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PERMANENT CALL

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An intelligent system for guiding the use of dynamic concept maps in the zone of proximal development

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Abstract

With reference to the theory of the Zone of Proximal Development, the aim of this paper is to describe an intelligent tutoring model capable of learning and reproducing intervention rules to make learning experiences based on the use of dynamic concept maps more effective. The work starts from DCMapp, a software application for the creation and navigation of dynamic concept maps. DCMapp allows to build maps, draw nodes and arcs, upload multimedia contents and manage the dynamic visualization of concepts. The use of DCMapp has been shown to improve study times and student learning outcomes. The paper proposes the integration of an intelligent tutoring system based on Vygotsky's theory of the Zone of Proximal Development. This system suggests actions to students to maintain learning within their Zone of Proximal Development, avoiding boredom and confusion. It is trained through the observation of a human tutor and uses artificial neural networks to predict future actions. The goal is to ensure effective and personalized learning, adapting the difficulty of the activities to the cognitive and emotional abilities of the learners.

KEYWORDS: Artificial Intelligence, Neural Network, Dynamic Concept Maps, Zone of Proximal Development (ZPD), e-Learning.

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1. Introduction

In the dynamic landscape of modern education, the integration of technology plays a pivotal role in enhancing learning experiences. Among these technologies, dynamic concept maps have emerged as powerful tools, offering visual and interactive representations of knowledge that can significantly benefit students. This paper builds upon the demonstrated advantages of dynamic concept maps, particularly through the use of DCMapp, a software application designed for the creation and navigation of these maps. DCMapp, which is integrated into the e-Lena platform (a customized version of Moodle), allows users to build maps, draw nodes and arcs, upload multimedia content, and manage the dynamic display of concepts (Nye, 2023). Previous research has shown that the use of DCMapp, employing the DynaMap Remediation Approach (DMRA), can act as a remediator in teaching and learning processes, leading to reduced study times and improved learning outcomes for students.

Despite these benefits, the effectiveness of learning experiences can be further enhanced by providing personalized guidance that adapts to each student's unique needs. This necessity leads us to the critical role of tutoring in learning, and specifically to Intelligent Tutoring Systems (ITS), which aim to simulate the behaviour of a human tutor to support students (Roll & Wylie,2016). A foundational theory guiding the development of ITS is Vygotsky's Zone of Proximal Development (ZPD). The ZPD represents an optimal learning space where tasks are neither too difficult nor too easy, thereby avoiding states of boredom or confusion which can lead to distraction, frustration, and loss of motivation. Optimal conditions within the ZPD are highly individualized and dynamic, shifting with each student and learning context.

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Given the inherent complexity in modelling the vast number of states and transitions within dynamic concept maps, particularly when a user navigates them, traditional rule-based expert systems for ITS become challenging to implement. Therefore, this paper proposes an adaptive approach for an intelligent tutoring system that can learn directly from the observations of a human tutor.

The primary aim of this paper is to describe an intelligent tutoring model capable of learning and reproducing intervention rules to make learning experiences based on the use of dynamic concept maps more effective. Specifically, we propose the integration of an intelligent tutoring system with DCMapp that leverages artificial neural networks to observe and learn from a human tutor's actions. This system will then predict and suggest optimal actions to students in real-time, thereby maintaining their learning within their individual Zone of Proximal Development, preventing boredom and confusion, and ensuring effective and personalized learning.

This work lays the foundation for designing an intelligent system that, by integrating with modules for detecting students' cognitive and emotional states and their individual tolerance limits for difficulty, can adapt to personal needs and guarantee truly personalized and effective learning pathways.

2. The adopted methods

The research described in the paper aligns with the principles of Design-Based Research (DBR). It involves the iterative development of an intelligent tutoring system grounded in educational theory (ZPD), implemented within a real-world learning platform (DCMapp), and aimed at improving student outcomes through adaptive technology. The absence of empirical data or a bounded context rules out a case study approach, while the emphasis on design, theory, and future experimentation strongly supports a DBR classification.

2.1 DCMapp: the tool for dynamic concept maps

DCMapp is a software application designed and created as an integration of the e-Lena platform, an e-learning platform obtained by customizing Moodle, the renowned framework for the creation of e-learning platforms. DCMapp provides different types of access that include, in short, the functionality of creating and navigating concept maps. It is possible to build concept maps, draw nodes and arcs, upload multimedia content, manage the dynamic display modes through which concepts linked to others can be displayed or hidden depending on the needs of the person navigating it (for example, displaying one level at a time in a hierarchical map and opening the next ones depending on curiosity or training needs). This implies that, for the various modes of use, there is a different set of functions accessible through the graphical interface (see Figure 1).

If we focus only on one mode of use, namely navigation, among the various available functions, we will be able to limit the actions that a user may find themselves performing.

Specifically, the possible actions during navigation are the following:

1. Node selection
2. Content display
3. Opening child nodes
4. Closing child nodes
5. Node dragging
6. Map dragging.

The number of actions is therefore limited but must be contextualized to the map being navigated and its current display form. For example, all closed nodes, all open nodes, i.e. the "child" nodes of other nodes displayed at the same time, or partially open, i.e. providing only parts containing nodes and their children displayed.

That said, it has been verified (Auth.1 & Auth.3, 2021a) that dynamic concept maps can act as remediators in the teaching and learning process, encouraging, precisely, processes of remediation and integration between conventional contents such as books and handouts and

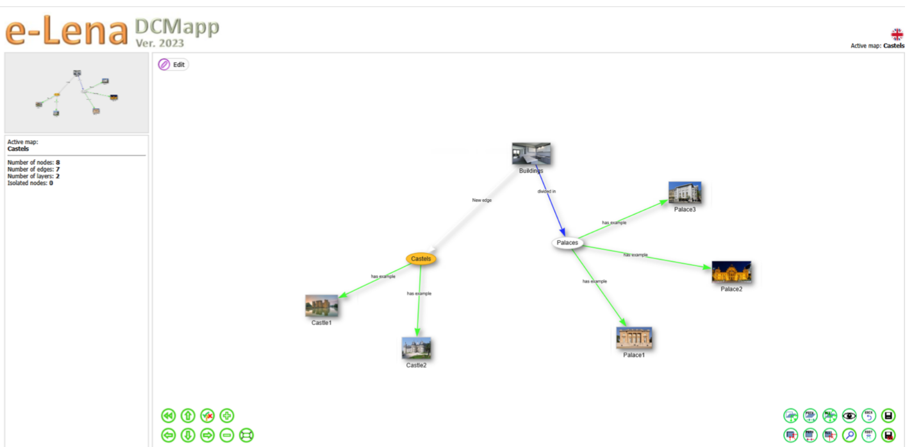

Figure 1 - The graphical interface of DCMapp.

new types of digital media such as dynamic concept maps themselves. Through the use of DCMapp, students had access to dynamic concept maps on the topics under study, enriched with explanatory contents that they explored from time to time during the study by moving between the nodes, opening the nodes corresponding to the "child" concepts, viewing the uploaded contents, observing the relationships and, at the same time, studying the textbooks (Auth.1 & Auth.3, 2021b). The results of the cited work show that their use has brought real benefits both in terms of reducing study times and in terms of learning results.

The advantages of this approach (called DMRA, DynaMap Remediation Approach; Auth.1 & Auth.3, 2021a) could be further enriched if the DCMapp tool were integrated with a tutoring system that, by analysing each student's actions in real time, is able to suggest the actions to be taken at any time (Ifenthaler & Yau, 2020).

2.2 Intelligent tutoring and the ZPD

Since tutoring is a fundamental element in learning, its transposition based on the use of computers has been addressed in research initiatives (Merrill, 2013; Shin, Sutherland, & Norris, 2012). Over the years, moreover, many experiments have been conducted on the integration of artificial intelligence techniques and tutoring systems with the aim of obtaining an aid capable of simulating the behaviour of a human tutor and supporting the student during his learning activities (Brusilovsky, 2006; Peebles & Cooper, 2010), giving rise, precisely, to Intelligent Tutoring Systems (ITS). Usually, ITS refer to Vygotsky's theory of the Zone of Proximal Development (ZPD, Vygotskij, 1978; Wertsch, 1985). In short, the ZPD can be characterized from both a cognitive and an emotional point of view. From a cognitive point of view, when a student is engaged in learning activities, the tasks proposed to him should be neither too difficult nor too easy. From an emotional point of view, the student should neither be bored nor confused. Boredom is a direct consequence of tasks that are too simple. Obviously, asking a student to perform actions that are too simple inevitably leads to a decrease in attention and a feeling of boredom. Conversely, confusion is a direct consequence of tasks that are too difficult. Asking for complicated actions leads participants to be confused. Both boredom and confusion can lead to distraction, frustration, and loss of motivation.

Of course, optimal conditions differ for each student, and, for the same student, they differ depending on the contexts and learning environments. It is possible to imagine the ZPD of a student who interacts with a given learning environment, as a space consisting of a set of states outside of which there are two extremes represented by boredom and confusion.

During learning, the trajectory that the student follows among these states is not linear and depends both on his abilities and on the stimuli that he receives in terms of activities and tasks to be completed. Starting from an initial state, choices, or actions of the student himself, determine the transition to a new state.

Attention and memory take on a voluntary and controlled connotation by the student when the mediation process supports abstraction, synthesis, and symbolization. Higher psychic functions are enhanced in the space of the ZPD if the activities presented are supported by the action of an expert (peer or adult) or by any artefact/tool capable of supporting the advancement process (Vygotsky, 1934/1997). Effective teaching is such when it precedes development, that is, it guides the psycho-intellectual functions in the maturation phase. For this reason, the minimum threshold exceeded to start a mediation that activates the potential for expanding intellectual capacities must be considered, moving from what the student is able to do to what he or she does not yet know how to do (Vygotsky, 1934/1962). In this way, knowledge is not fixed, but it is dynamic, and it is constructed and redefined every time the student interacts with different tools and sources, giving rise to active and conscious learning (Vygotsky, 1934/1997; 1978).

Starting from the new state reached, it will then be possible to move further towards other states until a pre-established objective is achieved. Starting from a state Si it is possible to perform an action a_j that determines the transition to a new state. So, to clarify the ideas on this matter, it is possible to hypothesize a representation model in which there is a set of states that characterize a student's learning path until reaching a training objective. Alongside these states, there are others that can identify, precisely, the states corresponding to boredom or confusion (see Figure 2).

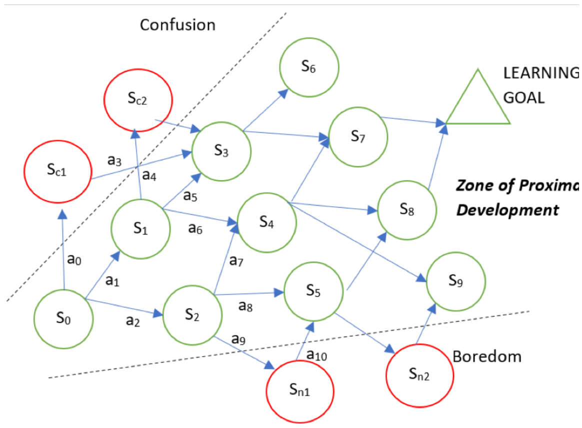

Figure 2 - Set of states of the ZPD.

Moving within the ZPD without "crossing the line" into boredom or confusion means ensuring effective and efficient learning. The role of a tutor could be understood precisely as a "guiding" intervention capable of suggesting to the learner the actions to be performed from time to time based on the difficulty of the actions themselves and the learner's abilities, in order to allow him to reach the learning objective set in the best possible way, that is, going through states that are within his ZPD and avoiding actions that are too simple that lead him to a state of boredom, or actions that are too complex that lead him to a state of confusion. Furthermore, the role of the tutor is also to implement corrective measures to return to the ZPD from a state of confusion or from a state of boredom (Van de Pol et al., 2015; Liu & Wang, 2021).

When working with ITS, two phases must be foreseen: the first, in which the intelligent system is trained to carry out its role as a tutor; the second, in which the system, ready after training, is used to support a learner during his learning path.

The first training phase can follow various algorithmic approaches (supervised training, clustering, rules, Fuzzy logic, etc.) that depend on the operating logics that you want to implement or on the availability of the data to be processed. In any case, the first phase is fundamental and preparatory to the second phase.

In the second phase, the ITS must be able to operate within a learning environment (i.e. an e-learning platform; in this case, DCMapp) analysing the learner's actions, preferably in real time, and intervening as a tutor, precisely, when particular events or situations occur (Fenza, Orciuoli & Sampson, 2017).

3. The DCMapp integration project

3.1 The intelligent system for DCMapp

Let us now try to contextualize the learning environment in which a learner moves and the related states in which one can find oneself, when using DCMapp in navigation mode (Novak & Cañas, 2020). The state is, therefore, what the learner is viewing in the application, it is the set of displayed/closed nodes and their arrangement on the screen. The actions that determine the transitions from one state to another are, in fact, the actions that the user can perform on DCMapp.

Imagine, for example, a map with only the "root" node displayed (see Figure 3). The permitted actions are: 1. Node selection, 2. Content display, 3. Opening child nodes and 5. Node dragging. While instead, if the map already displays the root node and two child nodes (see Figure 4) that in turn have other child nodes that can be displayed, the possible actions are, for the root node, 1. Select node, 2. Display content, 4. Close child nodes, 5. Drag node and for the other nodes, 1. Select node, 2. Display content, 3. Open child nodes and 5. Drag node; furthermore, on the entire map it is possible to perform the action 6. Drag map. Naturally, as you proceed, the possible actions increase with exponential growth depending on the nodes displayed and the overall situation that the student is experiencing.

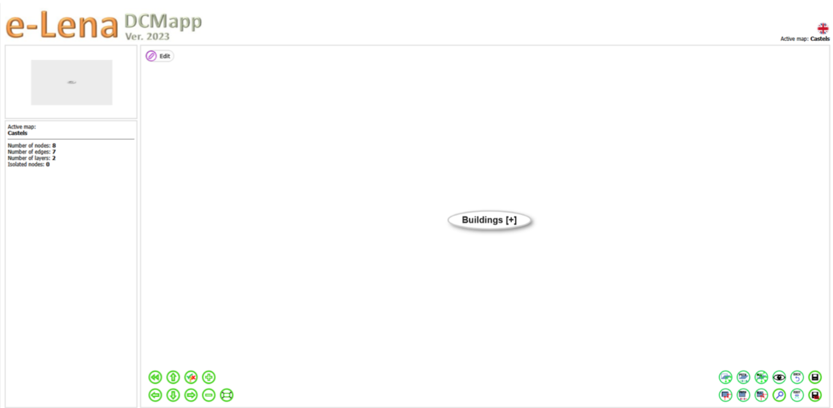

Figure 3 - Map with only the root node displayed.

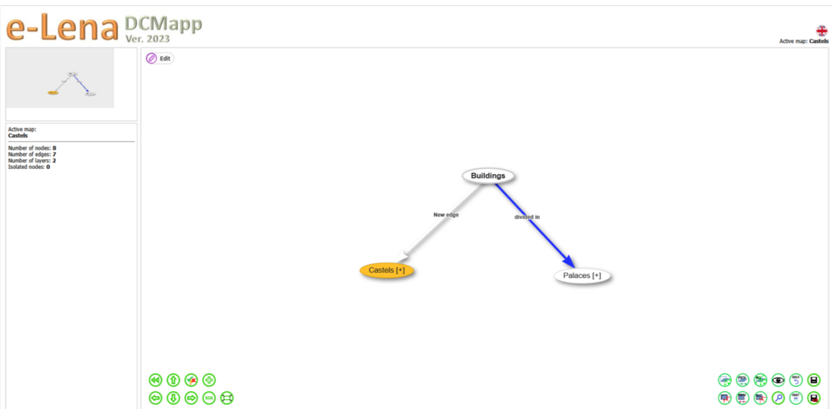

Figure 4 - Map with the root node and two child nodes displayed.

Therefore, it is possible to observe many states related to the current view and many transitions from the current state to other states based on the actions that the user performs directly in DCMapp. Since the user-learner has the ability to choose the action to perform by determining a transition from the current state to a new state of the system, a possible integration of an ITS in this environment could be aimed at suggesting the action to perform based, obviously, on the current state and with the intent of keeping the learner in his ZPD.

However, due to the exponential growth of possible actions due in part to the characteristics of the map and in part to the actions that the user performs during navigation, it is complex to estimate how many states and possible transitions there are in the entire system considered in order to model an ITS and design its operating rules. This means that it is difficult to contemplate a priori the possible suggestions to provide to the user who navigates based on the actions that he has performed, or the state he is in.

Therefore, an approach to designing the ITS as a rule-based expert system for which the operating rules are defined before it is put into operation would be difficult to implement.

This implies that we need to lean towards adaptive approaches that are able to learn directly from a human tutor, to adapt to the situation that occurs and to replicate what the tutor himself would do to support the learner.

Let us try to imagine a device that observes a tutor while he presents the navigation of a map within DCMapp and learns his actions. Therefore, considering DCMapp during navigation as a system able to change state starting from an initial state and depending on the actions performed by the person using it to navigate, the whole thing can be traced back to a temporal series of states. Each state S_t at time t is a function of the previous state S_{t-1} at time t-1 and of an action a_{t-1} performed by the user at time t-1.

$$S_t = f(S_{t-1}, a_{t-1})$$

The function f depends on the DCMapp application, that is, on the functions allowed to the user and on the characteristics of the map that the user is navigating.

After the tutor user has used DCMapp and navigated the map by interacting with it and performing actions, there will be a series of states that go from an initial state S_0 to a current state S_C, passing through the various states corresponding to various moments experienced during navigation.

$$S_0, S_1, S_2, \dots, S_C$$

Imagining this temporal sequence as the sequence of reference states, the role of the tutor can be traced back to the function of suggesting the next state, given the current state. Since the current state can be reached by going through various sequences of states, it would be preferable to take into account the entire sequence of states from S_0 to S_C, to suggest the action to be performed to determine the transition to the next state. The intent of the tutor is, in fact, to suggest an action that leaves the learner in his ZPD. This therefore implies that the ITS must be able to learn and do the same.

Learning could be based on a set of patterns each consisting of sequences of states of length p and the action to be performed to determine a transition to a state that is still in the ZPD of the learner.

$$(S_0, S_1, S_2, \dots, S_{p-1}, a_{p-1})$$

$$(S_1, S_2, S_3, \dots, S_p, a_p)$$

$$(S_2, S_3, S_4, \dots, S_{p+1}, a_{p+1})$$

$$\dots$$

$$(S_{C-p}, S_{C-p+1}, \dots, S_{C-2}, S_{C-1}, a_{C-1})$$

In the first phase, the training of the ITS on these sequences should be such as to allow, in the second phase, to estimate, given the sequence of the last p states, what action could be performed to determine the transition to the next state ensuring that the learner remains in his ZPD.

This approach requires three considerations. The first concerns the algorithmic technique to be used to train the ITS; the second concerns the length p of the patterns for training the ITS; the third, finally, concerns the effectiveness on different learners who have different ZPDs.

With regard to the algorithmic technique to be used, it has already been previously underlined that, given the exponential number of states of the system based on the navigation of a dynamic conceptual map using DCMapp, any technique based on the definition of rules is not easily practicable (Russell & Norvig, 2016). Therefore, techniques based on adaptive learning algorithms (e.g. supervised artificial neural networks) appropriately designed to learn the logical relationship between each sequence of states and the action to be taken remain practicable (Zhang & Lu, 2022). A system trained in this way will then be able to offer support, when a sequence of states occurs, providing a prediction of which action to take (Chen & Chung, 2019). Among the adaptive techniques, the one that could be used is precisely an artificial neural network. It would have p input neurons, each of which acts as a receptor of one of the states of the temporal sequence of states crossed and a single output neuron that reproduces the action to be taken based on the sequence of states detected by the input neurons. This network would be trained using as a training set, the patterns obtained from the navigation carried out by a human tutor. In other words, it would involve applying a supervised learning algorithm to a neural network and using the trained network as a prediction system. Thus, the number of input and output neurons is defined (see Figure 5). Its internal structure, i.e. the numbers and levels of intermediate neurons (the hidden neurons), would still need to be defined. For this, one can rely on statistical analysis techniques performed on the available data (the training set) or on heuristics regulated by classification experiments conducted on the same data by models with a different structure.

