

**Proceedings of the
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ON VIRTUAL LEARNING – ICVL 2023**

**VIRTUAL LEARNING – VIRTUAL REALITY
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EDITORS

**Carmen Elena CÎRNU • Grigore ALBEANU • Natalia BURLACU
Ella Magdalena CIUPERCĂ • Carmen HOLOTESCU
Radu JUGUREANU • Paloma PETRESCU • Dorin Mircea POPOVICI**

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ICVL 2023, 18th Edition**

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Section 1

Technologies & Virtual Laboratory

Training of higher-order thinking skills using ChatGPT

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Abstract: *The paper presents an approach for training and assessing higher-order thinking skills using Bloom's Taxonomy. The capabilities of ChatGPT for creating assignments aimed at forming and evaluating specific types of cognitive skills, namely – analysis, synthesis, and evaluation have been experimented. The experiment focuses on training in graph databases, but the approach can be successfully used in training other disciplines.*

Keywords: Higher order thinking skills, HOTS, Bloom's Taxonomy, ChatGPT.

1. Introduction

Modern education should prepare learners to cope with the rapidly changing and complex world we live in. It is a world of new technologies, artificial intelligence, and increasingly more straightforward access to knowledge, but also a world of wars, financial and health crises. More and more futurists believe that in the next 10 years, many professions will disappear, and today's pupils will work in professions that don't yet exist. The need to stimulate creativity and innovation, actively and informedly advocate for civic positions to uphold democracy, and the ability to learn autonomously throughout one's life – all of these require creative, reasonable, and innovative thinking.

Higher-Order Thinking (HOT) can be defined as a non-algorithmic, complex way of thinking which often leads to finding multiple solutions to a problem (Barak & Dori, 2009). Higher-Order Thinking Skills (HOTS) are usually associated with critical, logical, reflective, metacognitive, and creative thinking. Many scientists categorize these types of skills into 3 categories: transfer of knowledge and skills, critical thinking, and problem solving (Brookhart, 2010).

HOTS cannot be taught to learners directly. They can be acquired through a variety of educational activities that are student-centered and involve the active participation of learners. There are many models and strategies suitable for HOTS training – problem-based learning, project-based learning, discovery learning,

problem solving, and more. Suitable activities for improving these types of skills are also group discussions, solving cases and complex interdisciplinary tasks, etc.

Over the past year, artificial intelligence tools have been increasingly used in education. The AI chatbot ChatGPT, developed by OpenAI, is particularly relevant. It can conduct conversations, answer questions, create literary works, and explain concepts and ideas. Pedagogical specialists are interested in the potential for its use in the preparation and conduct of the educational process. Naturally, the question arises whether ChatGPT can assist in the creation of educational materials that foster higher-order thinking skills.

The current paper presents an approach for training and evaluating HOTS using the knowledge metric of Bloom's Taxonomy. The capabilities of ChatGPT have been experimented with for creating assignments aimed at assessing specific types of cognitive skills. The experiment focuses on training in graph databases, but the approach can also be successfully applied to education in other disciplines.

2. Bloom's Taxonomy. Higher-Order Thinking Skills

Numerous taxonomies are described in the scientific literature, that propose various approaches to classifying and categorizing the knowledge and skills that learners need to acquire during the educational process. Examples include Bloom's Taxonomy (Bloom et al., 1956), SOLO Taxonomy (Biggs & Collis, 1982), Fink's Taxonomy (Fink, 2003), and Webb's Depth of Knowledge (Hess, 2013), etc. Bloom's Taxonomy is one of the most popular taxonomies used by pedagogical specialists to define learning objectives. It defines a hierarchy of thinking skills, in which the higher levels of thinking encompass all cognitive skills from the lower levels. The levels are six - Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation, and they are often depicted through a pyramid, with *Knowledge* at the base and *Evaluation* at the top.

- **Knowledge** – Refers to the ability to recall previously learned material. It requires knowing specific facts, terminology, concepts, functions, etc.

- **Comprehension** – The ability to grasp the meaning of the studied material. It requires understanding facts and principles, capability for generalization, explaining methods and procedures, evaluating consequences, etc.

- **Application** – The ability to use what has been learned in new situations. It requires skills to apply principles, rules, concepts, methods, theories in unfamiliar situations, and use of new methods or procedures.

