed by a coherent organisational framework. This finding is consistent with the position of the OECD (2023), according to which an effective digital education ecosystem should be pedagogically structured and purposefully organised.

Digital technologies should facilitate learning interaction rather than generate additional information overload. Accordingly, the key priority for the lyceum should not be the quantitative expansion of digital services, but the development of a coherent and well-structured digital learning environment.

From a practical perspective, this implies the need for a single platform or a unified system of digital communication. Such a system should integrate the timetable, homework assignments, learning materials, online tests, announcements, assessment results, teacher feedback and resources for preparation for the National Multi-Subject Test (NMT). It could also serve as a tool for formative assessment and support for self-regulated learning, provided that students are able to monitor their own progress, deadlines and recommendations for revision.

The second finding concerns the cognitive and learning characteristics of the students. The results indicate a strong demand for visualisation, video explanations, practical tasks, interactive formats and digital resources for revision. This finding is consistent with the principles of the multimedia learning theory, which emphasises the value of integrating verbal and visual information while avoiding excessive cognitive load (Mayer & Fiorella, 2021). At the same time, the indicators of concentration and independent learning planning suggest that students are not always sufficiently prepared for autonomous learning without appropriate pedagogical support.

Therefore, adapting the educational process should not entail lowering academic expectations, but rather modifying the ways in which learning activities are organised. Lessons should be clearly structured, with explicit stages, comprehensible learning objectives, visual scaffolding, practical tasks, brief opportunities for self-assessment and the possibility of revisiting the material after the lesson. This approach is consistent with the principles of Universal Design for Learning (UDL), which advocates providing multiple means of engagement and representation in order to accommodate diverse learner needs (CAST, 2024).

The third finding concerns students' learning autonomy. Only 46.4% of the respondents rated their ability to plan their own learning highly. This indicates that autonomy cannot be regarded as an inherent characteristic of a digitally oriented generation. Rather, it needs to be deliberately developed through specific tools and practices, including checklists, revision plans, weekly study schedules, individual learning goals, reflective questions, error-analysis procedures, digital reminders and self-assessment rubrics. The study by Faza and Lestari (2025) confirms that self-regulated learning in digital environments requires the purposeful development of planning, monitoring and reflective strategies.

The fourth finding relates to students' psychological well-being. Although the majority of respondents reported experiencing support from teachers and peers, a substantial

proportion experienced academic stress. The principal sources of stress included assessments, preparation for the final exams, a high volume of homework, fear of making mistakes and high academic expectations. These findings indicate that psychological support should not be treated as an isolated or supplementary intervention, but should instead be integrated into the everyday organisation of the educational process.

In this context, formative assessment is of particular importance. When an error is treated as grounds for punishment, it may increase anxiety; when it is used as a basis for feedback and further improvement, it can support learning progress. The Education Endowment Foundation (2021) emphasises that effective feedback should be specific, timely and focused on the learner's subsequent actions. Angela M. Lui and Heidi L. Andrade (2022) likewise emphasise that effective feedback depends not only on its provision, but also on the learner's ability to understand, accept and use it.

The fifth finding concerns career development and vocational self-determination. The data indicate that a substantial proportion of students have not yet developed a clear career trajectory, while 64.3% require additional career guidance and support. This finding is consistent with the conclusions of the OECD (2024), which emphasise that effective career guidance should involve not only the provision of information but also opportunities for interaction with the world of work. For the lyceum, this implies the need for a systematic career guidance programme for students in Years 9–10.

Career guidance and support may include interest and aptitude assessments, individual consultations, meetings with representatives of different professions, project-based tasks related to specific occupational fields, digital portfolios, mentoring sessions with alumni, exploration of university programmes and the development of individual career development plans. It is important that career guidance be integrated with school subjects. This would enable students to understand more clearly how knowledge and skills acquired in mathematics, languages, history, information technology and other subjects relate to potential future careers.

The sixth finding concerns the development of critical thinking and the responsible use of artificial intelligence. Some students already use ChatGPT and other AI tools, creating both opportunities and risks (Kostikova et al., 2024). AI can assist students in explaining complex topics, generating ideas and supporting revision. At the same time, it may encourage superficial copying, academic misconduct and an uncritical attitude towards information. UNESCO (2023a) emphasises that the use of generative AI in education should be human-centred, ethical and pedagogically guided.