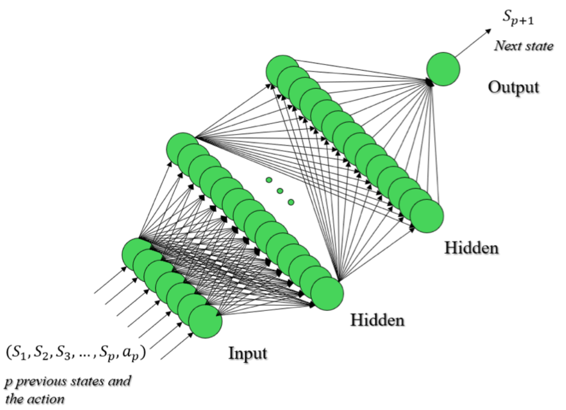

Figure 5 - The artificial neural network that gets as input the p previous states and the action and returns back as output the next state.

Regarding the length *p* of the patterns for training, we fall into a known problem when using intelligent systems based on learning algorithms for the prediction of historical series. Beyond the statistical analyses that can be done with an available training set, it is a good idea to carry out, as for the structure of the neural network, experiments and comparisons to be able to choose the one that works best with full knowledge of the facts, having a human tutor as a reference. In any case, both for these details and for the underlying algorithmic choice, an experimental verification is what is needed to confirm or refute the choices made.

Finally, regarding the effectiveness on different learners and therefore on different ZPDs, the reflection is decidedly complex since the problem could be addressed in several ways. The first is to capitalize on the experience of a human tutor and reproduce it in the ITS. This means enriching the training set with all the cases that concern different students and related situations. A practicable approach, not impossible, but decidedly expensive. Another possible approach is instead to limit the training set to ideal situations that gravitate around what the human tutor would show and to address the specific cases of individual students by detecting in real time, through appropriate indicators, their cognitive and emotional state to have feedback on the effectiveness of the actions performed and on their actual permanence in the proximal development zone. These indicators would thus provide signals to be able to intervene with actions aimed mainly at recovery: a student who is going outside his or her proximal development zone must be corrected with a suggestion that makes him or her stay within it; a student who has fallen outside his ZPD, must be corrected with a suggestion that allows him to re-enter it and ensure effective learning.

Generally, the reference indicator for remaining in the ZPD is the difficulty. According to Vygotsky (1978), the ZPD is the range between what an individual is able to do alone and what he can do with the help of a more experienced partner. A task placed within his ZPD is sufficiently challenging to stimulate learning, but not so difficult as to discourage it. The optimal difficulty allows the individual to extend his knowledge and skills, with adequate support. In other words, the difficulty acts as a catalyst for cognitive growth, pushing the individual to overcome his limits and build new knowledge (Wood, Bruner, & Ross, 1976). Where it is possible to discriminate between more difficult and easier actions, an effective learning path is structured with a sequence of actions that present a level of difficulty suitable for the participant. This means proposing more or less difficult actions based on the state in which the learner finds himself.

Having seen which actions are available in DCMapp during navigation, with regard to the measure of difficulty, it is not so much the action itself that can be defined as more or less complex, but rather the knowledge that is "discovered" by the learner who navigates. The concepts that are represented within the map refer to elements of knowledge, to specific knowledge, but also the relationships between them represent notions, logical links that can be more or less complex to understand. While navigating the dynamic map, the learner can discover parts relating to concepts, can visualize relationships that were previously hidden, can visualize the contents relating to the various nodes. The learner, by carrying out actions in DCMapp, can therefore choose what to visualize and find himself represented something that has, in any case, its own complexity.

Each of these elements can be assigned a difficulty. This difficulty is therefore the indicator to take into account during navigation to verify permanence within the ZPD. Imagine that each action of the learner during navigation corresponds to the visualization of something that has an overall difficulty. For example, there is only one concept displayed on the map, or there are multiple concepts with relationships between them. The difference in difficulty between two states corresponding to the elements displayed before and after a completed action could be more or less high. This difference should be monitored because, if too high, the learner could find himself in a state of confusion; if too low, the learner could find himself in a state of boredom. Both situations, as previously mentioned, are situations that should be avoided. The intelligent tutoring system should monitor these parameters for each learner and avoid these situations.

But what is missing to complete this picture? What is missing is the assessment of each learner's ability in terms of how much overall difficulty, or how much variation in difficulty, they can tolerate during navigation, in order to avoid limit states and ensure an effective learning path that does not go out of the ZPD.

Each learner has this aspect as a specific characteristic and it refers to the optimal difficulty, that is, the appropriately calibrated challenge that stimulates learning without demotivating it (Wiggins & McTighe, 2005). To assess whether a task or activity presents the optimal difficulty, it is essential to carefully observe who is tackling it. If the student seems bored or distracted, the task may be too easy; on the contrary, if they show frustration or anxiety, it may be too difficult (Hattie, 2009). This assessment through observation could be usefully enriched by collecting feedback through questionnaires or interviews to understand how each person perceives the level of challenge (Marzano, 2007).

This aspect allows us to better define the ZPD and translates, in fact, into a pair of limits that should not be exceeded during learning, or in our case relating to the use of DCMapp, during the navigation of a dynamic conceptual map. These limits are a minimum threshold below which not to go to avoid falling into boredom and overly simple conceptual representations and a maximum threshold above which not to go to avoid crossing the line into confusion and overly complicated conceptual representations. These limits are not static and absolute, but dynamic and a function of the state that the learner is experiencing. This means that the detection could require real-time interactions. Therefore, starting from the sequence of reference actions obtained through the tutor's navigation, our ITS should be able to suggest the next action to be performed and, in the event that the difference in complexity should be beyond the thresholds of the individual learner, suggest alternative actions that allow him not to exceed these thresholds. The ITS should provide, in addition to the action to be performed based on the sequence of states, also alternative actions that allow for increasing or decreasing the overall difficulty of the conceptual representation that is being shown to the student.

On the other hand, what a teacher does when explaining something is to adopt simpler definitions and examples when he sees his students in difficulty or, vice versa, to proceed towards more complex concepts when he realizes that his students are following him and are able to grasp the meaning of his explanations.

All of this, therefore, can be addressed by training the ITS through a training set consisting of sequences of states and actions to be undertaken that are alternatives to each other and correspond to different levels of difficulty. That is:

$$(S_0, S_1, S_2, \dots, S_{p-1}, a_{p-1}^{inf}, a_{p-1}, a_{p-1}^{sup})$$

$$(S_1, S_2, S_3, \dots, S_p, a_p^{inf}, a_p, a_p^{sup})$$

$$(S_2, S_3, S_4, \dots, S_{p+1}, a_{p+1}^{inf}, a_{p+1}, a_{p+1}^{sup})$$

$$\dots$$

$$(S_{C-p}, S_{C-p+1}, \dots, S_{C-2}, S_{C-1}, a_{c-1}^{inf}, a_{c-1}, a_{c-1}^{sup})$$

In each pattern of the training set, there are p states and three actions: an action marked with a superscript inf that corresponds to making the overall difficulty lower than the current one; an action marked with a superscript sup that corresponds to making the overall difficulty higher than the current one; an action without a superscript that corresponds to the action performed by the tutor.

The structure of the intelligent system to be trained on this training set changes slightly as the inputs remain p while the outputs are now 3. The same considerations made previously apply to the choices relating to p, the structure, the number of internal neurons and the hidden layers.

3.2 The operation of the intelligent system for DCMapp

The operation of the ITS for DCMapp includes, as previously mentioned, a training phase and a run-time operation phase. The training phase includes a teacher-tutor who navigates, and the operation phase includes the presence of a student who uses DCMapp.

Let us then imagine the presence of a dynamic conceptual map within DCMapp and imagine a teacher-tutor who, while giving an explanation to his students, navigates the map starting from the root node and gradually opens the child nodes, viewing the relationships and contents. The teacher-tutor, at every moment of navigation, must contemplate alternative actions that may be simpler or more difficult than the one performed.

All this navigation is traced in terms of system states and alternative actions, to be able to prepare the training set as described previously.

Once the training set is ready, it is possible to proceed to the training phase. In this phase, the ITS learns which actions to perform based on the sequence of states observed during navigation.

Once training is complete, the ITS is ready to be used at run-time as an intelligent tutor capable of suggesting to each learner, based on the sequence of states experienced, what their next action could be and any alternative actions that allow them to remain in their proximal development zone, or to continue on an effective learning path.

To function at its best for each learner, as a final step, a module is needed to detect the learner's conditions with regard to their ability to tolerate the level of complexity proposed to them. In short, it is necessary to detect the cognitive and emotional state of the learner to deduce what their limits of tolerance are with respect to the situation they are experiencing.

This module becomes fundamental because it allows the ITS to choose which action to suggest to the learner based on simple rules. The idea to be applied can be formalized in an operating rule:

$$\text{IF } Delta_{TotDiff} > SUPlimit_x \text{ THEN } a_p^{inf}$$

$$\text{ELSE IF } Delta_{TotDiff} < INFlimit_x \text{ THEN } a_p^{sup}$$

$$\text{ELSE } a_p$$

Where $Delta_{TotDiff}$ means, given a topic covered, the overall difficulty difference of the representation of concepts and relations in *DCMapp* calculated between the current state and the immediately preceding state, $SUPlimit_x$ and $INFlimit_x$ are respectively the upper and lower limits of the learner *x* regarding the variation in difficulty that he is able to tolerate within the topic covered. If the overall difficulty difference calculated on two consecutive states $Delta_{TotDiff}$ exceeds the capacity of the learner *x* (i.e. his maximum tolerance limit $SUPlimit_x$), it is necessary to lean towards an action a_p^{inf} that makes the conceptual representation simpler. Conversely, if the overall difficulty difference $Delta_{TotDiff}$ falls below the lower tolerance limit $INFlimit_x$, it is necessary an a_p^{sup} action that makes the conceptual representation more complicated and, thus, more stimulating.

The overall architecture of this integrated system is shown in Figure 6.

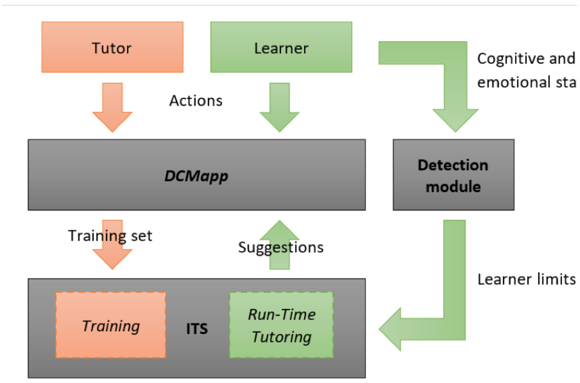

Figure 6 - The operation of the integrated DCMapp and ITS system.

4. Conclusions

This work lays the foundation for the design of an intelligent system that, appropriately integrated with modules for the detection of the cognitive and emotional state of students, can adapt to the individual needs of students and ensure effective and personalized learning (Fenza, Orciuoli & Sampson, 2017).

The work described here starts from the use of dynamic concept maps through the DCMapp application, integrated into the e-Lena platform, to improve learning. DCMapp allows the creation and navigation of dynamic concept maps, facilitating the integration between traditional and digital content. Dynamic concept maps, as demonstrated by Marzano and Miranda (2021a), can reduce study times, and improve learning outcomes. The article proposes the integration of an intelligent tutoring system based on Vygotsky's (1978) theory of the zone of proximal development, to suggest optimal actions to students while navigating the concept maps. The details proposed in this paper can represent the foundation for the design and the implementation of this intelligent system and become the starting point for a future experimentation.

Author contributions

Conceptualization: Rosa Vegliante and Sergio Miranda; *Design and methodology*: Sergio Miranda; *Writing-Original*: Rosa Vegliante and Sergio Miranda; *Writing-Review and Supervision*: Antonio Marzano.

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Gamifying Cultural Heritage: the digitization journey of Genoa University Museum System (SMA-UniGe)

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Abstract

The vast collection of paper documents and books stored in university archives worldwide represents a significant, yet often inaccessible, cultural heritage. To address this, the University of Genoa, Italy, is digitizing a variety of materials, including books, manuscripts, archival documents, and museum-related items. Making this heritage accessible requires providing alternate descriptions, metadata, and transcriptions, especially for ancient texts where OCR is ineffective. This paper presents the design of a transcription system for the University Museum System (SMA-UniGe), which is currently under development, featuring user-friendly interfaces and engagement techniques. The system leverages gamification to turn transcription into an engaging experience, aligning with the University's mission to promote public engagement and contribute to social, cultural, and economic development through knowledge sharing.

KEYWORDS: Cultural Heritage, Gamification, User Experience.

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1. Introduction

After completing the inventory of cultural assets within the University of Genoa in July 2021, it became clear that this heritage should be accessible without barriers. The University decided to establish the University Museum System (SMA) to digitize and archive its cultural heritage on a single online platform, making it accessible as an interactive exhibition. This collection includes structured museums, archives, botanical gardens, biobanks, and smaller collections.

Digitization and transcription are key to making this heritage discoverable and accessible for education, research, and public sharing, following the FAIR principles (Reiser et al., 2018) and Open Science (Ignat & Ayris, 2021). While OCR and HTR tools have shown promise, they are not accurate enough for the fine handwriting and contextual elements in UniGe manuscripts, despite the progress achieved with the implementation of AI and Machine Learning (Khan et al., 2024; Memon et al., 2020). Therefore, a novel human-based transcription system has been developed, leveraging Citizen Science (Bonney et al., 2016), crowdsourcing (Estellés-Arolas & González-Ladrón-de-Guevara, 2012), and public engagement (Davies, 2020), aligning with the "third mission" of universities to generate knowledge for societal benefit. Maintaining user engagement is crucial, as gamification encourages higher participation and work quality (Lin & Ding, 2023; Morschheuser et al., 2017). This crowdsourced, gamified transcription project also provides educational benefits, enhancing volunteers' understanding of cultural heritage, archival research, and language proficiency (Kim et al., 2015). It fosters critical thinking, attention to detail, and technological literacy, as volunteers learn to use digital tools for transcription and archiving. Collaborative problem-solving and peer-to-peer interaction further enrich the experience, promoting teamwork and community.

Peer review processes encourage accuracy and foster critical evaluation skills. Gamification elements, such as points, levels, and rewards, enhance motivation and engagement, making the transcription process more enjoyable and fostering sustained participation.

Since the transcription portal is still under development, this paper focuses on analyzing the engagement and

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gamification strategies adopted, as well as the design choices that shape its usability and aesthetic identity. In accordance with a user-centered and iterative design approach, comprehensive formative evaluations, including usability testing and pilot studies, will be conducted once the platform is finalized. These evaluations will involve the diverse target groups identified and characterized in this study, allowing for the refinement of both interface design and gamification mechanisms prior to full deployment.

2. Related Works

The web has enabled anyone to have access to a free space for acquiring information on a large scale, leading to new methods of content delivery and tools for accessing it (Schreiber, 2013). In the last two decades, numerous projects for document transcription were developed (Leon, 2014), but to realize this one, two specific realities have been taken as a model. In particular, the study focused on information architecture and engagement dynamics, to create a satisfying environment in terms of user experience and user interface design.

The former is the American Smithsonian Institution, which, with its platform "Smithsonian Digital Volunteers: Transcription Center" has created a space where "digital volunpeers" (Ferriter, 2014) can collaborate and contribute to transcription. The latter is the European Europeana, which has devised a more comprehensive transcription experience with "Transcribathon" (Feliciati, 2022) applying gamification dynamics to motivate users in a collaborative and competitive context, comparing the transcribed characters to miles covered in a marathon.

2.1 Smithsonian Digital Volunteers: Transcription Center

The Smithsonian Institution was founded in 1846 by James Smithson (1765-1829) with the aim of creating a place for culture and the dissemination of knowledge. Currently, it comprises 21 sites including museums, galleries, and a national zoo, making it the largest museum, educational, and research complex in the world. Its main goals are to preserve cultural heritage, foster new discoveries, and share its resources with the world. To pursue its mission, the Smithsonian Institution has been engaged in the process of digitizing its cultural heritage since 2013. It created a portal where "volunpeers" can access documents, browse and transcribe them (Gunther et al., 2016). After completing their transcription, volunteers have the opportunity to review their own work, while also having the option to review the work of others.

2.2 How to transcribe

The "Smithsonian Digital Volunteers: Transcription Center" portal lacks a responsive design, complicating navigation on devices other than desktops or laptops. The homepage features a mixed layout: a non-fixed header with the Smithsonian logo linking back to the homepage on the left, a navigation menu on the right, and links for "signup" and "login". Below this, a slideshow displays news, new projects, and invitations to collaborate on transcriptions. Upon scrolling, the page is divided into three columns:

1. Instructions for volunteering or following Smithsonian on social media;
2. A central section with a drop-down menu for browsing projects;
3. Updates on transcription activity, including revisions and completed pages with links to the relevant documents.

The footer contains links to the Smithsonian homepage, collections page, terms of use, privacy policy, and an Adobe Reader download. Document searches can be performed via a "search" button in the header, allowing keyword searches across all projects or specific ones from a drop-down menu. The search results appear in a table displaying pages with matching terms, including project and collection details. Projects can also be viewed by selecting the "projects" option in the header, showing clickable boxes with status markers: red for ongoing transcription, yellow for review, and green for completed pages. The transcription page is split into two resizable columns: on the left, a viewer shows the document image, and on the right, volunteers can input transcriptions and notes. Buttons for layout modification, document navigation, PDF download, and social media sharing are located around the transcription area.

2.3 The community engagement

The organization of a community is not foreseen within the Smithsonian transcription portal, as can be seen from the official document "Tracking Volunteer Work in the Transcription Center" which highlights that it is not necessary to register to transcribe. However, the account becomes essential at the time of review and if you want to keep track of your work, even if a note reads: "The Transcription Center does not record the number of hours a volunteer contributes, but the "My Work" report does include dates and times that a volunteer participated on a project page"; this means that in the "My Work" section it is possible to view the date and time in which your contribution was made to that specific project, but not the total amount of time spent carrying out the transcriptions themselves. In reference to a personal aspect of the target of the experience, according to the community management policies, registration on the portal is intended exclusively for over 14s while users under 14 can only consult the material. However, there is no real age control, but it is entirely up to the user to declare whether or not, by clicking on a button, they are more or less than 14 years old.

2.4 Europeana Transcribathon

Europeana is a digital library that brings together the cultural heritage of European archives, libraries, and museums, making their collections available for anyone who wishes to browse their documents out of curiosity, educational purposes, and research. Directly quoting the official website, its mission is to "empower the cultural heritage sector in its digital transformation" and "develop expertise, tools, and policies to embrace digital change and encourage partnerships that foster innovation" (Europeana, 2022). Europeana's vision is to provide cultural heritage for professional, educational, or leisure purposes, promoting its development on the web through the integration and enrichment of metadata for the digital content made available (Di Giorgio, 2014; Macrì and Cristofaro, 2021). Through the hamburger menu located at the top left of the homepage screen, users can access the "collections", which are macro-categories containing individual objects in different forms. However, the content of these media is not easily discoverable through a simple search on providers, and it is not possible to extract citations for theses or research if needed. For these reasons, they create "Transcribathon", a portal cofinanced by the European Union where anyone, upon registration, can engage in the transcription, geolocation, and dating of digitally acquired documents.

2.5 How to transcribe

The registration process requires users to provide a username, first name, last name, email, country, language, and password. All users begin at the "Trainee" level and can progress through higher profiles by accumulating miles and unlocking new features as they complete transcriptions. Documents for transcription can be found through the archive, an interactive map, the search bar, or by joining themed "runs".

Search results are displayed as a grid or list, with document status indicated by color: gray for "not started," yellow for "in progress," orange for "awaiting review," and green for "completed". Filters are available on the left side to refine search results. Clicking on a document opens its "cover" page, which includes general information, metadata, and progress percentages. On the transcription page, users can transcribe text and add tags such as dates, locations, people, document type, keywords, and external resources. All edits and additions require confirmation through a review process.

2.6 The community engagement

Undoubtedly, among the two analysed portals, "Europeana Transcribe: Transcribathon" has the most comprehensive and interactive experience, considering the playful context in which the transcription action is placed, metaphorically likened to the world of a marathon where miles become transcribed characters, and users can assume the roles of "Trainee", "Runner", "Sprinter", and "Champion", as well as create their own running team (Morschheuser et al., 2019). For Transcribathon, an engagement system was designed based on the world of marathons, matching written characters to miles traveled and some categories and themed events to "runs", i.e., monothematic races. As anticipated in the introduction to this portal, the volunteer transcriber climbs four levels, which are also linked, in their naming, to the environment of the marathon. Each level has its own "skills", rewards for continuity in transcription and for user loyalty.