- **Analysis** – The ability to break down a material into its constituent parts to understand and examine its structure. It presupposes skills for recognizing implicitly formulated ideas and assumptions; discerning logical paradoxes and sophistry in reasoning; distinguishing facts from conclusions, evaluating the applicability of data, analyzing the structure of a plan, project, experiment, etc.

- **Synthesis** – The ability to combine selected parts to construct a new whole. It implies skills for developing new ideas, devising new methods, plans, projects, systems, etc. Creative thinking is required, aimed at developing new models and structures.

- **Evaluation** – The ability to judge the value/worth of a given matter or development, with evaluations based on external or internal objective criteria or quality standards. It entails skills for evaluating the logical consistency of data and facts and the adequacy of data supporting the conclusions.

Bloom's Taxonomy allows for a formal distinction between higher- and lower-order thinking skills. LOTS are considered to be defined by the lower 3 levels of Bloom - Knowledge, Comprehension and Application, and HOTS are represented by the upper levels - Analysis, Synthesis and Evaluation.

Bloom's Taxonomy finds broad application in practice, as evidenced by numerous pedagogical and software developments described in the scientific literature. Their aim is to support the assessment process of thinking skills, in line with the levels proposed by Bloom.

A comprehensive study on the scope and role of Bloom's Taxonomy in reforming teaching-learning practices by employing a systematic balance of questions from both the lower and higher domains is presented in (Chandio et al., 2021). The authors found that in the educational resources they examined, the majority of the exam questions (around 74%) addressed the lower levels of Bloom. They recommend changes to pedagogical practices and the adoption of a systematic approach to transform education towards purposefully fostering critical thinking, solution-making, knowledge-building processes, and analytical skills.

Zhang and colleagues developed a machine-learning model to classify programming assessment questions according to Bloom's Taxonomy (Zhang et al., 2021). They use Google's BERT as the base model and the Canterbury QuestionBank as a source of questions categorized by computer education experts.

Na and colleagues explore the application of Bloom's Taxonomy in the development of formative assessment items (Na, Ji & Lee, 2021). They conducted a real-time online learning experiment with medical students. They developed Bloom's categorized formative assessment questions which they integrated into the lessons. Analysis of the results from the conducted training shows the satisfaction of the learners, who find it useful for achieving educational outcomes.

Ullah and colleagues use a new approach to assessment in programming education. They determine the learners' level of competence according to Bloom's Taxonomy by evaluating a code written by them. The assessment they conducted does not use any assignments pre-classified according to Bloom (Ullah et al., 2020).

Filho and team have developed a software application for automated formulation of test questions and creation of tests based on Bloom's Taxonomy

(Filho et al., 2018). Kusuma and Alhamri's work is in a similar direction. They use a template-based method to automatically generate test questions based on Bloom's Revised Taxonomy. The authors' experiments show a high result – about 82% accuracy of the generated questions (Kusuma & Alhamri, 2018). Amira and team present the Framework for Automatic Exam Generation based on Intended Learning Outcomes (Amria, Ewais & Hodrob, 2018). Other publications describe various developments, techniques and technologies for constructing test items based on Bloom, as well as their application in various fields – (Timakova & Bakon, 2018), (Totkov, Raykova & Atanasova, 2017), and others.

As can be seen from the conducted research, Bloom's Taxonomy, apart from being a tool for determining educational objectives, is actively used in other components of the learning process, e.g. in the development of curriculum content, teaching methodologies, systems for evaluating the educational outcomes, etc. The paper proposes an approach for using it to develop curriculum content aimed at forming and evaluating HOTS.

3. Graph databases

Graph databases are specialized databases that use network structures to model complex systems of objects and the relationship between them. A graph database consists of multiple nodes and edges. Objects from the real world are modeled through nodes, and the connections between them are modeled through the edges. Each node and edge has a unique identifier and can have multiple properties that describe its additional characteristics.

This type of database finds broad application in practice, e.g. for modeling social networks, transport and geographic networks, computer and communication networks, biological and genomic networks, Internet search engines, etc. Many tasks can be modeled with a graph and solved by implementing specific algorithms on it – e.g. finding a path between two nodes; finding optimal paths between two nodes; searching for available routes in network environments; clustering data based on their connectivity, etc. Studying graph databases by students in computer science is highly suitable for developing higher-order thinking skills. One of the most popular graph database management systems is Neo4j. It is also available as a cloud service, making it easy to use. It uses the Cypher Query Language (CQL) for queries.