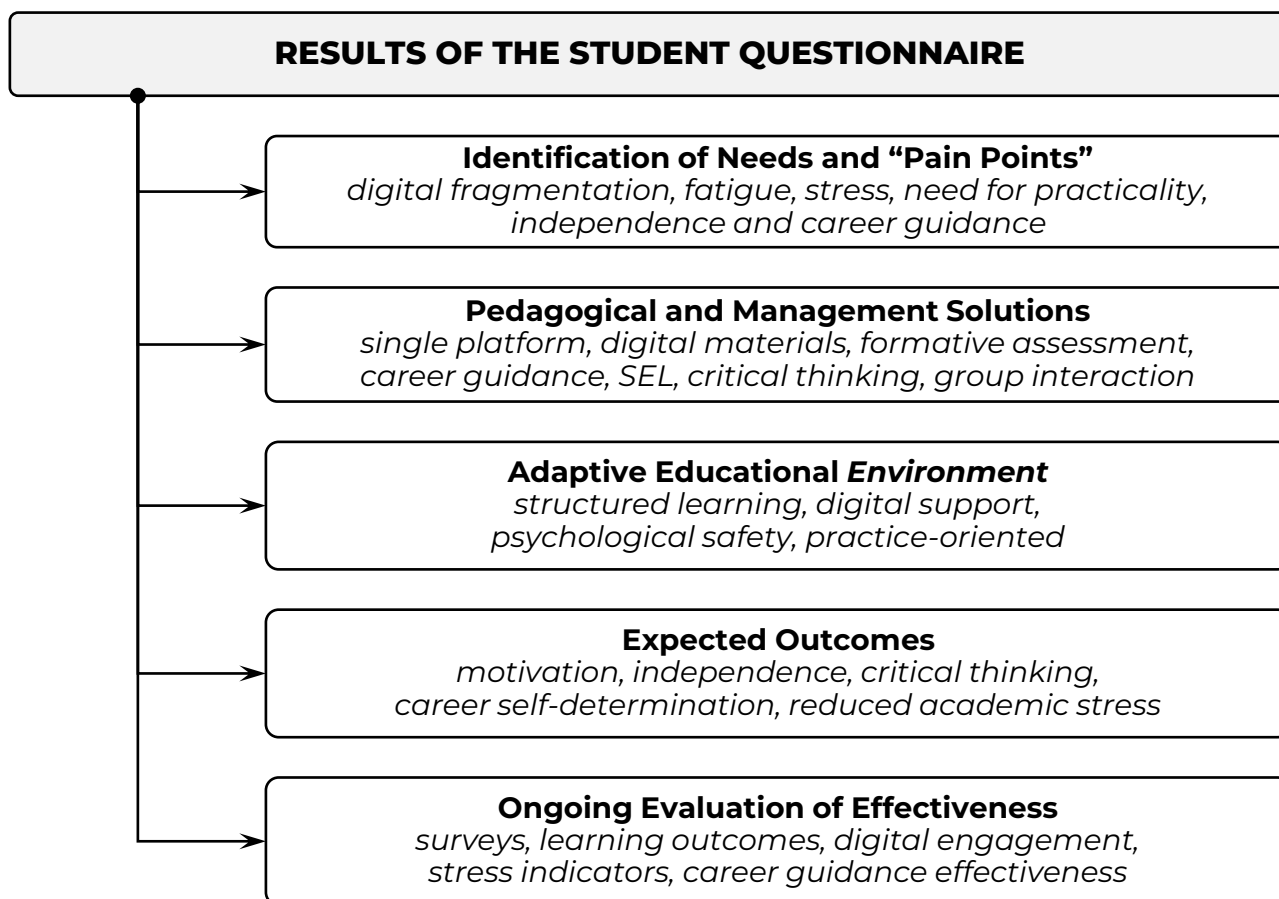
Accordingly, the lyceum should neither simply permit nor prohibit the use of AI, but should equip students with the competences required for its responsible use. Appropriate measures could include the development of academic integrity guidelines, activities focused on verifying AI-generated responses, tasks requiring comparison and evaluation of sources, and dedicated learning modules on media literacy, digital safety and critical information analysis.