3. The case study of University Museum System at UniGe (SMA-UniGe)

3.1 Methodology & Goals

The SMA-UniGe project arises from the need to consolidate the extensive cultural heritage of UniGe into a single repository and make it readily accessible online through a user-friendly interface and an engagement system specifically designed for this purpose. The primary goal was to capture, using high-performance 2D and 3D scanners, images of each individual page of ancient tomes, manuscripts, postcards, labels, cartography, and even exam papers, ensuring their high-definition presentation to all individuals interested in participating in their digitization process or those who simply wish to remotely browse through them. The census of these documents was completed in July 2021, resulting in a significant number of documents that need to be digitized and categorised to prevent them from being lost or scattered. The mission of the project is evident: to make the cultural heritage of Genoa University discoverable, understandable, and accessible to individuals worldwide. By doing so, researchers, students, professors, and enthusiasts will have the entire archive of UniGe's cultural heritage at their fingertips with a simple click, regardless of their location.

The transcription of scanned documents will be carried out by the so-called "digital volunteers". A digital volunteer can be anyone, from a university professor to a student, from an enthusiast to a curious individual. They will be the driving force behind the transcription process and are the ones who, out of experience, passion, or simply for fun, dedicate their time to deciphering each individual character that composes the works in the archive. Digital volunteers resemble the role of paid solvers of CAPTCHAs (Completely Automated Public Turing test to tell Computers and Humans Apart) (Woods, 2021). CAPTCHAs are sequences of distorted letters and numbers often displayed in a confusing background and are typically encountered at the end of online registrations or used as a Turing test to confirm one's human nature and keep malicious bots at bay.

Similarly, digital volunteers use their free time to decipher the often complex and challenging documents presented on the platform. However, their motivations are different from simply seeking monetary gain. In fact, in the SMA-UniGe, there is no monetary reward. However, engagement is fueled by a gamification system that includes an immersive setting, various gameplay modes, as well as interaction with other volunteers. This system also allows volunteers to earn experience points and receive rewards from affiliated organizations.

Figure 1 - Homepage after login.

Gamification is the process of transforming a non-game activity by incorporating game elements and game design techniques to make it more captivating, thereby stimulating cognitive processes associated with satisfaction and providing an additional positive impetus for accomplishing that activity (Werbach and Hunter, 2012). The ultimate aim of gamification is not to create an immensely complex triple-A title, but rather to devise effective methods that enhance individual motivation in both work and personal daily objectives (Coccoli et al., 2015). Gamification prompts individuals to improve their online and offline behaviours through the utilization of game mechanics that ensure a constant state of engagement. By actively engaging the user, the experience becomes closely linked to the message being conveyed, resulting in enhanced comprehension. Gamification enhances communication, collaboration, and creativity, while boosting learning, motivation, and interest in a flexible, mistake-tolerant, and digitally adaptive environment (Lee, 2023; Zeybek and Saygı, 2024).

The design of our gamified platform is based on the MDA framework created by Hunicke et al. (2004). The MDA framework consists of three components: Mechanics, Dynamics, and Aesthetics. Mechanics refers to the game's specific components and algorithms. Dynamics describes how these mechanics interact and behave in real-time. Aesthetics focuses on eliciting desired emotional responses from players when they engage with the game. The framework emphasizes that games are designed artifacts, with behaviour and interaction being more important than the media presented to the player. This perspective supports clear design choices and analysis throughout the development process. The platform's design aimed to take into account both the selected objectives for the platform itself and the intrinsic motivations of the users. It sought to choose the most suitable mechanics based on the needs and motivations of the end-users, offering a flexible structure for the experience, allowing users to personalize their journey according to their specific requirements (Seaborn & Fels, 2015).

In order to study the different personas that could potentially interact with our gamified platform and predict how they would engage with it, we analysed various player types. According to Richard Bartle (Bartle, 1996), players can be categorized into four distinct profiles.

(i) *Achiever*: This player embarks on gaming experiences with the goal of obtaining all possible badges and achievements, which they proudly showcase on their dashboard.

(ii) *Explorer*: The explorer is drawn to the world presented to them and enjoys the thrill of uncovering secrets and Easter eggs, finding fulfilment in the discovery of new experiences.

(iii) *Socializer*: The socializer prioritizes collaboration and socialization, dedicating less attention to competition. Their primary objective is to connect and engage with others.

(iv) *Killer*: Similar to achievers, killers find gratification in acquiring badges and achievements. However, what sets them apart is their intense competitiveness and the subsequent satisfaction derived from seeing others lose.

The conducted analysis served the purpose of selecting the most effective mechanics and internal rules within the platform to make engaging the potentially tedious experience of transcription. By understanding the different player types, we aimed to incorporate game elements that would cater to each user's motivational needs. The objective is to prevent premature abandonment of the platform by ensuring that users find mechanics that align with their individual preferences, thereby making the offered content more appealing.

However, the assistance of all digital volunteers is crucial to maximize the addition of as many documents as possible. Therefore, it is important for each individual to feel active and satisfied in their contribution, so that the cultural heritage of UniGe can be continuously enriched with new and valuable content day by day.

3.2 The target

The target audience for which the experience is intended is very broad and, in particular, includes curious people, experts in a specific field of work, study or research and secondary schools students undertaking transversal skills and orientation path ("PCTO", "Percorsi per le Competenze Trasversali e l'Orientamento", in Italian). For this reason, it was decided to create three user profiles. The first two can be selected during the sign-in process while the last can be obtained after interacting for a certain time within the platform:

(i) *"Curious" user*: the curious user has the possibility to browse, transcribe, review, earn experience points and badges and manage his dashboard independently via favorite topics selected during registration or elaborated based on his search preferences.

(ii) *"PCTO" user*: the profile is reserved for students who have undertaken the Transversal Skills and Orientation Path and it is linked directly to the young user's school email address. This type of profile has a personalized user experience to allow the student to complete the tasks required by the PCTO activity. In fact, the student must complete some tasks shown in his dashboard previously selected by the tutor professor who will see the work done once it is finished. Depending on the amount of time expected from the PCTO activity, the state of progress -and therefore the time spent active on the platform- will be considered based on the level reached within the game system. Once the PCTO period has ended, the student will be able to request, via a specific button in the account settings, to change it to a "Curious" user.

(iii) *"Expert" user*: as soon as the user reaches level 20, the account is upgraded to "Expert" status. The "Expert" user has gained the trust of the community and, therefore, can review a transcript and mark it as "complete" without the intervention of a moderator.

3.3 The environment

To immerse the digital volunteer in a hi-tech environment and with the aim of maintaining the visual identity of the University of Genoa, a color palette has been chosen, and it includes two of the primary colors of University's corporate identity: "Blu Unige" (HEX: 002677) and light blue (HEX: 199BFC). To these two main colors, a gray for written texts (HEX: 333333), a contrasting blue (HEX: 005DBF), and a neon green (HEX: 48E55A) for links and hover state activation for some clickable elements on the screen have been added (Figure 2).

Figure 2 - S.M.A. transcription system color palette.

The homepage after logging in (Figure 1) is structured to allow the user to reach all the pages of interest for the transcription and the features inserted to appreciate the experience. The page is designed with a central layout and is divided into three main sections:

1. The two transcription modes and the community button.
2. Suggestions.
3. Documents to which a contribution has already been made that are still pending completion.

Additionally, it features a navbar that provides access to the search bar, instructions, archive, rankings, messages, notifications, and the user's profile (Figure 3).

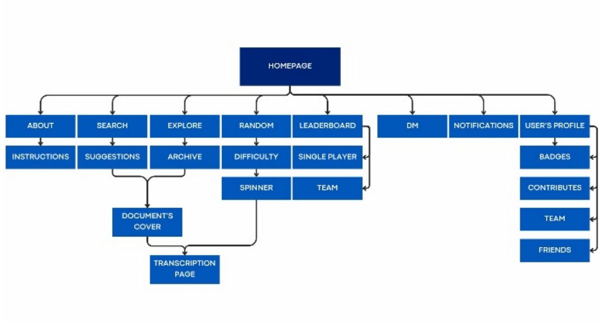

Figure 3 - Sitemap.

4. Proposed Gamification Strategies

Once logged into the platform, the player will have the option to choose a document to transcribe in three different modes through the "Classic Mode". The first mode is through a search bar located on the homepage, where suggested documents based on user-entered keywords will be displayed. The second mode is accessed via a dedicated button positioned in the centre of the homepage, which leads to the catalogue page equipped with a search bar and filters. The content can be filtered by "category", "difficulty", and "document conditions". Lastly, there will be a section dedicated to recommended documents within the homepage. However, to cater to the needs of Explorers, a "Random Mode" has been devised, allowing the player to engage in transcribing a random document (Figure 4). The player will need to select a difficulty level from "Easy", "Medium", or "Hard" to initiate a "Wheel of Fortune Game" (Woodward and Woodward, 1994) containing all the categorized document categories. When the wheel stops, it will randomly and automatically open a document for transcription from scratch or one that has been started by another user but remains unfinished, encouraging the player to try their luck with a psychological mechanism of information-seeking similar to the famous Google's "I'm Feeling Lucky" button (Kalbach, 2006).

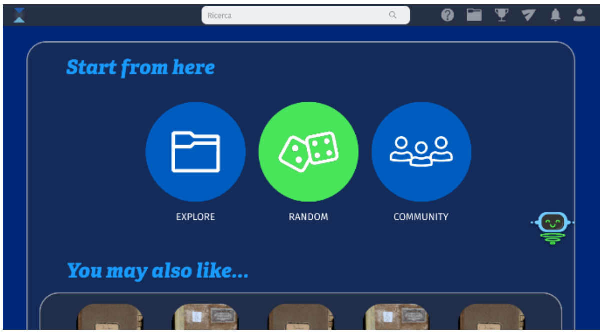

Figure 4 - Random Mode, Step 1.

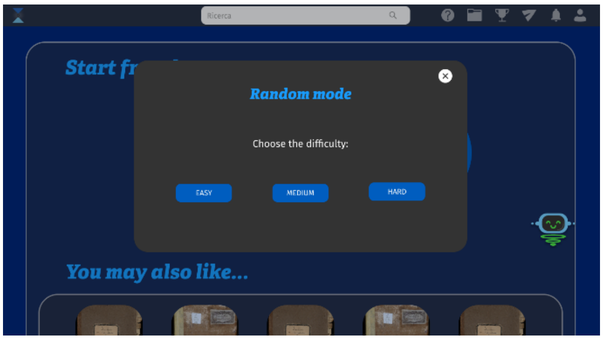

Figure 5 - Random Mode, Step 2.

Figure 6 - Random Mode, Step 3 .

Figure 7 - Random Mode, Step 4.

The Achievers will derive their satisfaction within the experience by collecting and acquiring rewards such as badges, experience points, and items, while the Killers strive to achieve higher rankings compared to other users. Therefore, various collectible items have been selected, based on the actions undertaken by the players. Players can earn badges within the platform, which will be displayed on their profiles. Badges are unlocked upon the completion of specific tasks indicated by the platform through special missions or upon reaching a certain level or ranking. The requirements for obtaining each badge are clearly stated, enhancing the player's sense of autonomy and satisfaction by increasing positive feelings (Bandura, 1993). Additionally, obtaining all available badges to showcase to other players serves as an extra incentive that can influence player behavior, particularly among achievers who are motivated to earn them all (Hamari, 2017). The inclusion of challenges within gamification, for instance, those that must be completed to earn badges, along with a user-centered design, enhances user performance (Legaki et al., 2020).

The primary form of rewards is experience points, and a level advancement system has been devised for them, following the Fibonacci sequence in the hundreds. Each number in the Fibonacci sequence is generated by adding the two preceding numbers. By assigning appropriate values to the first two numbers, the entire sequence can be defined. This recursive formula ensures that each term in the sequence relies on or "recurs" the values of the previous terms, specifically the last two numbers. The Fibonacci sequence is often denoted by the symbol F(n), where n represents any natural number, and F(n) represents the corresponding number in the Fibonacci sequence (Coppola, 2014).

$$F(n) = F(n-1) + F(n-2)$$

This means that reaching level 1 will require earning 100 experience points, progressing from level 1 to level 2 will require an additional 100 experience points, and advancing from level 2 to level 3 will require 200 points, and so on, as outlined in Table 1. The presence of a significantly high maximum level, which entails a substantial increase in experience points, serves as a strong incentive for achievers and killers to persist in their transcription efforts (Mekler et al., 2013). It caters to their ambitions of collecting badges, attaining higher levels, and competing with fellow users. Moreover, this gradual levelling system enables long-term engagement with the platform, fostering an increasingly immersive experience. Experience points within the platform can be earned through three actions:

1. Document transcription: each character, including spaces, is equivalent to 2 experience points, which are immediately credited upon saving. However, the content may undergo verification by other users capable of reviewing it for adherence to the original text.
2. Revision: each reviewed character of a transcribed document is worth 0.5 experience points during the revision process, which are earned upon validation of the review.

3. Daily logins: by accessing the platform for five consecutive days, experience points are awarded according to the guidelines outlined in Table 2. The consecutive day count resets after the five-day period.

The acquisition of experience points can be expedited through the presence of the 2x Boost. The 2x Boost is a condition that, when triggered, doubles the recently acquired or yet to be acquired experience points. Specifically, this enhancement occurs in two circumstances. The first circumstance occurs when a document transcription is completed and saved as “Ready for Review.” This triggers a 2x Boost, effectively doubling the experience points just obtained, making longer documents significantly more rewarding. The second circumstance arises when reaching two thousand typed characters within a single session. This situation activates a 2x Boost that doubles the value of all characters from the two-thousand-and-first character onward, even if they are typed in another document. It’s important to note that the boost is only applicable during the current session and will be nullified upon logging out.

Table 1 - Fibonacci sequence for Levels and Experience Points needed to progress.

Level	Experience Points
1	100
2	100
3	200
4	300
5	500
6	800
7	1300
8	2100
…	…

Table 2 - Experience Points earned for daily login.

Day	Experience Points
1	5
2	10
3	15
4	50
5	100

The documents on the platform will be categorized into different completion statuses that users can easily understand through a color-coded system. Specifically, the documents can have the following states (Figure 8):

1. Not Started: A document present in the archive that has not yet been transcribed. The document icon will be displayed in grey.
2. In Progress: When a digital volunteer starts transcribing a document but does not complete it, saving only the work done up to that point, the icon on the main page will appear in yellow.
3. Pending Review: Once the transcription is completed, the digital volunteer can confirm their work by clicking the “Ready for Review” button. In this case, the icon will change to blue, indicating that another volunteer is needed to perform the review.
4. Reviewed: Anyone has the opportunity to review a document, but the contributors’ names are not shown during the review process. Once the review is completed, the icon will turn green.

Figure 8 - Documents’ status (Grey=Not Started; Yellow=In Progress; Blue=Pending Review; Green=Reviewed).

Social interaction plays a crucial role in fostering engagement within the platform, especially in a voluntary activity (Lee et al., 2016). As a result, we decided to create an environment where digital volunteers can connect, send friend requests, exchange messages in private chats, leave comments in a dedicated section on the document pages, and even form work teams to compete against one another and compare their experience points on a team leaderboard. Players will have the ability to create work groups consisting of their friends, each with a unique team identification code. The group leader will choose a name for the team, which will be displayed as an abbreviation on each member’s profile along with an image uploaded by the creator. Having a team can greatly enhance users’ motivation by fostering a sense of involvement and collaboration through teamwork (Cohen & Levesque, 1991).

Leaderboards are a crucial tool for engaging and motivating users, fostering competitiveness, and inspiring them to strive for higher rankings (Landers et al., 2017). The leaderboards will be based on the results achieved in single player, displaying the names of individual users alongside their respective counts of badges and transcribed characters, and team mode, showcasing the names of teams along with the cumulative count of badges and transcribed characters achieved by all team members.

To accompany the digital volunteer on this journey, they will have a companion named Christopher (Figure 9), a virtual entity who guides the player into the realm of transcription and remains with them throughout the entire experience. Christopher will keep the player informed about updates, and can help in navigating the platform, if needed. The interaction with the buddy helps the user become acquainted with the environment and develop an emotional connection (Vercelli et al., 2021). Christopher's demeanour will vary based on the player's actions in the game. If the player experiences more defeats, the buddy will become sadder, motivating the player to strive for improvement and avoid disappointing their friend.

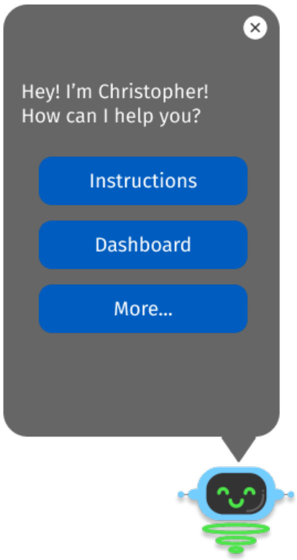

Figure 9 - Christopher, the buddy.

5. Discussion and Conclusions

This paper analyzes portals that utilize gamification to engage users in transcription tasks, showing how this approach can enhance the transcription experience for both casual users and experts. By following FAIR, Citizen Science, and Open Science principles, users are guided by clear instructions to ensure tasks are completed correctly, maintaining community harmony.

The launch of version 1.0 of the platform will be closely monitored to identify which features users appreciate most, allowing for improvements that better meet their needs. Gamification has been shown to boost motivation and performance across disciplines and institutions, as well as enhance analytical and problem-solving skills (Rodríguez et al., 2020; Vargas-Murillo et al., 2023). However, it is important to evaluate whether the selected mechanics foster meaningful engagement or lead to superficial content acquisition (Featherstone and Habgood, 2019). A key area for further study is whether the gamified structure effectively meets students' needs and motivations. The project aims to engage users in transcriptions with non-monetary rewards, such as ranking positions or badges. It will be necessary to adapt the structure to meet the personal needs and motivations of users (Rowicka & Postek, 2023).

Additional incentives for high achievers could include University of Genoa merchandise, Genova University Press books, cultural heritage reproductions, and museum discounts, awarded after completing specific tasks. Another potential improvement involves partnerships with museums and departments, allowing digital volunteers to visit archives and learn about cultural preservation efforts firsthand. This would offer volunteers a shared experience of enhancing university cultural heritage. Gamification plays a key role in fostering good community practices through engaging activities (Thomas et al., 2023). Future projects could further immerse users in transcription tasks through storytelling, creating a narrative that transforms their contributions into part of an exciting adventure, thereby enhancing motivation and involvement.

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Gotcha! Enhancing Argumentation as a Basis for Critical Thinking via Generative AI-Supported Learning in Higher Education

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Abstract

Generative AI introduces complexity by offering potential support for human skills development, while also generating noise and false information in a postdigital context. Grounded in a Vygotskian perspective, this study explores the combined use of argument mapping (AM) and ChatGPT as mediational tools for developing argumentative skills as a proxy for critical thinking in higher education. These tools are conceptualized as socio-technical assemblages providing double stimulation within students' Zone of Proximal Development (ZPD), addressing how multimodal texts and AI mediate comprehension of information (CoI) and critical thinking (CT). Adopting a case study approach with a quasi-experimental design, the research involved 17 female undergraduate students from the University of Padua, divided into three groups: G1 working with analog texts, G2 with multimodal texts, and a control group interacting only with ChatGPT (G3). Chatbot interactions were analyzed to explore its potential to support reflection and personal information re-elaboration. Results indicate improvements in comprehension and critical thinking, especially in the multimodal group (G2). G1 achieved weaker outcomes, possibly due to limited external stimulation. G3 outperformed G1 but showed stable yet comparatively lower results in advanced argumentative reworking despite a positive median. Overall, AM seems to support text comprehension and meaning reconstruction, while multimodality fosters the integration of multiple perspectives. Generative AI can further support critical engagement and understanding of AI systems when embedded in a structured pedagogical design rather than used "in the wild".

KEYWORDS: Argumentative Skills, Generative AI, Argument Maps, Critical Thinking.

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1. Introduction

Gathering and processing information is challenging (Colombo, 2018), especially in today's digital age, where pervasive digital systems make accessing and sharing true and false information effortless (Cortiana, 2017). Digital spaces have changed, evolving into what is termed the post-medial (Rivoltella, 2020) or postdigital era (Jandrić et al., 2024; Raffaghelli, 2024). The "post" prefix reflects a reaction to digital transformation, encompassing manipulation, misinformation, and personal data marketisation (Knox, 2019). All these phenomena raise educational concerns about addressing postdigitality critically, balancing individual agency with democratic values (Means et al., 2022; Macgilchrist, 2021).