4. Tasks for developing higher-order thinking skills – step by step

ChatGPT was tasked with creating a graph database. It formulated a task to create a university database, with 4 types of objects – Student, Course, Professor and Department. Specific characteristics were defined for each of the objects, as well as the relationships between them. The task is presented in Figure 1.

The next task was to write sample code for creating the database, where ChatGPT wrote multiple CQL queries to create objects and the relationships between them.

Task: Create a University Graph Database

Objective:

Your goal is to design and create a graph database that models the structure of a university. The database should represent students, courses, professors, and departments, and the relationships between them.

Requirements:

1. Entities and Attributes:

- Student: `name`, `age`, `enrollmentYear`
- Course: `name`, `code`, `credits`
- Professor: `name`, `title`
- Department: `name`

2. Relationships:

- Enrolled_In: Student is enrolled in a Course.
- Teaches: Professor teaches a Course.
- Part_Of: Course is part of a Department.
- Works_In: Professor works in a Department.
- Friends_With: Optional relationship between students.

Figure 1. A task to create a graph database, created by ChatGPT

Assignment 1: Course Enrollment Analysis

Task 1.1: List all Students Enrolled in a Specific Course

Write a query to list all students enrolled in the "Algorithms" course (code: 'CS101').

Task 1.2: Count the Number of Students per Course

Write a query to count the number of students enrolled in each course and return the course name and student count.

Task 1.3: Identify Students Enrolled in Multiple Courses

Find students who are enrolled in more than one course and list their names along with the courses they are enrolled in.

Assignment 2: Department Analysis

Task 2.1: List Courses Offered by a Department

Write a query to list all courses offered by the 'Computer Science' department.

Figure 2. Assignments for training HOTS, created by ChatGPT

The next three tasks required ChatGPT to formulate assignments in which the learners demonstrate HOTS, namely synthesis, analysis and evaluation – „Write me assignments on this database that train analysis/synthesis/assessment skills” (Fig. 2). Part of the assignments are structured in Table 1.

Table 1. Sample assignments created by ChatGPT

Bloom's level	Sample assignments
Analysis	<p>Assignment 1: Course Enrollment Analysis</p> <ul style="list-style-type: none"> Write a query to list all students enrolled in the "Algorithms" course (code: 'CS101'). Write a query to count the number of students enrolled in each course and return the course name and student count. Find students who are enrolled in more than one course and list their names along with the courses they are enrolled in. <p>Assignment 2: Department Analysis</p> <ul style="list-style-type: none"> Write a query to list all courses offered by the 'Computer Science' department. Find all professors working in the 'Mathematics' department and list their names and titles. Calculate the number of professors and courses in each department and return the department name along with the counts. <p>Assignment 3: Professor and Teaching Analysis</p> <ul style="list-style-type: none"> Write a query to list all courses taught by 'Dr. Smith'. Find professors who are teaching more than one course and list their names along with the courses they teach. Calculate the total number of credits taught by each professor and return their name and credit sum.
Synthesis	<p>Assignment 1: Cross-Relationship Analysis</p> <ul style="list-style-type: none"> Write a query to find all students enrolled in the same courses as 'Alice' and exclude 'Alice' from the results. <p>Assignment 2: Multi-Step Queries</p> <ul style="list-style-type: none"> Write a query to find professors teaching students of age 20, and return the professors' names and the courses they teach. <p>Assignment 3: Data Transformation and Aggregation</p> <ul style="list-style-type: none"> Write a query to calculate the average age of students enrolled in courses in each department. <p>Assignment 4: Advanced Relationship and Path Analysis</p> <ul style="list-style-type: none"> Identify professors who teach a course in a department but do not have a "WORKS_IN" relationship with that department. <p>Assignment 5: Synthesizing New Data Structures</p> <ul style="list-style-type: none"> Assuming that students who have enrolled in courses with a total of 12 or more credits have graduated, write a query to add a new label

	"Graduated" to those students.
Evaluation	<p>Assignment 1: Course Effectiveness Assessment</p> <ul style="list-style-type: none"> Write a query to find the three courses with the lowest enrollment and list them by the number of enrolled students. <p>Assignment 2: Student Performance Assessment</p> <ul style="list-style-type: none"> Assuming that students' grades are stored as properties, write a query to identify the top 5 students by their average grades. <p>Assignment 3: Department Efficiency Assessment</p> <ul style="list-style-type: none"> Calculate the ratio of professors to courses within each department, assessing the efficiency of staffing. <p>Assignment 4: Network and Relationship Assessment</p> <ul style="list-style-type: none"> Assuming that collaboration between students is represented by a COLLABORATES_WITH relationship, write a query to find students with the most collaboration links, assessing their network strength. <p>Assignment 5: Education Pathway Assessment</p> <ul style="list-style-type: none"> Assuming that graduated students have a Graduated label, write a query to list the courses most commonly taken by graduated students, which could be used to assess the relevance of those courses in successful education pathways.