Building on the findings of the study, an adaptive educational environment model for a private lyceum can be proposed (Fig. 3). The model should incorporate digital, cognitive, socio-emotional, communicative, assessment and career-guidance components. Their integration would enable the educational process to respond not only to students' digital practices, but also to their cognitive, emotional, social and professional

development needs. Such an approach shifts the focus from the technological adaptation of education towards the systemic personalisation of the educational environment, in which digital technologies function as means of supporting learning rather than as an end in themselves.

Figure 3

Model of an Adaptive Educational Environment for a Private Lyceum



Note. Developed by the authors.

The proposed model is cyclical in nature. It assumes that the adaptation process begins with the diagnosis of students' needs, proceeds to the development and implementation of pedagogical and management decisions and subsequently requires a repeated assessment of their effectiveness. This approach corresponds to the logic of evidence-informed education, according to which educational changes should be grounded in empirical data concerning specific learners and the particular educational environment in which they study.

To provide a more comprehensive rationale for the proposed model, its components should be correlated with the empirical findings of the student survey and the relevant theoretical and methodological approaches. Such a comparison demonstrates that the model of an adaptive educational environment is not merely a declarative framework, but is grounded in specific needs identified among the students and in contemporary scholarly approaches to the digital transformation of education, self-regulated learning, formative assessment, socio-emotional support and career guidance (Tab. 7).

Table 7*Theoretical Rationale for the Components of an Adaptive Educational Environment*

Model component	Empirical basis from the survey findings	Theoretical and methodological basis	Expected effect
Digital component	78.1% support the introduction of a single digital platform; 56.3% report an excessive number of platforms	Digital educational ecosystem; DigComp 2.2; technology as a tool for improving the quality of education (OECD, 2023; UNESCO, 2023a; Vuorikari et al, 2022)	Reduction of fragmentation within the digital environment; improved organisation of learning
Cognitive component	69.6% report that digital materials help them understand the topic; 59.4% identify fatigue as a factor contributing to reduced concentration	Multimedia learning; cognitive load management; Universal Design for Learning (CAST, 2024; Fazan et al, 2025; Mayer & Fiorella, 2021)	Improved comprehension of learning materials and reduced information overload
Self-regulation component	Only 46.4% rate their ability to plan their own learning highly	Self-regulated learning; learner agency (Faza & Lestari, 2025)	Development of learner autonomy, planning skills, and responsibility for learning outcomes
Assessment component	43.8% associate stress with fear of making mistakes	Formative assessment; internal mechanisms of feedback processing (Education Endowment Foundation, 2021; Lui, A. M., & Andrade, 2022)	A more constructive attitude towards errors and greater understanding of subsequent learning steps
Social-emotional component	61.6% periodically or frequently experience learning-related stress	Social and emotional learning; the concept of 'happy schools' (Durlak et al, 2011; UNESCO, 2024)	Reduced stress and enhanced psychological safety
Career guidance component	64.3% require additional career guidance support	Career guidance; MOOCs and non-formal learning (OECD, 2024; Salun & Zaslavskaya 2024)	A more informed educational and career trajectory
AI literacy component	31.3% use ChatGPT and other AI tools	Ethical use of generative AI; academic integrity (Gulich & Chetveryk, 2025; UNESCO, 2023b; Yurchenko & Nalyvaiko, 2025)	Responsible use of AI and development of critical thinking

Note. Compiled by the authors.

The data presented in Table 7 confirm that each component of the adaptive educational environment has a dual rationale: on the one hand, it is grounded in specific findings from the student survey; on the other, it corresponds to contemporary theoretical and methodological approaches in education. This makes it possible to move beyond the fragmented implementation of individual innovations towards a coherent model for adapting the educational process.