The rise of generative AI (GenAI), such as ChatGPT (OpenAI, 2022), complicates this landscape. Unlike earlier tools that supported information navigation, ChatGPT generates personalized responses through dialogic interaction. Such generated information can be extremely problematic and, as with past digital paradigms (like the pro-social web represented by social

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media), it requires a critical stance more than ever. Not knowing how to deal with them consciously makes navigating the abundance of increasingly complex information even more difficult (Roose, 2022; Lund & Wang, 2023).

This research examines the incorporation of generative AI, particularly ChatGPT, in higher education to enhance argumentative skills, linked in the literature to critical thinking (Wang et al., 2023; Crudele & Raffaghelli, 2024a). The research is framed as an in-depth case study conducted in a single authentic educational context. It aims to explore how students engage with argument mapping (AM) and AI-mediated learning. The study does not pursue statistical generalisation. Instead, it seeks to develop a situated understanding of how these tools can support students' comprehension of information (CoI) and critical thinking (CT). Beginning with AM as the primary scaffold, ChatGPT was subsequently introduced as an additional socio-technical mediator to assist students in reworking argumentative texts. The study involved 17 female students enrolled in the "Training Evaluation" course at the University of Padua. A hybrid learning environment was established, combining asynchronous information with face-to-face interactions. A quasi-experimental structure was adopted with three groups: one using analog texts, another multimodal text, and a control group interacting solely with ChatGPT. The findings indicated an improvement in comprehension and critical thinking, particularly in the multimodal group. Students' interactions with ChatGPT were examined for its capacity to facilitate students' reflection and personal reinterpretation of material. The study posed critical inquiries on the role of multimodal texts and artificial intelligence in facilitating learning within the student's Zone of Proximal Development (ZPD). While both AM and ChatGPT contributed to CT development, challenges remain regarding the effective integration of AI in educational practices. Overall, results suggest that, within the limits of this case study, multimodal and AI-supported methods can enhance students' critical engagement and argumentative skills.

2. Background

2.1 The massification of Generative AI

Large Language Models (LLMs) and AI-driven chatbots, like ChatGPT, have recently become widely used for tasks such as verifying information, providing feedback, and generating ideas (OpenAI, 2022). These systems align with Luciano Floridi's (2023) notion of "artificial agents", as they can "do things" – such as generating responses – based on probabilistic associations of topics and words. Beyond their artificial nature, they exhibit "agency", meaning they act in contextually relevant ways.

AI holds promises for addressing significant challenges in education (Bozkurt et al., 2023). Chatbots offer distinctive opportunities for flexible learning experiences, immediate personalized feedback, complex problem-solving, and anytime access to resources (Al-Abdullatif, 2023).

However, their potential must be weighed against limitations identified by empirical research. Generative AI (GenIA) faces issues like "hallucinations" (Petkauskas, 2023) and inaccurate content generation (Haque & Li, 2024). Therefore, it cannot be considered as an enhancement per se. Without critical evaluation, such tools risk spreading misinformation (Petkauskas, 2023).

Moreover, the ability of AI to produce complex, human-like texts raises ethical concerns. Connected to this are all those concerns and consequent prohibitions of use in the school and university context, especially because of the possibility of using them to avoid intellectual work (García-Peñalvo, 2023). The use of chatbot technology is a valuable educational resource, but it sparks a broader debate about its implications. Developing "Artificial Intelligence Literacy" (Cuomo et al., 2022) is essential to ensure responsible use and to address its educational, personal, social, and ethical impacts (Ranieri et al., 2024).

2.2 Argumentative Skills and their role in the postdigital world

In today's digital and complex world, the ability to understand and rework information remains essential (Canale et al., 2021; Crudele & Raffaghelli, 2023a). Yet traditional cognitive and educational tools are increasingly insufficient for addressing contemporary learning demands. Although access to information has expanded significantly, this does not necessarily translate into greater autonomy in thinking. This condition has prompted renewed reflection on the effects of postdigitalization on learning (Ranieri, 2019) and on the personal and educational needs required to navigate this landscape effectively (Means et al., 2022).

These challenges become especially evident when students engage with arguments. The development of argumentative skills fosters critical thinking and prepares individuals to engage actively in society (Iordanou & Rapanta, 2021). Facing a discussion, if prepared to understand, evaluate, and reflect, one learns by "formulating new hypotheses" without mechanically repeating what has been read and deemed most correct (Avenia, 2021). However, many students still struggle with understanding, recognizing, and reframing arguments (Alotto, 2021; Crudele & Raffaghelli, 2023a). A difficulty further intensified by multimodal (Kress, 2013, 2015) and digital information systems (Pangrazio & Selwyn, 2019), which complicate traditional reading and writing processes (Howell, 2017).

For these reasons, this case study focuses on future educators and professionals in the educational sector. Providing them with tools that highlight the value of argumentation in the digital age enables them to apply newly acquired skills to real educational contexts. The aim is not only to strengthen argumentative competence during the intervention, but also to prepare them to navigate an evolving educational environment and face the challenges of using AI critically and responsibly as future professionals.

Within this framework, argumentative maps (AM) offer graphical support for clarifying the logical-syntactic chain of complex reasoning (Carrington et al., 2011; Lidåker, 2018; Crudele & Raffaghelli, 2023c). Unlike common mind or concept maps, they use an inverted-tree structure with boxes and arrows to represent propositions and inferential relations. Propositions are color-coded according to their function (thesis, objections, reasons, etc.), while arrows indicate the type of logical relation involved ("because", "but", etc.). This visual system simplifies argument structures, helping readers follow the analysis and evaluate the coherence of the reasoning (Alotto, 2021). Already effective for decoding and reconstructing arguments, AMs have now been reimagined for navigating dynamic digital environments effectively (Crudele & Raffaghelli, 2023b).

An additional layer of complexity lies in interacting with human, non-human, or "multi-agent" systems. Recent research explores how AI integration into learning, such as algorithms drawing valid inferences (Kim et al., 2022), can support the development of new argumentative skills. Today, we can talk about how interaction with AI can foster argumentative learning, refining the "best way to talk to the machine" (Mollick & Mollick, 2023; Ranieri et al., 2024). Effective interaction with AI requires critical questioning of its outputs rather than passively accepting them (Panciroli & Rivoltella, 2024).

This approach reframes AI as an intelligent "peer" rather than a mere tool, encouraging a deeper, more specific engagement to generate meaningful outputs (Ferrarelli, 2024). One should think about introducing students not so much to the basic actions of interacting with AI, but to the activation of knowledge and more critical use of these new channels (Ranieri et al., 2024). This marks a new dimension of argumentative skills through a post-human lens.

2.3 Double Stimulation and Mediation

In a reaction to the behavioral psychology based on the "stimulus-response" deterministic vision, Lev Vygotsky (1978) asserted that human actions and psychological functions are facilitated by tools. The concept of "mediated action" is typically illustrated by a triangle including subject, mediating artifact/tool, and object (Wertsch, 2007). This scheme encompasses both technical tools that interact with objects and psychological tools that mediate the mind and environment. The tools introduce cultural symbols and signs (Vygotsky, 1934/2023), thereby supporting the relationship between the subject and her cultural context and highlighting that no response can just be triggered by a stimulus as an abstract entity. Vygotsky called this "double stimulation". The two categories of stimuli are, for example, a given piece of information in a digital context, and the ability to read it (hence introducing informational literacy). These categories aim to objectify internal psychological processes to track the evolution of advanced cognitive capabilities and elucidate their structure. Sannino (2015) problematizes this process, considering that "although second stimuli play a crucial mediating function, (…) the emergence of volitional action involves conflicts of motives as a key component which has largely been neglected in discussions of double stimulation" (p.2). The volitional action that this author brings to the fore is key to the subject's intention to interact with the signs.

Several authors have considered the relevant role of mediation within digital contexts, going beyond the idea of the digital as a phenomenon "producing" learning (Fadeev, 2019). In this literature, the digital spaces, interfaces and applications become mediational means that introduce socio-cultural and semiotic elements. In an intentional act of interacting with such elements, the learner decodes signs and triggers inner dialogues that let her cross the zone of proximal development (ZPD) in some direction. Building on this theoretical framework, this paper investigated the double stimulation produced by AMs and ChatGPT as socio-technical artifacts on students' argumentative responses. We emphasise here the relevant role of volitional interaction with such tools. With AMs, the study assumed that creating a structured space for understanding, revising, and reconstructing information (CoI) is a key element in the development of argumentative skills. Likewise, it was hypothesized that critical and goal-oriented interaction with the ChatGPT agent for reformulating and rethinking argumentative perspectives could develop these skills while fostering a deeper understanding of intelligent agents (Crudele & Raffaghelli, 2024a).

3. Materials and methods

3.1 Aims and Research Questions

The research starts with a) a macro-focus comparing the 3 groups, and b) within this, a more specific comparison between two of the experimental groups.

Starting with the second focus, the study aimed to 1) investigate whether AMs supported students' CoI enhancement and critical reframing (CT) and 2) investigate whether interaction with generative AI supported students in reframing information (related to CoI) and critically constructing assessment tools from scratch (skills related to CT).

These objectives led to an initial reflection on how the two tools mediated learning within the Zone of Proximal Development (ZPD), focusing on skill acquisition in CoI and CT. At the macro level, the research explored whether not mastering the mapping methodology might hinder students' ability to rework opinions effectively.

As a third objective, the study 3) investigated whether, required to produce a complete opinion about a given topic, communicative interaction with GenIA alone, without the mediation of AMs, still supported the reworking of information and integration of different points of view for one's reflection.

Following the order in which the objectives to be investigated were presented, the following research questions (RQs) were formulated:

RQ 1 - Does AM-based training support students' development of text comprehension and critical thinking?

RQ 2 - How do students and educators perceive and engage with artificial agents while reworking argumentative texts, and what learning needs emerge from their experiences?

RQ 3 - Are there differences in the effects of argument mapping combined with ChatGPT or the sole use of ChatGPT as mediators of critical thinking development and performance in educational tasks?

Starting from these general questions, some specific expected results were drawn (see Table 1).

3.2 Participants

The target sample consisted of 17 female students, aged 18 to 25 years old, enrolled in the course "Evaluation of Education", within the Bachelor of Science in Education and Training at the University of Padua (L-19).

3.3 Research Design

For this study, a case study approach was combined with a quasi-experimental design. As a case study, the contribution allows for a situated and context-sensitive understanding of how students engage with argument mapping and AI-mediated learning within an authentic university setting. Rather than aiming for statistical generalization, case studies pursue *analytical generalization*. They offer an in-depth empirical inquiry into a contemporary phenomenon and insights into future investigations (Yin, 1984/2014; Hollweck, 2016). The goal is therefore not to produce universally generalizable findings, but to examine in depth the dynamics emerging in a specific learning environment and to identify patterns that may be meaningful for similar contexts.

This methodological stance is particularly appropriate for early-stage research on rapidly evolving educational phenomena, such as the integration of generative AI into students' argumentative practices. In these contexts, the priority is to capture complexity, observe processes as they unfold, and refine emergent hypotheses. Within this framework, the quasi-experimental design serves an exploratory function, enabling comparisons across different learning conditions while preserving sensitivity to contextual features and ecological validity.

Embedded in the case study, we adopted a quasi-experimental design, which offers the flexibility required in dynamic educational settings. In educational settings – where variables are numerous and deeply interconnected – these designs enable exploration of causal relationships while preserving ecological validity (Shadish, 2002). Moreover, a mixed-methods approach was considered, with a triangulation of quantitative indicators and qualitative information to enhance the comprehensive understanding and robustness of the findings (McLeod, 2024).

Quantitative data supported the exploration of differences in trends in text comprehension and critical thinking development across the three conditions. While qualitative analyses provided insight into how generative AI mediated students' reasoning processes, sense-making, and reflective engagement.

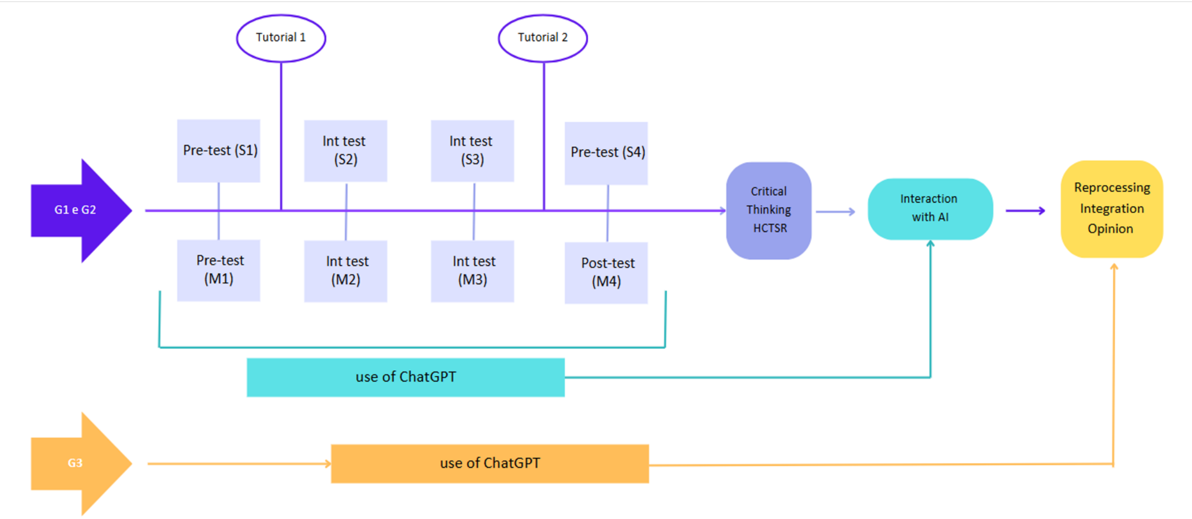

Figure 1 - Outline of the research design.

Together, these components enabled both a macro-level comparison among groups and a more fine-grained examination of differences between the two experimental conditions.

The first experimental group (G1) used maps with fully analog texts. The second experimental group (G2) used maps with multimodal texts. The control group (G3) was not subjected to the map variable but only to the ChatGPT interaction.

The study was conducted over the duration of a three-month university course (Figure 1). The course included three laboratory sessions focusing on different tools for learning assessment. The experimental activity took place in one of the three labs and centered on the use of AMs and rubrics as tools to develop and assess argumentative skills. The control group counted students from the other two labs on structured tests and peer feedback, respectively.

The learning environment was hybrid, combining in-person group work with asynchronous activities via the Moodle platform. Online materials included argumentative texts, tutorials, and guided activities. ChatGPT was integrated to compare and enhance students' argumentative interactions.

The experimental phase involved 10 female students (5 each in G1 and G2) across four data collection stages, starting with text comprehension (RQ 1). To investigate this ability to identify the basic structural components of an argumentative text, a semi-structured survey tool with closed stimulus questions (S1, S2, S3, S4) was developed.

Research question	Mediational means	Data Collection tools	Data Analysis tools	Expercted results for RQ
RQ 1. Does AM-based training support students' development of text comprehension and critical thinking?	Argument Maps (Analogical / Multimodal) Preparatory phase.	- Semi-structured survey instrument with closed stimulus questions. - Graphic elaboration of an AM.	- Checklist of students' ability to identify structural elements of the text. - Checklist of correct map construction. - An adapted version of the Holistic Critical Thinking Scoring Rubric (HCTSR).	- Increased comprehension of an argumentative text, in terms of identifying structural elements. - Increased AM construction skills, in terms of identifying and juxtaposing components in space. - Increased level of critical thinking, in terms of reconstructing the meaning of the text and constructing one's own thinking.
RQ 2. How do students and educators perceive and engage with artificial agents while reworking argumentative texts, and what learning needs emerge from their experiences?	ChatGPT	Student messages on the forum regarding interaction with GenIA.	Codebook Creation	- Indication of the presence or absence of prior knowledge and reflection on the positive and negative aspects of the first approach. - Indication of new emerging learning needs (including critical training in the use of chatbots). - Indication of the personal idea of the potential and limitations of intelligent agents in educational practice.
RQ 3. Are there differences in the effects of argument mapping combined with ChatGPT or the sole use of ChatGPT as mediators of critical thinking development and performance in educational tasks?	Argument Maps + ChatGPT	Final reworking of G1, G2 and G3 students in comparison.	Opinion detection grid	- Lower reworking performance of G3 than the other two groups. - Indication of the effectiveness of MAs and ChatGPT as a mediator of critical thinking development.

Table 1 - Tools and procedures of the method.

Students read an argumentative text, identified key components (problem, thesis, arguments, objections, evidence, conclusion) and expressed their opinion about the topic in a final open-ended question. Next, they built an AM (M1, M2, M3, M4), bringing together and arranging the components of the text they read in space. A checklist with scores from 0 to 7 was created to assess the completeness of map construction.

Based on the data collected from text comprehension, critical thinking (CT) was assessed using an adapted version of the Holistic Critical Thinking Scoring Rubric, HCTSR (Facione & Facione, 2014). The mastery levels of the rubric (strong, acceptable, weak, absent) were combined with four categories obtained from the text comprehension test questions:

- Identify important information.
- Identify arguments and counterarguments or alternative points of view.
- Conclude and explain the reasons.
- Understand and modify one's opinion based on the evidence.

The instrument was used by the researchers in parallel with the four phases mentioned above (CT1, CT2, CT3, CT4).

To address RQ2, ChatGPT's role as a "collaborator" for mediating argumentative reworking was analyzed through student prompts and forum posts. Students offer the chatbot the same tasks of comprehension and identification of argumentative text components. At the end of each activity, they reported the comparison between their answers and those of the chatbot. Forum contributions were qualitatively coded by preparing a codebook (see Open Data Crudele & Raffaghelli, 2024b). This focused on 1) interaction, in terms of prior knowledge, reflection on the prompt, and first-approach bias; 2) application, in terms of critical use, possible areas of use, and identified limitations; and 3) relevance, in terms of original insights to put into action, starting from and with ChatGPT.

The role of ChatGPT was tested on two main levels: 1) at the descriptive level, starting from their experience and input on the use of the tool, and 2) at the activation level, first in terms of developing a rubric for correct argumentation writing, and afterward constructing two new rubrics for analyzing text comprehension and constructing correct AMs.

These contributions were then organized and analyzed using NVIVO. Subsequently, a thematic analysis (TA) was conducted based on three themes with 11 sub-themes:

- students' interaction, including reflections on whether they had prior knowledge of using the intelligent agent and their initial approach to it (3 sub-themes);
- encompassing reflections on potential future uses, possible areas of application, and emerging training needs, such as fostering critical use (4 sub-themes);
- relevance, focusing on ChatGPT's demonstrated potential, starting from original insights and leading to future work (1 sub-theme).

To pursue RQ 3, the level of reworking and integration of personal and others' thinking was investigated. Final contributions produced during the last exam by students in the previous two groups (n=10) and those in the third group (n=7) were collected, analised and compared.

Data was analyzed using a grid assessing reworking and integration alongside the HCTSR (Annex 1). Differences in the mediation tools' impact on argumentative skills were explored, with results and tables available in the Open Data repository (Crudele & Raffaghelli, 2024b).

For clarity, please refer to the overview in Table 1.

4. Results

The following sections present the results in response to the proposed research questions.

RQ1 - *AM-training-based effects.*

To answer RQ1, data on the correct identification of the structural components of argumentative text (Figure 2) and the respective construction of an AM were first analyzed (Figure 3).

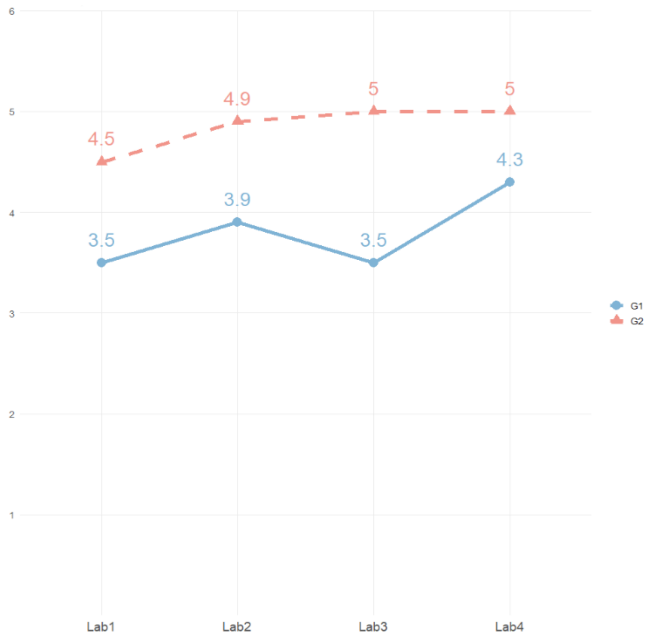

Figure 2 - Text comprehension between G1 and G2.

The data show an improvement in text comprehension scores from beginning to end. Despite initial challenges, G1 achieved strong final scores (S1 = 3.5; S4 = 4.3). G2, however, demonstrated a gradual and consistent increase across all data collection points (S1 = 4.5; S4 = 5.0).

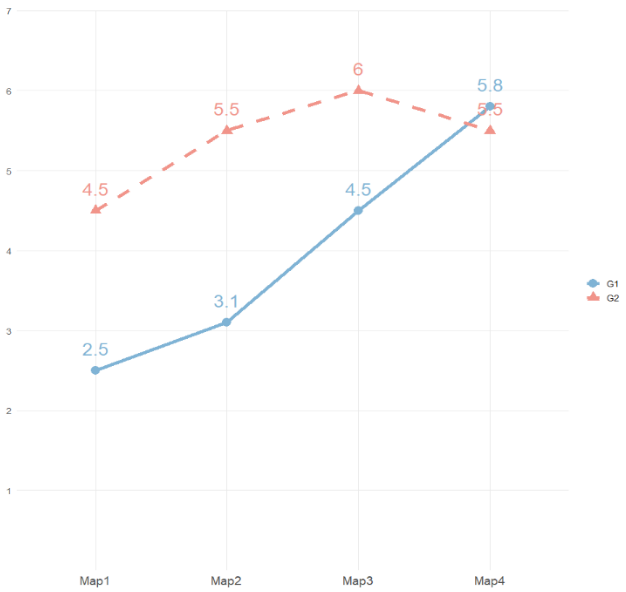

Figure 3 - AMs' construction between G1 and G2.

Similarly, AM construction results mirrored text comprehension trends. G1, starting with difficulty (M1 = 2.5/7), ultimately reached an excellent score (M4 = 5.8/7, "complete map"). G2 also showed significant progress, ending with high scores for correct argumentative map construction (M1 = 4.5; M4 = 5.5).

Assuming a correlation between text comprehension and critical thinking, the analysis examined students' ability to reconstruct the meaning of the text by identifying structural elements and formulating personal opinions.

Critical thinking levels were generally positive (Figure 4).

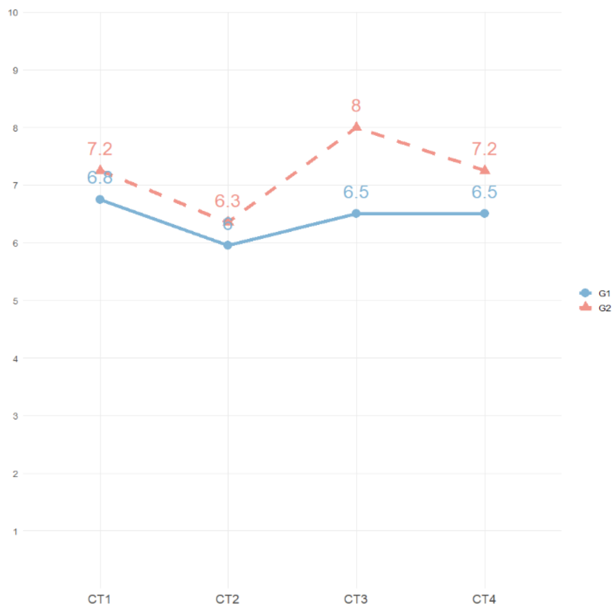

Figure 4 - Level of critical thinking between G1 and G2.

G1 achieved a final critical thinking score of 6.5/10, while G2 scored 7.25/10. A closer analysis revealed some instability in G1's ability to understand and reformulate opinions (CT1 = 6.75; CT4 = 6.5), whereas G2 maintained stable performance (CT1 = 7.25; CT4 = 7.25).

RQ2 - *Perceived engagement with AI agents*.

About RQ2, the contributions of 7 students, totaling 3,640 words in Italian, were analyzed and labeled based on themes and sub-themes identified in the codebook (cfr Annex 2). The text corpus was categorized into three key areas: interaction with the chatbot, students' needs and applications, and relevance for learning and education. These reflections will be addressed in the context of the three specific research questions.

4.1 Interaction

The analysis of the contributions revealed that most of the students had little to no prior knowledge of ChatGPT, also because at that time it had only recently been released to the market. This led to an initial approach to interaction driven by curiosity and expectations, some of which were pleasantly confirmed, while others were not. Among the five students who recorded their first impressions, six references were classified as positive, stating that it was "very interesting as a first use" and that ChatGPT was perceived as "a very useful tool in several aspects." Two references were negative: "In our case, it wasn't very helpful" and "I noticed flaws in the way it processes responses; in my opinion, they are often far from the central topic. I don't think I'll use it again!" Despite being in the minority, the negative reflections clarified potential initial difficulties with the interface and unmet expectations. The only student who had prior experience with ChatGPT moved beyond seeing it as merely "a useful but complex tool", particularly during rubric construction. She highlights its potential when paired with a more "human" element: "During the construction of the rubrics, we used ChatGPT and noticed how useful it could be to use the rubric it suggested for a particular topic. In fact, we used it as a starting draft to personalize and make it our own by adding the 'human' element that artificial intelligence can never provide."

Regarding prompt refinement, only one student detailed the steps taken to build her interaction with ChatGPT.

4.2 Application

In the "Application" section, reflections on potential uses and emerging new training needs were explored. Repeated interactions with the artificial agent during the course seemed to activate critical thinking among students. All the participants expressed at least one thought about the need to engage critically with available intelligent agents.

Two students explicitly demonstrated a critical approach in practice, interacting with ChatGPT while already aware of the need for personal re-elaboration: the first student stated, “The only thing to pay attention to is not to use such tools improperly or incorrectly, but to consider them as a 'right-hand' helper to ask for assistance and collaborate with.” The second added, “It is necessary to rely on artificial intelligence not automatically but by reworking and enhancing the responses obtained, so we always keep our intellectual and re-elaboration skills active.”

Other students, however, expressed the need for further training in the critical use of ChatGPT: “With these technologies, we should start learning to live with them and use them correctly since they don’t always enhance our learning” and “From this, I can deduce and argue that there is a connection that goes 'beyond' the simple question-answer mechanism.”

Five contributions indicated that the interaction with ChatGPT during the course provided insights into further application areas and potential uses. Initially contextualized to lab activities, “as a starting point to add new indicators and criteria to the rubric proposed by the teacher”, or as “a source of inspiration to draft the indicators and criteria we then presented in the rubric more accurately and completely.” Later, the potential applications became broader: “useful for obtaining factual information in any field of interest” or “to provide solid starting foundations for formulating any type of task”.

4.3 Relevance

Lastly, this research question explored students' personal perceptions of ChatGPT's limitations and their reflections on its integration into learning and teaching.

Regarding perceived limitations, the main issues focused on difficulties encountered during activities: “as it was not able to provide us with a proper rubric”, or “it gives arguments, objections, and foundations that are very different from yours and often off-topic, missing the point of the question.”

A second recurring limitation across contributions was the “human-robot” dichotomy, particularly regarding creativity. This limitation concerned the chatbot's impersonal responses, excessive rationality, and the necessity of human intervention to “complete” the work. Notable statements included: “The limitations of a digital tool regarding creativity and reflective reasoning were very evident, in my opinion” and “ChatGPT, being artificial intelligence, tends to be entirely rational and objective, following a positivist approach that strictly adheres to goals and programs without adding personal and subjective critiques that only a human can provide.”

Building on this limitation, the “Original Insights” section reflected how, as future educators and evaluators, the students recognized “the qualitative leap a human can make when adopting the intelligent agent.” One student stated: “We used it as a starting draft to personalize and make it our own, adding the 'human' element that artificial intelligence can never provide.”

However, some reflections focused on the potential downsides of this integration. From an evaluator’s perspective, a student commented: “It’s impossible to assess someone’s competence solely based on the use of these 'artificial programs. This way, the human and intellectual aspects of the individual being evaluated are overlooked.” From the perspective of the evaluated individual, another student remarked: “Putting myself in the shoes of someone being evaluated, I cannot derive educational or learning benefits by asking questions to a 'person' that doesn’t even exist.”

RQ3 - *Impact of Mediation Type on Final Elaboration*.

Regarding RQ3, Table 2 and Figure 5 show that all three groups achieved above-average scores (out of 6 points) in constructing an elaborate and integrated opinion. Among them, G2 (the multimodal group) displayed the highest overall performance (M = 4.40, SD = 1.19). G3 also achieved a relatively high score (G3. M=3.93; SD=1.02), while G1 (the analog group) recorded the lowest values (M = 3.38, SD = 1.09). Distributional analyses revealed distinct group profiles: G2 showed the highest central tendency (Me = 5.00; IQR = 1.00); G3 displayed a slightly lower but still positive and relatively compact distribution (Me = 4.00; IQR = 1.50); while G1 presented the lowest median and the greatest dispersion (Me = 3.25; IQR = 2.25).

To further contextualize these findings, one-sample Wilcoxon tests were conducted using a high reference value (5). None of the groups scored significantly above this benchmark. When testing for deviation below the reference value, only G3 resulted significantly below the

Group	Mean	Std. Dev.	Min	Q1	Median	Q3	Max	Skewness	Kurtosis
General Opinion Level between G1-G2-G3									
G1	3.38	1.65	1.50	2.25	3.25	4.50	5.50	0.16	-1.90
G2	4.40	1.19	2.50	4.00	5.00	5.00	5.50	-0.61	-1.54
G3	3.93	1.02	2.50	3.00	4.00	4.50	5.50	0.06	-1.50

Table 2 - Descriptive statistics, overall opinion of the 3 groups.

standard (V = 2, p = .025). This finding indicates a consistent position under a demanding reference standard rather than low overall performance. Indeed, despite this deviation, G3 maintained a relatively high median and lower variability compared to G1, which displayed lower and more dispersed scores that did not reach statistical significance, possibly due to the small sample size.

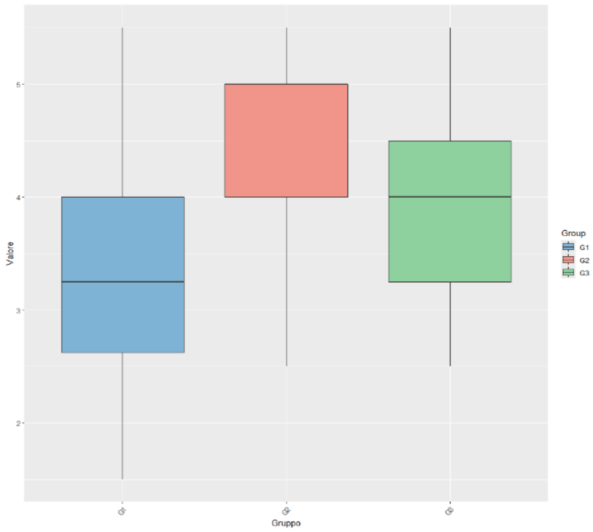

Figure 5 - Boxplot Opinion Trends Between Groups.

Focusing on the more specific comparison between G1 and G2, a further response emerges on the reflection about AMs' effectiveness as a mediator of the development of critical thinking. As seen in Figure 3, G2 achieved a higher critical thinking score, particularly in CT3 (M = 8.00), following engagement with AMs and multimodal texts. Integrating this with the results on written opinion elaboration provides additional insights. G2 scored higher on both clarity and coherence in opinion elaboration (G1: M = 2.25, SD = 0.65; G2: M = 2.50, SD = 0.35) and integrating supporting and opposing viewpoints (G1: M = 1.12, SD = 1.03; G2: M = 1.90, SD = 0.89). Notably, G2 displayed lower data dispersion compared to G1, further highlighting its advantage.

5. Discussion and Conclusions

Reconstructing information through broader thinking and reorganizing structural elements remains a complex task. Regarding RQ1, data on text comprehension – particularly the identification and spatial juxtaposition of structural components – suggested a general improvement in both experimental groups (G1 and G2). Within this overall trend, G2, which engaged with multimodal information, experienced a more consistent and gradual progression across phases. Although such results cannot be generalized, they provide initial indications that rethinking textual modalities and designing skill-development activities around them may offer meaningful support for learners.

Multimodality may have encouraged deeper reflection without introducing excessive cognitive noise. This is highlighted in how G2 outperformed G1 during the Cri-Think3 phase, which required exploring different sources of information and creating rubrics for text comprehension and spatial reorganization. These observations may suggest that consistent exposure to complex, multimodal information – combined with guided activities – offered students additional tools to navigate and be inspired by diverse perspectives. In this sense, AMs appeared helpful in supporting the identification of key elements and their use in designing assessment tools, ultimately contributing to the re-elaboration of critical opinions, particularly in G2.

Turning to RQ2, students' engagement with ChatGPT must be understood within the historical moment in which the course occurred – during the early public emergence of the chatbot. Unsurprisingly, many students approached it with limited prior knowledge. Their initial interactions reflected a mix of curiosity, apprehension, and occasionally unmet expectations due to irrelevant or inconsistent outputs. Over time, however, repeated use encouraged a more investigative stance: students began exploring possible applications and reflecting on forms of human-AI collaboration.

As prospective educators, they also considered the technological and pedagogical limits of the tool and the potential value of structured pathways for its integration into professional practices. From these reflections emerged the idea that targeted guidance might enhance both students' understanding and their development of argumentative skills.

For RQ3, G2 achieved the highest scores in opinion reworking, suggesting that sustained exposure to multimodal perspectives may have supported a richer integration of viewpoints. Although non-parametric analyses did not reveal statistically significant group differences, the observed descriptive patterns remain informative within the exploratory and case-based nature of the study. G1, while benefiting from AMs in reconstructing argumentative frameworks, obtained lower and more heterogeneous scores in the complete reworking of opinions. In contrast, G3 (interacting solely with ChatGPT) produced above-average scores with limited variability. Importantly, inferential analyses indicate that only G3's outcomes were positioned significantly below the high reference standard, despite maintaining a positive median. This result reflects a coherent and homogeneous positioning under a demanding benchmark rather than low overall performance. Compared to G1, which showed more dispersed outcomes and no significant deviation from the reference value, G3 showed greater stability and consistency. This pattern suggests a more complex profile for the control group. Interaction with the chatbot may have supported initial opinion refinement and stabilized students' responses, without necessarily leading to fully developed or high-level re-elaboration. This grey result is consistent with recent research. Several studies suggest that conversational AI can reduce cognitive load but does not always foster critical re-elaboration, particularly when it overly facilitates task completion (Ayman et al., 2023). When used in isolation, such agents may support task execution. However, they are increasingly perceived as tools to which learners delegate argumentative decisions, potentially reducing critical functions and bypassing deeper learning processes (Ayman et al., 2023; Jahani et al., 2024). Conversely, when AI is embedded within a framework of structured engagement – as a support tool rather than a substitute for intellectual effort (Martha et al., 2025) – it may contribute to the development of critical thinking. In this case, AI can provide motivation and prompts that encourage students to reconsider their own positions (Song & Song, 2023).

Taken together, these preliminary findings do not allow firm conclusions but tentatively point toward differentiated contributions of the tools examined. AMs appear particularly useful for understanding and structuring information (CoI). Multimodal exposure (G2) and indirect multimodal exploration via ChatGPT (G3) may play a more prominent role in supporting argumentative reworking. However, if used as the sole tool for opinion elaboration, ChatGPT does not seem to provide sufficient support for fully articulated and structurally complex re-elaboration. Overall, the intervention suggests that multimodal resources may represent a promising avenue for fostering comprehension, openness to multiple perspectives, and early forms of opinion construction. Within this framework, AMs primarily functioned as scaffolds for structural understanding (CoI). Instead, ChatGPT could offer mediation for 1) re-elaborating information (CoI), 2) reorganizing it for the construction of critical tools (CT), and 3) promoting reflective thinking about the role of AI in educational contexts – particularly when integrated with other instructional supports rather than used in isolation. At this stage, critical re-elaboration emerges as a complex competence requiring multiple, structured phases that unguided interaction with a conversational agent alone does not appear to adequately support.

Rather than establishing the superiority of one tool over another, this case study sought to explore their potential complementarities and to inform the design of integrated learning approaches.

Several limitations must be acknowledged. First, the study was conducted as a small-scale case study with a reduced and homogeneous sample, limiting the possibility of statistical generalization. The quasi-experimental design, while suitable for exploratory purposes, entails inherent constraints, including the absence of randomization, the potential influence of contextual differences between groups and the challenge of controlling external variables. Moreover, the duration of the course allowed only a short period for the development of complex skills such as argumentative reframing, critical integration, and human–AI dialogic interaction. These abilities typically require extended, iterative instructional support. Additionally, students' limited familiarity with ChatGPT – understandable given the early stage of the tool's public release – may have shaped the nature and depth of their interactions. Patterns of use may therefore differ from more established applications of generative AI. The research design was also shaped by the emergent character of the technology under investigation. Working with a rapidly evolving tool limited the possibility of fully refining the design at the outset and introduced additional uncertainties. For these reasons, the findings should be interpreted as exploratory rather than as definitive evidence.

Future research could address these limitations by implementing longer interventions, involving more diverse samples, and refining the comparative design to isolate better the effect of multimodality, mapping, and AI mediation. Longitudinal approaches may further clarify how learners' argumentative repertoires evolve as they gain experience with AI-supported practices, offering a more robust understanding of the relationship between these tools and the development of critical thinking skills.

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The research was approved by the University of Padua Ethics Committee. Qualitative data include statements taken from university syllabi, which are public and visible to all. The transcripts are faithful to the original and have not been edited for the paper. The identities of professors and others involved in writing these syllabi have been left anonymous.

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Annexes

Annex 1 - Grid opinion argumentation

Categories	Indicators	Descriptors	Yes	Partially	No
Rielaboration	Clarity of the opinion expressed	The opinion emerges clear and concise			
	Coherence of the opinion expressed (before and after reading)	The opinion follows a logical thread, without contradictions			
	Originality of the reworking	The opinion does not stop at the surface, but contains original elements			
Integration	Integration of supporting arguments	The opinion is deepened by providing supporting arguments			
	Integration of counterarguments	The opinion is deepened by responding to objections and counterarguments			
	Integration of the author’s opinion	The personal opinion is explored by also integrating that of the author			

Annex 2 - Nvivo labeling codes

Name	Description	Files	References
Interaction	Approach to activities and integration of the artificial agent response	6	16
Prior Knowledge	Presence or absence of prior knowledge regarding the use of the intelligent agent	6	6
Yes		1	1
No		5	5
Reflection on the prompr	There is a reference to the reworking of the prompt to better communicate with the AI	1	2
First approach	The first impression is given by the first approach to the intelligent agent	5	8
Positive		5	6
Negative		2	2
Application	Reflection on possible future uses and any new emerging training needs.	6	27
Critical approach to the intelligent agent		5	8
Yes	A critical approach to the use of the intelligent agent is already emerging.	2	3
No	The need for critical training in the use of ChatGPT and other artificial intelligences is emerging.	5	5
Future uses	There is a general reference to the possibility of future uses of ChatGPT.	1	1
Possible areas of use	The possible areas of use of AI are specified.	4	10
Limitations	The limitations found in practice with the intelligent agent.	5	8
Relevance	Personal idea of limitations and potential of ChatGPT and other artificial intelligences for educational practice	4	9
Original Ideas	Some original ideas that the students have implemented starting from and with ChatGPT.	4	9

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Effects of interaction between teacher and e-Learning system in high school education

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Abstract

The interaction between teachers and e-Learning systems plays a crucial role in the effectiveness and quality of online and blended education in secondary schools. This paper examines how teachers influence the use of e-Learning platforms through their digital competencies, experience in creating educational materials, and perceptions of the usefulness of information and communication technologies, as well as how e-Learning systems shape teaching practices and instructional strategies. The research is based on a quantitative study conducted among secondary school teachers, using a structured survey questionnaire and statistical methods including factor analysis and multiple regression analysis. The findings indicate that teachers' actual and perceived IT knowledge and their experience in developing digital educational materials significantly affect the intensity and scope of e-Learning system usage. The results further highlight the need for systematic professional development of teachers to enhance effective interaction with e-Learning systems. The study provides empirically grounded insights that can support the design of teaching strategies and institutional policies aimed at improving the quality of e-teaching in secondary education.