Thus, the proposed model of an adaptive educational environment can be regarded as a practice-oriented tool for managing educational change in a private lyceum. Its effectiveness should not be assessed merely by the presence of digital services or individual pedagogical practices, but rather by the extent to which these measures address the specific 'pain points' identified by students and support the development of motivation, learner autonomy, critical thinking, and career self-determination (Tab. 8).

Table 8

Practical Recommendations for Adapting the Educational Process

Recommendation	Survey finding underpinning the recommendation	Student need or 'pain point' addressed	Effectiveness indicators
Implementation of a single digital platform	78.1% support the idea of a single platform; 56.3% report an excessive number of digital services	Fragmentation of the digital environment	Reduction in the proportion of students who experience difficulty finding learning materials; increased satisfaction with digital organisation
Creation of a digital repository of revision materials	81.3% would like more online materials	Lack of accessible materials after lessons	Proportion of students regularly using the materials; performance in practice tests
Optimisation of learning workload	48.2% consider the workload optimal; 59.4% identify fatigue as a problem	Overload, fatigue, and reduced concentration	Fewer complaints about excessive workload; improved perceptions of the alignment between the timetable and students' levels of fatigue
Development of self-regulated learning	46.4% rate their ability to plan their learning highly	Insufficient learner autonomy	Increased proportion of students able to plan their learning; completion of individual learning plans
Formative feedback	43.8% identify fear of making mistakes as a source of stress	Perception of mistakes as failure rather than as a resource for learning	Proportion of assignments receiving high-quality feedback; reduced fear of making mistakes

Practice-oriented learning	78.6% want to understand the practical relevance of school subjects	Perceived disconnect between learning and real-life contexts	Proportion of lessons incorporating case studies/projects; students' assessment of the practical orientation of learning
Career guidance and support system	64.3% require additional career guidance support	Uncertainty regarding future career choices	Proportion of students with a clearly defined educational and career development plan; participation in career guidance activities
Critical thinking and AI literacy programme	Students actively use digital resources and AI tools	Risk of uncritical use of information	Performance on source-verification tasks; compliance with academic integrity principles
Social and emotional support	61.6% experience learning-related stress	Stress, anxiety, and fear of making mistakes	Reduction in the proportion of students experiencing high levels of learning-related stress; uptake of psychological support
Development of collaborative learning and group interaction	57.1% feel comfortable working in pairs or groups	Lack of confidence in teamwork	Increased comfort with group work; quality of collaborative projects

Note. Compiled by the authors based on the student survey findings.

The proposed solutions have direct practical implications for the lyceum, as each is explicitly linked to a particular empirically identified need or problem. This evidence-based orientation distinguishes the adaptive educational environment from a generic collection of educational innovations. Its effectiveness should therefore be evaluated not by the number of digital tools introduced, but by the extent to which specific difficulties experienced by students are reduced and motivation, learner autonomy, critical thinking, and career self-determination are strengthened.

– Limitations of the Study

The study has several limitations that should be taken into account when interpreting the findings:

1. The empirical sample comprised 64 students from Years 9–10 of a single private lyceum. Although this sample is sufficient for a diagnostic analysis of the needs of a particular educational institution, the findings cannot be automatically generalised to all private or state general secondary schools in Ukraine.
2. The study was based on students' self-assessments. Consequently, the data reflect their subjective perceptions of the educational process, digital platforms, workload, stress, and career guidance provision. Although such data are valuable for understanding students' educational experiences, they do not substitute for

objective measures of academic achievement, digital activity on educational platforms, or formal psychological assessment.

3. The study employed a cross-sectional rather than longitudinal design. It captures students' educational needs at the time of the survey but does not allow changes to be tracked following the implementation of the proposed solutions. Accordingly, an important direction for future research would be to conduct a follow-up survey after implementation of the adaptive educational environment model.
4. The study did not compare different types of educational institutions, such as private and state schools, lyceums with different educational profiles, or institutions with varying levels of digital infrastructure. Such comparisons could provide a deeper understanding of which of the identified needs are specific to the particular lyceum and which may be more broadly characteristic of Generation Alpha learners.
5. The adaptive educational environment model proposed in this study is conceptual and practice-oriented in nature. Its rationale is grounded in the survey findings and contemporary theoretical and methodological approaches; however, its effectiveness requires further empirical validation in educational practice. It is therefore important to establish a system of repeated diagnostic assessment to determine whether digital fragmentation has been reduced, students' capacity for independent learning has improved, levels of educational stress have decreased, and career guidance has become more effective.