KEYWORDS: e-Learning, Teachers, Interaction, e-Learning Delivery Systems.

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1. Introduction

The rapid development of information and communication technologies (ICT) has significantly accelerated the popularization of new methods for acquiring and transferring knowledge (Khan et al., 2024; Al-Ansi & Fatmawati, 2023; Arzeen et al., 2023; Osman, 2023). In this context, electronic learning (e-Learning) has seen dynamic growth, increased application, and substantial investment (Rabelo et al., 2024; Yas et al., 2024). Currently, education in Bosnia and Herzegovina faces the new challenge of e-education, which aims not to replace traditional pedagogy and teaching methodology entirely, but to expand and transform them, creating a new form of 'face-to-face' learning based on electronic interaction. The aim of this research was to obtain valuable results and solutions that will enhance the educational capacity of secondary schools in fulfilling their core mission. The primary focus areas of this research are e-Learning, learning management systems (LMS), standalone software tools, and virtual classrooms for e-Learning. The teachers who participated in this research utilized the Moodle LMS and the Google Classroom platform in their work. In Bosnia and Herzegovina, these two platforms are the most commonly used for conducting e-Learning. Research shows that teacher quality is the most prominent factor influencing students' perceived

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satisfaction in e-Learning systems (Chugh, 2023). It has been shown that the perception of teaching and learning among new generations of students requires an interactive multimedia approach to teaching content and collaborative learning supported by technology - with which students are very close, and that they will gladly accept such an approach to learning. In this sense, e-Learning systems offer enough opportunities to implement the new role of the teacher. In this context, we propose the main hypothesis: There is an interactivity, which can be expressed qualitatively and quantitatively, between teachers who use modern information and communication technologies (ICT) to support teaching in secondary education and systems for e-Learning. The objectives of the research presented in this paper were derived from the stated hypothesis. To determine whether the intensity and frequency of use of software tools and functionalities of the learning management system in the teaching process is greater, if the teacher has greater real and perceived information technology (IT) knowledge. To determine whether the intensity and frequency of use of software tools and the functionalities of the learning management system in the teaching process can be related to the experience in creating one's own educational digital materials. To examine whether the tendency to use software tools and functionalities of learning management systems in teaching can be explained by previously acquired experience in the use of ICT. To determine whether the scope of the used possibilities of the e-Learning platform is increased by the perception of the efficiency and usefulness of certain resources and software tools, which are used in e-Learning. The following scientific methods were used in the research of the effects of the interaction between the teacher and the e-Learning system: inductive, analysis, survey, comparative and statistical methods. This paper is structured in eight sections as follows. Section 1 is an introduction, and it states the problem addressed by the paper, hypothesis and research objectives. Section 2 – Learning in an electronic environment, explains the specifics and basic principles of learning in an electronic environment. Section 3 describes the creation of educational materials and instructional design. In Section 4, the principles of creating educational materials and the criteria by which they are evaluated are given. In section 5, the specifics of the application of the most commonly used systems for conducting e-Learning in Bosnia and Herzegovina are briefly mentioned, and in section 6, the state of e-Learning in Bosnia and Herzegovina is explained. In section 7, the research methodology is presented, the results of the conducted research are presented and discussed. Within this section, the classification of measurement variables and the evaluation of the measurement scale is given, and the model for proving the hypotheses of the work is presented. This is followed by factor analysis, multiple regression analysis and discussion of the obtained results. Finally, in Section 8, concluding considerations are given with regard to the findings of the research.

2. Learning in an electronic environment

The integration of information and communication technologies into education has enabled new models of teaching and learning supported by virtual classrooms and learning management systems, which facilitate communication, monitoring of learning progress, and timely feedback (Manegre & Sabiri, 2022). However, the effectiveness of learning in electronic environments depends not only on technological infrastructure but also on pedagogical design, teacher engagement, and meaningful interaction throughout the learning process (Sabeh et al., 2021; Tawafak et al., 2020). Prior research also indicates that successful e-teaching requires alignment with learning objectives and active student participation supported by appropriate digital tools (Mastan et al., 2022). In this context, teachers remain central in mediating technology use and shaping interaction quality; recent evidence suggests that pedagogical design and teacher presence are more decisive for effectiveness than infrastructure alone (Arezky, 2025; OECD, 2025).

3. Creation of educational materials and instructional design

The effective use of e-Learning platforms depends on the systematic development of digital educational materials aligned with instructional goals and pedagogical principles. Instructional design provides a framework for organizing content, selecting appropriate digital media, and supporting learning processes within electronic environments. Well-designed digital materials facilitate learner engagement and interaction by structuring content in ways that support understanding and timely feedback (Clark & Mayer, 2023). In e-Learning contexts, teachers assume a dual role as both content providers and designers of learning experiences. Through the creation and adaptation of digital materials, teachers shape instructional strategies and align learning activities with students' needs and curricular objectives. Consequently, experience in developing digital educational materials contributes to more effective use of e-Learning platform functionalities and supports meaningful teacher-student interaction.

4. Principles of creating and evaluating digital educational materials

The quality of digital educational materials depends on the alignment of technological solutions with pedagogical, didactic, and methodological principles. Teachers are responsible not only for selecting appropriate technologies, but also for ensuring that digital materials support learning objectives, student engagement, and meaningful interaction within the e-

Learning environment (Tomić & Juričić, 2018). Given the absence of formally established evaluation criteria for digital educational materials in Bosnia and Herzegovina, this study refers to the criteria proposed by the Croatian Academic and Research Network (CARNet, 2016) as a relevant and structured framework. These criteria encompass scientific accuracy, pedagogical and didactic alignment with curricula, ethical considerations, technological usability, and organizational clarity. An overview of the CARNet evaluation principles is presented in Table 1. The application of such structured evaluation frameworks can support teachers in developing high-quality digital materials and contribute to more consistent and effective e-teaching practices.

Table 1 - CARNet principles for the evaluation of digital educational materials (CARNet, 2016).

Criterion type	Description
Scientific	Accuracy, validity, and relevance of content based on reliable sources
Pedagogical-didactic	Alignment with curriculum, learning outcomes, and teaching methods
Psychological	Adaptation to learners' cognitive abilities and learning styles
Ethical	Promotion of inclusiveness, tolerance, and responsible digital behavior
Technological	Usability, accessibility, interoperability, and responsive design
Organizational	Clear structure, logical organization, and ease of navigation

5. Specifics of applying the most commonly used e-Learning systems in Bosnia and Herzegovina

In secondary schools in Bosnia and Herzegovina, the most commonly used e-Learning platforms are Google Classroom and Moodle. These systems differ in complexity, functionality, and implementation requirements, which directly influences teachers' instructional practices. Google Classroom is often adopted due to its simplicity and low technical demands, whereas Moodle provides a more comprehensive learning management environment with advanced options for course organization, assessment, and monitoring student progress (Ketut Sudarsana et al., 2019; Gamage, 2022). The choice of platform affects the scope and quality of teacher-student interaction and the extent to which digital tools are pedagogically utilized. Teachers' digital competencies, experience, and pedagogical approaches are critical in determining the effective use of platform functionalities. Accordingly, successful implementation of e-Learning systems in secondary education depends not only on technological solutions but also on continuous teacher training and institutional support (Zou et al., 2025).

6. e-Learning in secondary schools in Bosnia and Herzegovina

International assessments indicate persistent challenges in the development of functional competencies among students in Bosnia and Herzegovina. Results from the Programme for International Student Assessment (PISA) show that 15-year-old students achieve scores below the OECD average in reading, mathematics, and science, with a substantial proportion not reaching minimum proficiency levels required for the effective application of knowledge in new contexts (OECD, 2019). The broader educational context, including issues related to evaluation, quality assurance, and learning outcomes, has been analysed in national and international policy reports (UNICEF Bosnia and Herzegovina & OECD, 2022). These findings highlight the need for instructional approaches that promote higher-order thinking and active student engagement. In this regard, e-Learning can support pedagogical transformation in secondary education when it is based on sound pedagogical principles rather than emergency or ad hoc solutions. Research distinguishes between emergency remote teaching and well-designed online learning environments, emphasizing that effective e-Learning requires careful planning, adequate infrastructure, and continuous professional support for teachers (Otto et al., 2024). Accordingly, the development of sustainable e-Learning practices in secondary schools in Bosnia and Herzegovina depends on systematic teacher training, appropriate technological resources, and strategic integration of digital technologies into teaching and learning processes.

7. Research methodology, results and discussion

The primary instrument utilized in this research is a survey questionnaire designed for teachers (Krnjić-sq, 2022), consisting of 25 questions. The majority of the questions in the questionnaire feature "closed" responses, with options provided on a five-point Likert scale. To determine the factors influencing the effects of interaction, direct contact with high school teachers and literature providing primary and secondary data sources were used. The independent variables of the study were determined after combining frameworks and reviewing the literature. The survey questionnaire used in this study was originally developed in the Bosnian language as part of the author's doctoral research and was subsequently translated into English for the purposes of this study. Both the English version of the questionnaire and the classification table of the measured variables are publicly available via the provided online references.

7.1 Classification of measurement variables

The survey was structured such that the questions were grouped into six dimensions aligned with the formulated questions and research objectives (Krnjić-cmv, 2022). The questions were designed to measure specific manifest variables, including information literacy, use of software tools, skills in creating teaching content, use of e-banking, email correspondence, social networks, and using the Internet for reading news. Additional variables included participation in web conferences, writing and reading blogs, downloading music, playing games, downloading applications, using the Internet for scientific purposes, and preparing e-teaching materials. The survey also addressed the representativeness of resources in e-teaching, experience with software tools for e-teaching, use of the Internet when creating educational materials, downloading media from the Internet, respect for copyright, use of educational materials by other authors, and tools for conducting e-teaching. In addition, the areas of research included teachers' effectiveness in delivering e-Learning on the platform, participation in teacher forums, awareness of increasing digital competencies, the search for innovative solutions, willingness to participate in the development of e-Learning programs, the challenges of preparing for e-teaching, and the evaluation of the platform. Latent variables (dimensions) include a certain group of questions from the survey questionnaire, namely: D1. Actual and perceived IT knowledge of teachers, D2. Frequency and intensity of software tool usage, D3. Experience in producing of own digital educational materials, D4. Extent of utilization of the e-Learning platform's capabilities, D5. Teachers' perception of the usefulness and efficiency of ICT in education, and D6. The need for additional teacher education in the application of modern ICT in e-Learning. Each latent variable was assessed through a specific group of questions in the questionnaire, corresponding to the manifest variables being measured. For each manifest variable, a measurement scale was employed, facilitating the quantitative research. The entire questionnaire with manifest and latent variables represents a scale for measuring the effects of interaction between teachers and the e-Learning system.

7.2 Rating scale

The internal consistency of the measurement scale was evaluated using the Cronbach's alpha coefficient. Prior to assessing the overall scale for measuring interaction effects, the internal consistency of each scale's items (which measured the latent variables) was examined, followed by an evaluation of the internal consistency of the entire scale. Exploratory factor analysis (EFA) using principal component analysis with oblimin rotation was conducted to examine the underlying structure of the measured variables and to generate regression factors for subsequent analyses. The suitability of the data for factor analysis was confirmed using the Kaiser-Meyer-Olkin measure and Bartlett's test of sphericity. Given the focus and scope of this article, detailed tables of factor loadings are not presented; however, the complete factor structure and loading matrices are documented in the author's doctoral dissertation and are available upon request. The research procedure consisted of several sequential phases. Initially, six theoretical dimensions were defined based on the literature review and the conceptual framework of the doctoral research. Subsequently, exploratory factor analysis identified seven empirical factors. One of the extracted factors was not included in further analyses due to its limited theoretical interpretability and relevance to the research model. Therefore, six factors were retained and used as predictors in the regression analysis.

7.3 Research model and hypotheses

A research model was developed based on the relationship between the assessment of the effects of the interaction between teachers and the e-Learning system, and the identified latent variables. This model includes five auxiliary hypotheses derived from the main hypothesis:

AH1: The intensity and frequency of using software tools and the functionalities of the e-Learning system in the teaching process are greater when the teacher possesses higher levels of both actual and perceived IT knowledge.

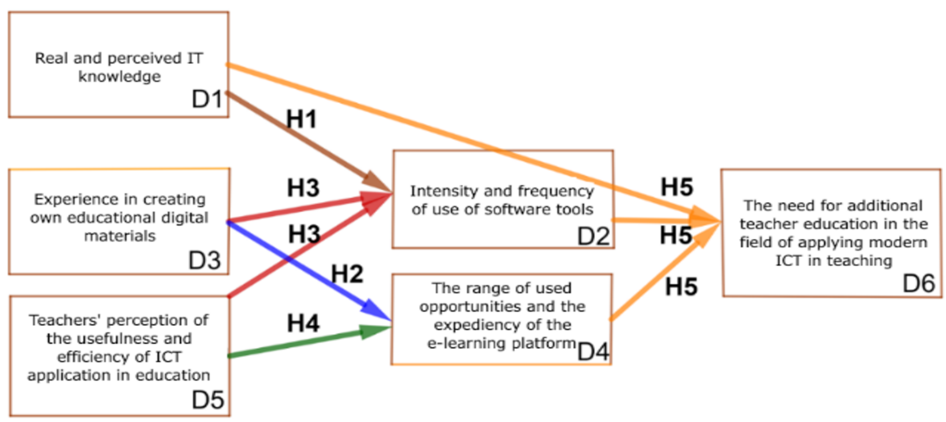

Figure 1 - Flow diagram of the evidence of formulated hypotheses.

AH2: Teachers' inclination to use software tools and the functionalities of e-Learning systems in teaching can be explained by the experience in creating one's own educational digital materials.

AH3: The intensity and frequency of using software tools and the functionalities of the e-Learning system in teaching can be linked to teachers' experience in creating their own digital educational materials, as well as their perceptions of the usefulness of ICT in education.

AH4: The range of used opportunities and the expediency of the e-Learning platform increases with the perception of the efficiency and usefulness of certain resources and software tools, which are used in the performance of e-Learning.

AH5: There is a recognized need to develop a strategy for the professional development of teachers, focusing on the use of modern software tools, educational platforms, and contemporary teaching methods within the e-Learning environment.

Figure 1 shows the flow diagram of the evidence of the formed hypotheses.

7.4 Factor analysis

This technique extracts the maximum shared variance from a set of variables and consolidates it into a single factor. Factor analysis was conducted on all latent variables. In conducting exploratory factor analysis, the principal components analysis method and the direct oblimin rotation method were employed to reduce the variables to a smaller number of factors. These factors represent the fundamental components of the observed latent variables (dimensions). Before conducting the factor analysis on each latent variable, the suitability of the data (Kaiser-Meyer-Olkin index, KMO) and the justification for its use (Bartlett's test of sphericity) were assessed. All tests indicated that the Kaiser-Meyer-Olkin (Tabachnick, Fidell & Ullman, 2007) measure of sample adequacy exceeded the required minimum of 0.6, and that Bartlett's test of sphericity was statistically significant (p=0.000). Therefore, the application of factor analysis is justified, and the data are adequate for this purpose (Tabachnick, Fidell & Ullman 2007). The method of principal components was applied to the scales of the latent variables. During the analysis, one or more factors with an eigenvalue greater than 1.0 (Guttman - Kaiser criterion) were identified. Additionally, the scree plot was examined to confirm the selection of the number of factors, focusing on the 'elbow' points. Based on Cattell's criterion, one or more factors were retained for further analysis of individual latent variables. To interpret the separation of variables into factors, direct oblimin rotation was also applied.

(D1) After conducting an exploratory factor analysis of "real and perceived IT knowledge of teachers," one regression factor was identified, which we named "INFORMATION KNOWLEDGE" and denoted as INF. KNOWLEDGE.

(D2) Similarly, when analyzing the scale "frequency and intensity of use of software tools," one factor was identified, which we named "Frequency of computer use for entertainment, scientific and educational purposes" and marked as FR.ENSCIED.

(D3) The variables of the measuring scale "experience in producing own digital educational materials" were subjected to principal component analysis. Two factors were identified. Regression Factor 1, covering "the use of digital aids and materials", was named UDAM. Regression Factor 2, covering "the use of visual aids and internet materials", was named VISAINTM.

(D4) Exploratory factor analysis of the scale "extent of used platform capabilities" revealed two regression factors. Factor 1, representing "the scope of utilized platform capabilities in e-teaching", was denoted as SUPP1. Factor 2, representing "the scope of used platform possibilities in e-teaching", was denoted as SUPP2.

(D5) The scale "teachers' perception of the usefulness and efficiency of the application of ICT in education" was analyzed, resulting in three factors. Regression Factor 1, associated with motivation and audio/video presentations for students, was named MAUDVID1. Regression Factor 3, related to motivation, interactive presentations, quizzes, and the teacher's usefulness of the platform, was named MIPRQUTEU3. Factor 2 was excluded due to failing the assumption of oblimin rotation and showing poor internal consistency.

(D6) The scale "need for additional teacher education in the domain of modern ICT" underwent principal components analysis. Two factors were identified. Factor 1, representing participation in forums, competence increases, and platform ratings, was named D6.PFICRP1. Factor 2, representing motivation for innovative solutions, development programs, and teaching preparation, was named D6.MISDPTP2.

7.5 Multiple regression analysis and hypothesis testing

The regression factors obtained from exploratory factor analysis were employed in multiple regression to evaluate the formulated model. The constructed model comprises dependent variables and regression factors that were determined through exploratory factor analysis with which the latent variable has a stronger correlation. Each latent variable (D1, D2, D3, D4, D5, and D6) in the model is associated with a corresponding function representing the average values of the respondent's answers to the manifest variables that define it. Each latent variable was operationalized as a composite score calculated as the mean of its corresponding manifest variables. The preliminary analysis evaluated the assumptions necessary for applying standard multiple regression analysis, including sample size, multicollinearity, singularity, presence of outliers, as well as normality, linearity, and homogeneity of variance.

7.5.1 The relationship between teachers' IT knowledge and the intensity and frequency of use of software tools

The standard multiple regression showed that the adjusted coefficient of determination was Adjusted R2 = 0.765 with a standard error of estimation, St.error = 0.4399. The proposed model explains 76.5% of the variance: intensity and frequency of use of e-Learning software tools, as predicted by teachers' real and perceived IT knowledge. The model reached statistical significance: F(1,49) = 164.025, Sig=0.000 at a significance level of p = 0.05. The impact of the independent variable, Real and perceived IT knowledge of the teacher (INF.KNOWLEDGE), on predicting the dependent variable—Intensity and frequency of use of software tools for e-Learning, as measured by the function F(D2)—is significant, with Beta = 0.877. This impact is unique (Part = 0.877) and statistically significant (t = 12.807, p < 0.001) (Table 2).

Based on the established indicators of the strength of the association between the intensity and frequency of software tool use, and the real and perceived IT knowledge of teachers, we can conclude that an increase in teachers' IT knowledge leads to a corresponding increase in the frequency and intensity of software tool use in e-teaching. This conclusion supports the auxiliary hypothesis AH1. Teachers with greater IT knowledge better understand the functionality of software tools and can apply them more effectively in teaching. Such teachers are more inclined to try out new technologies and tools, thereby leading to more creative and interactive approaches to learning. Greater IT knowledge enables teachers to more easily solve potential technical problems and quickly adapt to changes in technology. Knowledgeable teachers can better train students to use individual tools, thus improving the overall e-Learning experience.

7.5.2 The relationship between experience in producing own digital educational materials and the scope of utilized platform features

The standard multiple regression showed that the adjusted coefficient of determination was Adjusted R2=0.704, with the standard error of the estimate being St.error=0.3576. The model explains 70.4% of the variance: the range of utilized platform capabilities. The model reached statistical significance: F(1,49) =119.801, Sig=0.000, with a significance level of p=0.05. The contribution of the independent variable, the use of digital aids and materials (UDAM), to the prediction of the results of the measurement of the dependent variable, the range of used platform capabilities measured by the function F(D4), is Beta=0.842. That contribution is unique (Part=0.842) and statistically significant (t=10.945, Sig.=0.000) (Table 3).