CONCLUSIONS

The study demonstrates that adapting the educational process of a private lyceum to the needs of Generation Alpha learners requires a systematic approach. The survey findings indicate that students generally assess the lyceum's educational environment positively, particularly in terms of learning comfort, the clarity of teachers' explanations, and opportunities for communication with teachers. At the same time, several problematic areas were identified that require targeted pedagogical and managerial responses.

The students' primary needs include the development of a well-organised digital learning environment, access to online materials for revision, reduction of fragmentation across digital platforms, optimisation of academic workload, development of independent learning and planning skills, reduction of educational stress, enhanced career guidance, and stronger connections between learning and real-life contexts. The findings demonstrate that the principal challenge of educational digitalisation is not the lack of digital tools, but rather the need for their systematic and pedagogically coherent organisation.

The cognitive profile of Generation Alpha learners is characterised by a preference for visualisation, interactivity, practical tasks, and digital materials for revision. At the same time, some students experience difficulties with sustained concentration, extended tasks, and independent learning planning. This highlights the need to develop self-regulated learning, ensure clear lesson structures, implement formative assessment, and provide pedagogical support for students' digital autonomy.

The socio-psychological findings indicate that a supportive educational environment does not entirely eliminate educational stress. A considerable proportion of students experience tension associated with tests and examinations, preparation for the NMT, a substantial volume of assignments, and fear of making mistakes. Consequently, an

adaptive educational environment should incorporate social and emotional support, a psychologically safe attitude towards mistakes, high-quality feedback, and appropriate psychological support.

Students' value orientations are associated with future self-realisation, English language proficiency, IT skills, critical thinking, communication, independence, and career choice. At the same time, career self-determination remains incomplete for a considerable proportion of students. This substantiates the need for systematic career guidance encompassing interest assessment, individual consultations, projects, digital portfolios, and opportunities to explore educational and professional pathways.

The principal practical outcome of the study is a model of an adaptive educational environment for a private lyceum that integrates digital organisation, multimedia learning, practice-oriented education, formative feedback, the development of self-regulation and critical thinking, social and emotional support, and career guidance. The effectiveness of this model should be evaluated through repeated assessment of students' educational needs, levels of educational stress, satisfaction with the digital environment, development of learner autonomy, and degree of career self-determination.

The theoretical analysis and survey findings further demonstrate that adaptation of the educational process to the needs of Generation Alpha should take place at the intersection of three dimensions: digital organisation of learning, psychological and pedagogical support, and individualisation of educational and career pathways. The use of a broad range of sources—from state educational registers and regulatory and methodological documents to contemporary international research on digital education, self-regulated learning, feedback, social and emotional learning, AI literacy, and career guidance – made it possible to develop an adaptive environment model grounded not only in theoretical principles but also in specific indicators of students' needs.

The proposed model is practice-oriented because each of its components corresponds to an empirically identified need: the digital component addresses platform fragmentation; the cognitive component responds to difficulties with concentration and the need for visualisation; the self-regulation component addresses insufficient capacity for learning planning; the assessment component responds to fear of mistakes; the social and emotional component addresses educational stress; the career guidance component addresses uncertainty regarding future professional choices; and the AI literacy component responds to the increasing use of generative artificial intelligence tools. Thus, the effectiveness of an adaptive educational environment should be measured not by the number of digital tools implemented, but by the extent to which these tools reduce specific difficulties experienced by students and support the development of motivation, learner autonomy, critical thinking, and career self-determination.

Future research should focus on expanding the sample, comparing findings across different types of educational institutions, and evaluating the effectiveness of implementing the proposed solutions over time. Longitudinal studies would be particularly valuable for determining whether the proposed model produces sustainable improvements in students' educational experiences, self-regulation, psychological well-being, digital competence, and career self-determination.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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No artificial intelligence tools were used in the preparation of this manuscript.

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