The established indicators of the strength of the connection between the utilized platform capabilities and the experience in producing one's own digital materials indicate that the auxiliary hypothesis AH2 has been confirmed. We can conclude that the tendency for teachers to use software tools and functionalities of learning management systems in class can be attributed to their experience in creating their own educational digital materials. Educators who have already invested in the creation of digital educational materials have

Table 2 - Correlation between intensity and frequency of use of software tools, and teachers' real and perceived IT knowledge.

R=0.877	**Adjusted R^2**=0.765, **St.error**=0.4399		**F(1,49)=164.025**		**Sig.F, Sig.=0.000**[b]	
Model	Unstandardized coefficients		Standardized coefficients	**t**	Sig. **t**	**Part**
	B	Std. Error	**Beta**			
Constant	2.490	.062		40.426	.000	
INF.KNOWLEDGE	.797	.062	0.877	12.807	.000	0.877

Table 3 - Correlation of the range of used platform capabilities with experience in the production of own digital materials and the use of ICT.

R=0.842	**Adjusted R^2**=0.704, **St.error**=0.3576		**F(1,49)= 119.801**		**Sig.F, Sig.=0.000**[b]	
Model	Unstandardized coefficients		Standardized coefficients	**t**	**Sig. t**	**Part**
	B	Std. Error	**Beta**			
Constant	2.297	0.050		45.871	0.000	
UDAM	.554	0.051	0.842	10.945	0.000	0.842

gained an understanding of the various software tools and functionality that an e-Learning systems provides. That experience will enhance their willingness and inclination to use those tools because they know how to apply them in their teaching. Creating your own educational materials involves the use of various digital resources, such as graphics, video content, interactive elements, and other multimedia content. This practice helps teachers to more easily adapt and use the functionalities of e-Learning systems that enable the integration and management of similar content. Teachers who have experience in creating their own digital materials often have an innovative approach to teaching, which can motivate them to use advanced functionalities of e-Learning systems that support innovative teaching and learning methods. There is also the possibility of creating more effective lesson plans. If teachers are used to creating their own educational materials, they have also developed effective strategies for planning and teaching. Such strategies can be supported and enhanced by using the various functionalities of the e-Learning delivery system.

7.5.3 The relationship between the frequency and intensity of the use of software tools with the experience in creating their own educational digital materials and the teachers' perception of the usefulness and efficiency of the use of ICT in education

The standard multiple regression showed that the adjusted coefficient of determination was Adjusted R2=0.868, with a standard error of the estimate, St.error=0.32551, indicating that the model explains 86.8% of the variance in the frequency and intensity of software tool usage. The model reached statistical significance: F(2,48)= 165.208, Sig=0.000, with a significance level of p=0.05. The contribution of the independent variable, the use of digital aids and materials (UDAM), to predicting the frequency and intensity of software tool usage, as measured by the function F(D2), is Beta=0.942. Its unique contribution amounts to (Part=0.714) and is statistically significant (t=13.887, Sig.=0.000) (Table 4). The contribution of the independent variable, motivation, interactive presentations, quizzes, and the teacher's perception of platform usefulness (MIPRQUTEU3), to predicting the results of the dependent variable, as measured by the function F(D2), is Beta=0.012. Its unique contribution amounts to (Part=0.009) and is not statistically significant (t=0.178, Sig.=0.859) (Table 4).

Based on the results of the standard regression analysis, we can conclude that the most significant contribution to the frequency and intensity of software tool usage comes from teachers' experience in creating their own educational materials. In contrast, the teacher's perception of the usefulness and efficiency of ICT does not make a significant contribution. Based on this, we can partially accept the auxiliary hypothesis AH3. Specifically, the part stating that the intensity and frequency of software tool usage and the functionality of the learning management system in teaching can be statistically significantly related to the experience in creating one's own educational digital materials. However, no statistically significant relationship exists with the teacher's perception of the usefulness of ICT in education. Teachers who create their own materials are more motivated to use e-Learning delivery systems to implement their content and ideas. Such teachers can more easily adapt their teaching to the needs of their students, which increases the frequency of tool usage. Experienced teachers in the creation of materials often explore new tools and functionalities, which increases the intensity of use of e-Learning systems. These factors indicate a strong relationship between experience in creating educational materials and the use of software tools in education. On the other hand, the results of this research showed that the intensity and frequency of software tool usage and the functionality of the learning management system do not have a statistically significant relationship with the teacher's perception of the usefulness of ICT in education. The following reasons may explain this: different motivations: teachers may use tools out of obligation or because of administrative requirements - not because of a personal perception of usefulness; lack of training: if teachers are not adequately trained - they can use tools superficially, without understanding their advantages; technical problems: such as unstable internet connection or bad software, can reduce the perception of usefulness – even

Table 4 - Correlation of the range of used platform capabilities with experience in the production of own digital materials and the use of ICT.

R=0.934	**Adjusted R^2**=0.868 **St.error**=0.32551		**F(2,48)=** 165.208		Sig.**F**, **Sig.=0.000**[b]	
Model	Unstandardized coefficients		Standardized coefficients	**t**	Sig. **t** **Sig.**	**Part**
	B	Std. Error	**Beta**			
Constant	2.490	.046		53.880	0.000	
UDAM	0.856	.062	0.942	13.887	0.000	0.714
MIPRQUTEU3	0.011	.062	0.012	0.178	0.859	0.009

if teachers use the tools frequently; expectations vs. reality: if teachers expect more from tools than they actually provide - their perception of usefulness may be diminished; contextual factors: specific school conditions, such as infrastructure or peer support can influence perceptions - not just tool use; different definitions of usefulness: the perception of usefulness can differ significantly among teachers - depending on their individual goals and approaches to learning; relationship with students: frequency of use may be high, but if teachers do not see improvements in student engagement or achievement - their perception of usefulness may remain low. These factors indicate the complexity of the relationship between the use of tools and the perception of their usefulness, which makes it difficult to establish a statistically significant relationship. To improve teachers' perceptions of ICT's usefulness in education, the following strategies could be implemented: organize regular trainings and workshops focused on the use of different ICT tools and platforms for conducting e-Learning; share inspiring examples and case studies from colleagues who have successfully integrated ICT into teaching - with a presentation of the results; implement pilot projects in which teachers will be able to test new tools and methodologies; ensure the availability of technical support to help teachers solve problems when using the tools; collect feedback from teachers - about their experiences with ICT and use it for further improvements; help teachers see how ICT can directly support their educational goals and curriculum; implement monitoring and reporting on the results of the application of ICT in teaching - in order to demonstrate the positive impact on learning and student engagement; and create a reward system for teachers who successfully integrate ICT in their teaching.

7.5.4 The relationship between the scope of the used possibilities of the e-Learning platform and the perception of the efficiency and usefulness of individual resources and software tools

The standard multiple regression analysis showed that the adjusted $R^2 = 0.276$, with a standard error of the estimate of 0.5556, indicating that the model explains only 27.6% of the variance in the range of utilized platform capabilities. The model reached statistical significance with $F(1,49) = 20.024$, Sig = 0.000, at a significance level of $p = 0.05$. The contribution of the independent variable: motivation, interactive presentations and quizzes and the teacher's perception of the usefulness of the platform (MIPRQUTEU3), in the prediction of the results of the measurement of the dependent variable, the range of used possibilities of the platform, measured by the function F(D4), is Beta=-0.539. The unique contribution amounts to (Part=-0.539) (t=-4.475, Sig.=0.000) (Table 5).

Based on the results of the standard regression analysis, we can conclude that the scope of the utilized e-teaching platform's capabilities is not adequately explained by the teacher's perception of the efficiency and usefulness of individual resources and software tools, as only 27.6% of the variance can be explained. Furthermore, it has not been established that an increase in teachers' perception of the efficiency and usefulness of certain resources and software tools used in e-teaching also leads to an increase in the range of utilized possibilities of the e-teaching platform. Therefore, the auxiliary hypothesis AH4 should be rejected. Several factors may influence or alter teachers' perceptions of the e-Learning platform's effectiveness and usefulness, thereby affecting the extent of its utilization in the educational process. These factors include: lack of administrative support (insufficient backing from the school administration may lead to a lack of essential resources such as time, training, or financial support for implementing and maintaining the platform), infrastructure and technological resources (inadequate infrastructure, such as a slow internet connection or limited access to computers or tablets, may hinder teachers' ability to fully utilize the e-Learning platform), and resistance to change (some teachers may resist new technologies, which slows down or prevents full integration of the e-Learning.

platform into their work). In addition, each teacher may have different needs in terms of e-teaching based on the subject, the age of the students, or the specific pedagogical methods they prefer, all of which can influence their perception and use of the platform. Enhancing teachers' perception of the efficiency and usefulness of certain resources and software tools in e-teaching can significantly expand the range of possibilities available on the e-teaching platform. In this

Table 5 - Correlation of the scope of used platform capabilities with the perception of efficiency and usefulness of individual resources and software tools.

R=0.539	**Adjusted R^2**=0.276, **St.error**=0.5556		**F(1,49)=** 20.024		**Sig.F, Sig.=0.000**[b]	
Model	Unstandardized coefficients		Standardized coefficients	**t**	Sig. **t** **Sig.**	**Part**
	B	Std. Error	**Beta**			
Constant	2.297	0.078		29.333	0.000	
MIPRQUTEU3	-0.354	0.079	-0.539	-4.475	0.000	-0.539

case, the previously described strategies, including teacher education, support, resources, demonstration of success, motivational programs, evaluation, and continuous support, are also applicable.

7.5.5 The need for additional education of teachers in the domain of modern ICT - as a result of the relationship between real and perceived IT knowledge, the intensity of the use of software tools and the extent of the platform's capabilities

Standard multiple regression shows that the adjusted value of the coefficient of determination, Adjusted R^2 = 0.399, and the standard error of the estimate, St. error = 0.37077, indicate that the model explains 39.9% of the variance in the need for additional education of teachers in the domain of modern ICT, F(D6). The model reached statistical significance: F(3,47) = 12.087, Sig = 0.000 at a significance level of p = 0.05. The contribution of the independent variable, the extent of the platform's possibilities used in e-teaching, as evaluated by the regression factor (SUPP2), in predicting the results of the measurement of the dependent variable - the need for additional education of teachers in the field of modern ICT, expressed by the function F(D2) - is Beta = 0.443. The unique contribution is (Part = 0.362) or 36.2%, and it is statistically significant (t = 3.299, Sig. = 0.002) at a significance level of p = 0.05 (Table 6). The contribution of the independent variable—real and perceived IT knowledge of teachers (INF.KNOWLEDGE) - was Beta = 0.176, t = 0.828, Sig. = 0.412, while the contribution of the independent variable—frequency and intensity of use of software tools (FR.ENSCIED) - was Beta = 0.137, t = 0.607, Sig. = 0.546, and neither was statistically significant.

Based on the results of the standard multiple regression and the statistical significance of the independent variables (SUPP2, INF.KNOWLEDGE, and FR.ENSCIED), we obtained the regression equation for assessing the need for additional teacher education in the field of ICT.

Although the need for additional education of teachers in the field of ICT is not sufficiently explained by the range of used platform possibilities (36.2%), the perceived and real IT knowledge of teachers (9%), or the frequency and intensity of use of software tools (6%), we can nevertheless conclude that the model indicates a need for additional teacher education in the application of ICT in e-teaching, thereby validating auxiliary hypothesis AH5. The obtained result is, to a certain extent, a reflection of the lack of adapted training, limited resources, an unfavorable learning environment, lack of continuous and individualized support, and teachers' resistance to change. These obstacles can contribute to the fact that the need for additional education of teachers in the field of ICT is not sufficiently recognized and addressed, despite their perceived and actual IT knowledge and frequency of using software tools. Understanding these barriers is crucial for developing strategies to improve teacher education in ICT and to encourage the successful integration of technology into teaching. With today's technological growth, instructors must learn to utilize various gadgets, such as smartphones and tablet computers, or face marginalization (Haleem, 2022). Adopting a strategy for the professional development of teachers is necessary. Technological progress in the digital sphere is rapid and continuous. New software tools and educational platforms are being developed and improved, and teachers must be trained to use them in order to keep up with these changes. Traditional forms of teaching are often not effective or attractive enough for modern students. E-environments offer a variety of teaching methods that can better suit different learning styles and the needs of students. The use of modern software tools and educational platforms enables greater interactivity and engagement of students in classes. This will result in better learning outcomes and greater motivation to learn. Educational institutions around the world are increasingly recognizing the importance of digital transformation in education. The e-environment

Table 6 - Correlation between the need for additional education of teachers in the domain of modern ICT – F(D6) and the real and perceived IT knowledge of teachers (INF.KNOWLEDGE), the frequency and intensity of the use of software tools (FR.ENSCIED) and the range of used platform capabilities (SUPP2).

R=0.660	**Adjusted R^2**=0.399 **St.error**=0.37078		**F(3,47)=** 12.087		**Sig.F, Sig.=0.000**[b]		**Tolerance**	**VIF**
Model	Unstandardized coefficients		Standardized coefficients	**t**	**Sig. t**	**Part**		
	B	**Std. Error**	**Beta**					
Constant	2.690	0.052		51.804	0.000			
INF.KNOWLEDGE	0.084	0.102	0.176	0.828	0.412	0.091	0.265	3.773
FR.ENSCIED	0.065	0.108	0.137	0.607	0.546	0.067	0.237	4.215
SUPP2	0.212	0.064	0.443	3.299	0.002	0.362	0.667	1.499

enables greater flexibility in the organization of teaching, which can be especially important in situations such as pandemics or other unforeseen events that may affect the regular teaching process. Well-trained teachers in the use of technology have a positive impact on learning outcomes and student motivation. These reasons indicate the need for a systemic approach to introducing professional development strategies for teachers to ensure that educational institutions and teaching processes are prepared for the modern challenges and opportunities provided by technology.

8. Conclusion

The research demonstrated that modernizing the teaching programs alone is insufficient; the didactic and methodological approaches in teaching must also evolve, as student perception demands an interactive and multimedia approach in education. Teachers play a central role in the implementation of information and communication technologies in e-Learning. It has been observed that there is an unsystematic approach to creating educational materials, as well as arbitrary and intuitive use of the functionalities of the e-Learning system by teachers, leading to significant variations in the quality of e-teaching for the same subjects. The new teaching methodology for the online educational process should involve standardized digital educational materials and well-prepared teaching strategies that utilize the various possibilities offered by e-Learning platforms. It is recommended that digital educational materials be developed by instructional designers in collaboration with teachers, using content authoring tools. The study also established that innovative methods recommended in e-teaching include the use of interactive multimedia presentations, educational games, and competitive quizzes, which teachers should implement through software tools. Therefore, teachers need to be proficient in using these tools. Today's students perceive e-teaching as a mode of education where they enjoy teamwork, the connection of teaching content with topics of interest to them, and they expect quick feedback on their progress and immediate responses to their questions. Consequently, these forms of teaching should be integrated into e-Learning by skillfully utilizing the appropriate functionalities of the learning management platform or through separate software tools. However, teachers must be adequately prepared to achieve this goal. The research further revealed that collaboration among teachers on the platform can be beneficial. Significant differences in teachers' digital competencies highlight the need for systematic and continuous improvement of these skills to ensure that their e-teaching is of high quality, motivating, and engaging for students. The acceptance of e-teaching is also closely related to teachers' motivation. The study underscored the necessity of formally recognizing the work and efforts of teachers in online teaching by defining appropriate standards and quality indicators. In this paper an inductive method was employed to prove the main hypothesis, by individually examining the auxiliary hypotheses. After an extensive analysis of the obtained research results, it was concluded that there is interactivity, which can be expressed qualitatively and quantitatively, between teachers who use modern ICT to support teaching in secondary education and e-Learning systems, thereby confirming the main hypothesis of the study.

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Attitude of Russian pre-service teachers in different training fields towards Artificial Intelligence

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Abstract

In recent years, artificial intelligence (AI) has been rapidly developing, and the issues concerning the use and implementation of AI in education and science are becoming increasingly relevant. Meanwhile, the effectiveness of introduction of digital technologies, including AI, into education largely depends on digital competence, the level of knowledge in this area, as well as the attitude of educators towards these technologies. In this regard the aim of the study was to identify the peculiarities of the attitude of students–pre-service teachers in different training fields towards artificial intelligence and their experience of its use in education. The study involved 249 bachelor students in Teacher education of Kazan (Volga Region) Federal University. The study showed that, in general, students show interest in the use of digital tools for both educational and personal purposes. In teaching practice, about 40% of students have experience in using AI at the stage of planning and constructing lessons. Students from different training fields identify the benefits of using AI in different areas of education and set different goals for the use of AI in lessons design. At the same time, pre-service teachers critically assess the possibilities of AI and more than 80% of them point out possible risks in the use of AI in education. About 60% of the respondents agree on the need to adapt to changes brought on by AI. The results of the study can be used in designing the students' curricula and planning their learning process using digital tools, including AI.

KEYWORDS: Artificial Intelligence (AI), Digital Tools, Digital Technologies, Students, Pre-Service Teachers, Higher Education.

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1. Introduction

Due to the rapid development of artificial intelligence technology and its active implementation in all spheres of human life, issues related to the use of AI in teaching, learning and research are becoming more and more relevant. Society needs highly qualified specialists who are able to meet the challenges of the modern world and effectively apply various high-tech solutions, including AI-based tools, in their activities. Consequently, the task of higher education is to train such kind of specialists, and this is no exception for higher education institutions engaged in training future teachers.

The integration of AI technologies has had a significant impact on the education system in recent years. Applications and services based on AI are actively used in teaching and learning processes due to a number of advantages they provide. For example, these technologies can be used by educators as an assistant for preparing teaching materials and learning simulators that can help students better understand and remember new material; as virtual assistant counsellors that can

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provide answers to typical student questions (Shirobokova, 2024). AI is used to personalize the learning process, adaptive testing and increase student engagement (Kumar et al, 2023). AI-powered tools have been shown to improve student engagement and academic performance, with some studies reporting a 15% increase in average test scores (Cerón Silva et al., 2025). In addition, AI technologies can help to increase manageability of educational processes and reduce the workload of teachers by reducing routine tasks (Liu & Baucham, 2023; Karan & Angadi, 2023). AI-based digital resources and tools also greatly facilitate research work by increasing efficiency and accuracy, simplifying various tasks, providing deeper analyses, and facilitating interdisciplinary collaboration (Lund et al, 2023; Alaa, 2024; Landis, 2023). Such technologies not only save time but also improve the quality of research results.

However, many serious concerns arise related to intellectual property, data privacy, ethical considerations, plagiarism, transparency, factual accuracy, potential bias, and equal access to resources (Li et al., 2022; Rudolph et al., 2023; Kasneci et al., 2023). The use of generative AI in education raises pressing questions about learning paradigms, pedagogy, authorship, and more (Williamson et al., 2023; Zembylas, 2023). Many scientists emphasize the importance of investigation of the issues related to AI technology implementation in education, possible risks of using AI and chatbots in learning, teaching and research (Alexeeva & Pronichkina, 2023; Dempere et al., 2023; Sarin & Kimkong, 2023; Delello et al., 2025). Regardless, it should be admitted that AI has become an integral part of education and teachers need to learn how to interact with it. Meanwhile, research works show that the successful introduction of new technologies into the teaching process depends largely on teachers' own attitudes towards these technologies (Kim & Kim, 2022; Sasota et al., 2021). Teachers should be well-prepared for the changes in the education caused by the introduction of AI into it, therefore it's quite important to assess future teachers' experience and attitudes towards AI. There is also a need for a better understanding of the factors that shape pre-service teachers' attitudes towards AI, their perceptions of its usefulness and the difficulties they face in using it (Strzelecki, 2024).

Despite the fact that recently there have been many studies devoted to the topic of AI in education, which indicates the growing interest in this problem, the issues of how it is perceived and used by students – pre-service teachers remain understudied. There is also a gap in studying and comparing the experiences and attitudes of education students depending on the direction of their training. This topic is important and relevant because understanding how students interact with AI tools is crucial for their effective use in educational contexts. In this regard, the purpose of our study was to identify the peculiarities of the attitude of students – pre-service teachers of different training fields to AI and their experience of its use in education.

In this respect, we formulated the following research questions: 1) What are the main opportunities of AI that students – pre-service teachers use for personal and professional purposes? 2) What difficulties they face when using AI? 3) What aspects most of all affect the use of AI-based tools by students of different training fields for further effective implementation in the educational process and application in the professional sphere (teaching and research practice).

2. Materials and methods

2.1 Research Methods and Techniques

A set of complementary methods was used in the implemented research: analysis of psychological and pedagogical literature, generalization; a confirmatory experiment, questionnaire method and methods of statistical data processing.

The questionnaire was developed by the research group in the ISATT online study "Exploring the Impact of Artificial Intelligence on Teacher Education" using the online service Google forms. The questionnaire consisted of 5 sections including questions of socio-demographic nature (gender, age, training profile, year of study), assessing the attitude of students – pre-service teachers to AI and the experience of its use during teaching practice or in teaching activities, as well as in everyday use for personal purposes, opportunities and risks of using AI in education. The questionnaire used closed, semi-open and open-ended questions, evaluation scales.

2.2 Experimental base of the study

The study was conducted on the basis of Kazan (Volga Region) Federal University in April-July 2024. The sample of the experiment involved 249 bachelor students in Teacher education studying at the Institute of Psychology and Education, the N.I. Lobachevsky Institute of Mathematics and Mechanics and the Institute of Philology and Intercultural Communication.

Participation in this survey was free and voluntary, the survey was conducted during the educational process.

Basic statistics (mean and standard deviation, percentages) were calculated for all subgroups of respondents participating in the survey. For the studied indicators, the acceptable level of significance was set at the level of $P \leq 0.05$ when identifying differences in the responses of students studying in different training fields using the Kruskal-Wallis test and χ^2 - criterion. Statistical processing was carried out using IBM SPSS Statistics version 23.

3. Results

3.1 Sample Characteristics

249 bachelor students took part in the online survey, among them 106 people (42.6%) were pre-service primary school teachers (training field: Primary education), 55 people (22.1%) were pre-service teachers of Russian language and literature (training field: Russian language and literature), 46 people (18.5%) were pre-service teachers of English language (training field: Supplementary education and English language) and 42 respondents (16.8%) were future teachers of mathematics and computer science (training field: Mathematics, computer science and information technology). Generalized socio-demographic indicators are presented in Table 1.

Based on Table 1, it can be identified that the majority of respondents are female between 19 and 23 years old, they are mainly in their 3rd year of study.

3.2 Attitudes and experiences of using digital tools in education

The study revealed that the students have received digital technology training/courses for teachers of various lengths, both in their free time and at university (Table 2).

As it can be seen from Table 2, students – pre-service teachers of primary school and English language (more than half of the numerical composition of these training fields) most often attend the longest training courses in digital technologies. More than 2/3 of them are getting the second specialty in IT and digital competences at the university within the framework of the project 'Digital Departments' with receiving a professional retraining diploma with the qualification 'Programmer'. Less than a third part of students in Russian language and literature, Mathematics, computer science and information technologies take courses in digital technologies, about 60% of which choose courses on their own.

Table 1 - Generalized socio-demographic characteristics of respondents.

Training field of students	Gender		Age		Year of study		
	female	male	mean	standard deviation	2	3	4
Russian language and literature	53 (96,4%)	2 (3,6%)	21,3	1,26	0 (0%)	31 (56,4%)	24 (43,6%)
Mathematics, computer science and information technologies	38 (90,5%)	4 (9,5%)	20,4	0,67	4 (9,5%)	38 (90,5%)	0 (0%)
Primary education	106 (100%)	0 (0%)	19,9	0,88	46 (43,4%)	60 (56,6%)	0 (0%)
Supplementary education and English language	46 (100%)	0 (0%)	20,4	1,3	12 (26,1%)	19 (41,3%)	15 (32,6%)

Table 2 - Completion of digital technology teacher training/courses by students (in %).

Training field of students	Course attendance*	Course duration	Course delivery mode		Confirmation documents			
			in free time	at university	Attestation	Certificate	Diploma	Not available
Russian language and literature	12,7	from 1 to 2 weeks	58,2	41,8	5,5	12,7	3,6	78,2
Mathematics, computer science and information technologies	28,6	from 1 week to 1 year	66,7	33,3	9,5	4,8	4,8	80,9
Primary education	57,5	from 9 weeks to 9 months	20,8	79,2	9,4	15,1	42,5	33
Supplementary education and English language	50	from 5 weeks to 9 months	30,4	69,6	8,7	2,2	30,4	58,7

Note: *differences at a high level of statistical significance (χ^2=32.330, at p<0.0001).

It was found that pre-service teachers are interested in using digital tools both for educational and personal purposes (Table 3). At the same time, the most expressed interest on a 5-point scale is shown for educational purposes, pre-service teachers of primary school and Russian language and literature have it to the greatest extent.

Table 3 - Assessment of students' interest in digital tools.

Training field of students	Interest in digital tools			
	personal purposes		educational purposes	
	mean	standard deviation	mean	standard deviation
Russian language and literature	3,87	1,03	4,21	0,89
Mathematics, computer science and information technologies	3,85	1,03	3,95	0,94
Primary education	4,0	0,88	4,2	0,88
Supplementary education and English language	3,8	0,91	4,0	0,82

Among the main digital tools used in personal life and education future teachers identified various text and graphics programs, including Microsoft products, AI-based services and neural network tools (ChatGpt, chatbots, Pinterest, Quizizz AI etc.), social networks, educational platforms, services for creating and editing educational and scientific material. AI and neural network tools are most often used by students – mathematicians (61.9%) and pre-service teachers of English language (56.5%), the least often they are used by students receiving philological (38.2%) and primary school teacher (14.2%) education. It is important to note that in addition to traditional AI services, students use tools related to their specialization. The most frequent use of social media in everyday life is by future teachers of English and primary education (39.1% and 31.1% respectively).

3.3 Everyday use of AI in personal life

According to the survey results we received the largest number of "no" answers to the question "Do you know what generative AI is?" from students studying in Russian language and literature and Primary education training fields (41.8% and 40.6% respectively), "yes" answers were more often noted by pre-service teachers of Mathematics and computer science (38.1%) and English language (39.1%). The highest percentage of unsure answers was demonstrated by students in Russian language and literature (40%).

According to the students' opinion, the following keywords are associated with AI, based on the dominant positions for each group of respondents: quickness and speed, technology, future, science, development and progress (training field: Primary education); quickness and speed, modern digital technologies, algorithm and program (training field: Russian language and literature); intelligence, future, development and progress, neural network (training field: Supplementary education and English language); neural network, intelligence, assistant (training field: Mathematics, computer science and information technologies).

Over the last 6 months, more than 70% of students expressed interest and desire to deepen their knowledge in this area, for this purpose, about 20% of respondents preferred to learn AI technologies on their own and only about 5% took a training course at the educational organization.

The majority of pre-service teachers positively assess the expediency of using AI both in everyday life and in education. According to the students, such expediency is especially significant in the sphere of education for the implementation of the educational process including research work of teachers and students. Interestingly, the largest number of students who expressed this judgment was found among mathematicians (71.4%), and the lowest number of votes among future teachers of Russian language (47.3%) (Table 4).

Table 4 - Students' assessment of the expediency of using AI (in %).

Training field of students	Using of AI in all spheres of life*	Using of AI in education**
Russian language and literature	40	47,3
Mathematics, computer science and information technologies	61,9	71,4
Primary education	61,3	53,8
Supplementary education and English language	47,8	50

Note: *differences ($\chi2$=20,331, at p=0,016);
** differences ($\chi2$=21,743, at p=0,01).

Despite the experience of using AI, the frequency of using the technology among students is rather low. For example, about 40% of respondents practiced AI only 'sometimes' when translating foreign texts, creating presentations, videos and images. Students also have experience in generating texts, searching for educational and scientific information when preparing reports, projects and writing term papers. In everyday life, students use AI to maintain a personal blog, find ideas for cooking dinner, for entertainment and leisure activities, and find answers to questions.

It was found that more than a half of the students are aware of AI capabilities and use it more often as a work tool (as we see in Table 5).

Table 5 - Areas in which students use AI (in %).

	Areas of students' use of AI			
Training field of students	**As a work tool**	**For leisure activities**	**As a game, leisure and work tool**	**Don't use**
Russian language and literature	54,5	7,3	25,5	12,7
Mathematics, computer science and information technologies	66,7	9,5	19	4,8
Primary education	66,9	5,8	16,9	10,4
Supplementary education and English language	60,8	0	19,6	19,6

Among the main advantages of using AI technologies in pedagogical activity, the majority of respondents (about 70%) unanimously noted: high speed of work performance, time saving, convenience, simplicity and accessibility in use, multifunctionality. Among other things, students – mathematicians also highlighted the possibility of generating tasks of different levels of complexity, students – Russian philologists emphasized the possibilities of high-quality visualization of educational material and improving the quality of learning, increasing free time for teachers; students – future teachers of English emphasized the uniqueness of generated texts and reducing the burden on the teacher (data collection, verification and control); primary education students identified opportunities for generating creative ideas and original tasks, structuring large amounts of information, and increasing children's interest to the learning process.

3.4 AI and teaching

Based on the pedagogical experience, obtained primarily during the pedagogical practice, in lesson design about 40% of students – pre-service teachers of primary school, Russian and English languages sometimes use AI in the planning and in the strictly instructive phases, while only about 13% of students demonstrate the use of AI in the evaluation phase. A distinctive picture is observed in terms of the frequency of AI use in the strictly instructive phase among the Mathematics, computer science and information technologies students. Thus, 66.7% of them in their primary experience of pedagogical activity often apply AI in all stages of lesson design, including the evaluation stage (Table 6).

In pedagogical practice, students in lesson planning had trial experience of using AI mainly for preparing teaching materials (34.8% – Supplementary education and English language, 37.7% – Primary education), for lesson design (30.9% – Russian language and literature) and frequent use to deepen their knowledge (23.8% – Mathematics, computer science and information technologies).

According to pre-service teachers, in the course of designing a lesson with the help of AI, special attention should be paid to the searching ideas for developing a lesson scenario, to the stage of motivating students to activeness at the lesson, generation of the learning content (preparing educational texts, didactic material, tasks and games with the help of image, video and sound generation), to the stage of control and evaluation of learning achievements.

Table 6 - Evaluation of the frequency of students' use of AI for lesson design (in %).

Training field of students	**Use of AI for lesson design**					
	in the planning phase*		**in the strictly instructive phase****		**in the evaluation phase*****	
	sometimes	**frequently**	**sometimes**	**frequently**	**sometimes**	**frequently**
Russian language and literature	12,7	12,7	21,8	12,7	10,9	9,1
Mathematics, computer science and information technologies	19	23,8	14,3	23,8	4,8	19
Primary education	27,4	9,4	20,8	23,6	17,9	7,5
Supplementary education and English language	28,3	6,5	26,1	10,9	10,9	6,5

Note: *differences (χ^2=26,082, at p=0,002); **differences (χ^2=28,844, at p=0,001); ***differences (χ^2=21,450, at p=0,011).

About 40% of Russian language and primary education students believe that the possible advantage of using AI is achieved in teaching science disciplines, 34.8% of future teachers of English language are confident in the potential advantage of humanities disciplines. Among mathematics and computer science students, the opinions were equally divided between humanities, natural sciences and other scientific disciplines.

In addition, students of different training fields identified different most likely benefits from AI also in administration (52.4% – Mathematics, computer science and information technologies and 60% – Russian language and literature), schooling management (44.3% – Primary education and 38.2% – Russian language and literature) and in housekeeping for ancillary tasks (47.8% – Supplementary education and English language and 45.3% - Primary education). The obtained differences were confirmed at a high level of statistical significance ($\chi2=34.116$, at $p=0.001$; $\chi2=29.669$, at $p=0.003$; $\chi2=26.316$, at $p=0.010$ in the corresponding areas).

The wide opportunities for the use of AI in different areas of education are related, according to respondents, to the simplification of reporting, automation of control over educational processes, and the possibilities for analyzing of big data.

3.5 Critical analysis

Students unanimously consider it necessary to develop the use of AI in education (average score 3.9 on a 5-point scale) in connection with time saving, convenience and simplification of solving multifunctional educational tasks, increasing students' interest in learning activities and involvement of students and teachers into the educational process, improving the quality of learning material, automatization of routine tasks and reducing the load on teachers and students. In general, according to the respondents' perceptions, AI acts as an assistant for teachers and students. In addition, future English language and primary school teachers emphasize the prospect of effective educational development thanks to AI.

However, in terms of students' confidence in AI, the results are lower and are unanimously on average only 2.96 points on average with a standard deviation equal to 0.97 on a 5-point scale. Future pedagogues critically assess the possibilities of AI and note possible risks in the use of AI in education (Table 7).

As can be seen from Table 7, the greatest number of agreements in assessing the presence of risks in the use of AI was given by students in Supplementary education and English language (91.3%), and the least by students in Mathematics, computer science and information technologies (76.2%).

Among these risks, future educators identified the following hierarchy: unreliability of information and the need to double-check it, plagiarism, access to personal data, lack of human interaction, decrease in intellectual abilities and critical thinking of learners, degradation of human society and the sense of insecurity and fear that things may be out of human control.

Nevertheless, about 60% of the respondents agree with the need to adapt to AI (Table 8) due to the digitalization of society (84.5% of the total number of respondents) and modern educational requirements (60.2% of students).

Table 7 - Assessment of risks from using AI (in %).

Training field of students	Risks of using AI		
	Yes	Maybe	No
Russian language and literature	16,4	65,5	18,1
Mathematics, computer science and information technologies	38,1	38,1	23,8
Primary education	29,2	56,6	14,2
Supplementary education and English language	30,4	60,9	8,7

Table 8 - Assessment of students' need to adapt to AI (in %).

Training field of students	Need to adapt to AI		
	Yes	Maybe	No
Russian language and literature	14,5	49,1	36,4
Mathematics, computer science and information technologies	4,8	52,4	42,8
Primary education	13,2	42,5	44,3
Supplementary education and English language	17,4	34,8	47,8

4. Discussion and Conclusions

Students' attitudes towards artificial intelligence vary across different educational fields and countries. Studies show that in different countries the attitude towards AI among students varies significantly depending on such factors as gender (Samreen & Hasan, 2023; Kim & Lee, 2023), level of education (Khater et al., 2023; Hajam & Gahir, 2024), specialty (Almaraz-López et al., 2023; Lavidas et al., 2024) and time spent on its study (Alzahrani, 2023). For example, Spanish students in economics and business management are willing to enhance their AI education but lack sufficient training (Almaraz-López et al., 2023). Medical students in Egypt and Kazakhstan demonstrate from moderate to good knowledge and positive attitudes towards AI, emphasizing the need for AI integration in medical curricula (Khater et al., 2023; Cruz et al., 2023). Dental students also show optimism towards AI advancements in dentistry, with a majority agreeing on its potential benefits and the importance of AI education in their studies (Karan-Romero et al., 2023). Overall, students across different disciplines recognize the significance of AI in their future professions and express a willingness to learn more about its applications. Our study also showed that pre-service teachers are interested in the use of digital tools in general; this is the most typical for students studying in the fields of Primary education and Russian language and literature.

Students' attitudes toward AI are determined, among other things, by the level of training and expected effectiveness of artificial intelligence for professional activities (Przybyła-Kasperek et al., 2023; Kim & Lee, 2023; Hajam & Gahir, 2024; Strzelecki, 2024). Understanding these elements is crucial to develop a positive attitude towards artificial intelligence in students.

According to our study, in the conditions of digitalization of education, about 40% of students – pre-service teachers are interested in acquiring additional digital competencies. The key motivator of students' learning is the administration of the institutes, which contributes to the creation of favorable conditions for taking courses in digital technologies at the university.

In their personal and professional lives, students use various digital resources, including both traditional AI-based services and neural network tools, so as related to their specialization. It is important to note that, despite the interest in use of digital technologies for the organization and implementation of the educational process and research work, pre-service teachers of primary school and Russian language use AI tools in their practice less often (about a quarter of respondents) compared to future teachers of mathematics and computer science and English language (about 60%). Moreover, the level of knowledge in the field of generative AI is lower among the Primary education and Russian language and literature students than among the Mathematics and computer science and English language students. Przybyła-Kasperek et al. (2023) in their study obtained similar results, finding that computer science students are more aware of the possibilities and applications that AI brings than education students.

At the same time, students' attitudes towards AI tools and their assessment of their feasibility in education differ from their previous assessments regarding the use of other digital technologies, with Mathematics and computer science students being among the most interested ones. Although according to the study of Kim & Lee (2023) students with high interest toward AI or experience with block- and text-based programming languages showed significantly positive attitudes toward AI. Meanwhile, a study by Lavidas et al. (2024) shows that the key factors influencing humanities and social science students' intentions to use these technologies for academic purposes are performance expectancy, habit and enjoyment of using AI applications. In our view, this may be due to the fact that despite the strong breakthrough of AI-based digital assistants in recent years, AI technologies are adopting in education much slower than in other fields, and the digital skills of unrelated educators are not sufficiently developed yet.

In this regard, over the last 6 months, more than 70% of pre-service teachers expressed interest in deepening their knowledge in this area, emphasizing the importance of effective and responsible use of AI technology in their future careers. At the same time, less than 20% of respondents tried to realize their intentions by learning new technology independently or in an educational organization. We believe that the situation of difficulty in realizing the students' intention to study AI applied in education is due to the insufficient number of developed special courses.

The results of the survey showed that students are aware of the possibilities of AI and use it sometimes as a work tool to create presentations, videos and images, generate texts, translate foreign texts, search for educational or scientific information in preparation for classes or research work. Students have an intention to use various functions of AI in pedagogical practice and further professional activity for effective implementation of educational process, namely: generation of visuals and educational material of various content, educational videos, tests, quizzes, text tasks of different levels of complexity, interactive tasks and games for lessons, lessons design, preparation of lesson plans and notes, scenarios of educational events, automation of routine tasks (checking homework, creating and checking tests), etc.

Among the main possibilities of AI in pedagogical activity were named: high speed of work performance, time saving, convenience, simplicity and accessibility in use, multifunctionality. Special emphasis was also made by students of different training fields on such advantages as generation of tasks of different complexity level, creative ideas and original assignments, improvement of the quality of learning process and involvement of students and teachers into the educational process, reduction of the workload on the teacher and student. The obtained results of our study partially confirm the previously published data on the benefits of using AI (Shirobokova, 2024; Kumar et al, 2023; Liu & Baucham, 2023; Karan & Angadi, 2023).

However, new interesting facts were also revealed. During the teaching practicum, students gained experience in using AI in the planning and development of lesson content, while mathematics and computer science students also practiced it in the evaluation phase. It was found that students of different training fields identify the advantages of using AI in different areas of education, for different academic disciplines and set different goals for the use of AI in lesson planning.

For future teachers, AI tools act primarily as assistants for effective organization of the educational process. Unfortunately, future teachers are not focused on using AI services in research activities. In our opinion, a cardinal change of the situation is possible with the increase of digital competencies of faculty and students, expansion of the arsenal of digital tools based on AI for the implementation of research work by students and adjustment of the content of practice for obtaining primary skills of research work taking into account the identified risks.

According to a study by Hajam & Gahir (2024) science students tend to have more positive attitudes toward artificial intelligence than their peers in the arts and commerce. According to the results of our study, AI and neural network tools are most often used by math and computer science students and least often by philology students, which also indicates a more positive attitude of the former. The data obtained by Kim & Lee (2023) indicating a direct correlation between interest toward AI and positive attitudes toward AI was partially confirmed in this study.

The work also revealed an interesting pattern: the higher the interest of students in the application of AI technology in education and the more experience in using it in practice, the lower the risk assessment of AI application. These results correlate with the data obtained by Przybyła-Kasperek et al. (2023), according to which the more experience and knowledge students have regarding AI, the less concerns and fears they have about AI development. In general, students – pre-service teachers unanimously consider it necessary to develop the use of AI in education and, if necessary, to adapt to AI in connection with the digitalization of society and modern educational requirements.

The findings can become the basis for further research and discussions on the role of AI in education and research work, as well as for the development of strategies for effective integration of these technologies into the educational process, taking into account the changing needs and expectations of students and teachers, as well as the specifics of the pre-service teachers' training fields.

Nevertheless, our study has a number of limitations. The limited number of participants does not allow us to generalize the results to a broader context, but our study can be a basis for future research. The study has opened interesting perspectives on approaches to educational content management in the training of future educators of different training fields using AI-based digital technologies. However, this study is only the beginning and future in-depth studies are needed, especially regarding different factors influencing the effectiveness of teacher training, especially in the direction of research work in the context of digitalization of education. Of particular interest is a comparative analysis of attitudes towards the use of AI and successful experiences of its use among pre-service and in-service teachers. Finally, it would be useful to conduct international studies to find out whether pre-service and in-service teachers from different cultures have different views on the use of digital technologies and AI services in education.

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