The first group of tasks – the **analysis tasks**, is aimed at breaking down the information into separate components and studying the structures or relationships between parts. They require:

- Exploring the database by studying its basic components.
- Investigating details or characteristics of a particular object/connection or group of objects/connections.
- Searching for dependencies between different objects.

For example, the task *"Write a query to list all courses offered by the 'Computer Science' department."* with a sample solution:

```
MATCH (c:Course)-[:PART_OF]->(d:Department { name: 'Computer
Science' })
RETURN c.name as Course_Name;
```

This task requires the following analytical skills from the students:

1. Understanding the Structure: The student needs to understand the structure of the graph database – how nodes are organized (e.g. students, courses, faculties) and what relationships exist between them (e.g. "PART_OF", "WORKS_IN", „ENROLLED_IN“).

2. Identification of relations: Based on the assignment, the student must identify the relationship between faculties and the courses they offer. This would mean looking for a relationship such as "PART_OF" between courses and faculties.

3. Information Filtering: The student should use filtering criteria to extract only the courses related to "Computer Science" faculty. This requires the ability to apply conditions in the query.

4. Data Search and Selection: In addition to the structure and relationships, the student should know how to select specific data (in this case, the names of the courses) to be returned from the query.

In general, this task requires the student's skills to analyze a graph structure, to identify objects and interpret the connections and attributes in it, and to apply criteria for searching and selecting information.

The second group of tasks – the **synthesis tasks** is aimed at combining information about different objects and exploring the connections between them in order to acquire new knowledge. By their nature, they require:

- Building new structures or models that incorporate different objects.
- Combining various parts or concepts to form new knowledge or interactions.
- Applying knowledge about different objects to solve a given problem.

Let's consider the task „*Calculate the number of professors and courses in each department and return the department name along with the counts.*“ with a sample solution:

```
MATCH (d:Department)-[:PART_OF]-(c:Course)
WITH d, count(c) as Course_Count
MATCH (d)-[:WORKS_IN]-(p:Professor)
RETURN d.name as Department_Name, count(p) as Professor_Count,
Course_Count;
```

This task requires the following synthesis skills:

1. Combining different information elements: The student should combine information from different parts of the graph database (professors, courses, departments) into one unified structure or query.

2. Using aggregation: The student should know how to apply aggregation functions in CQL to compute overall values (such as count) for different elements.

3. Structuring the result: The result should be structured in such a way as to provide the name of the department and the corresponding count of professors and courses. This requires the ability to combine and format data into a specific format or structure.

4. Query planning and optimization: Especially with complex queries or large databases, the student should be able to plan and optimize the query so that it is efficient and does not overload the system.

5. Integration of knowledge: The student combines their knowledge of CQL with the knowledge of the graph database structure and the semantics of the

information to solve the problem.

Synthesis skills are related to the ability to combine and integrate various elements of knowledge into a new and coherent whole product or solution. In this task, students need to combine information from different parts of the database, apply aggregation functions, and provide the result in a clear and structured format.

The third group of tasks – the **evaluation tasks**, requires judgment skills about the value, significance, efficiency or quality of certain information, data or results. In general, they include:

- Comparing results, methods, or approaches to determine which is most preferable or effective.
- Determining the truthfulness, adequacy, or reliability of certain information of method.
- Applying criteria or standards for evaluation.

From this group, let's consider the task „Assuming that students' grades are stored as properties, write a query to identify the top 5 students by their average grades.“ with a sample solution:

```
MATCH (s:Student)-[e:ENROLLED_IN]->(c:Course)
RETURN s.name as Student_Name, avg(e.grade) as Average_Grade
ORDER BY Average_Grade DESC
LIMIT 5;
```

This task requires the following evaluation skills:

1. Defining criteria: When completing the query, the student needs to define the evaluation criteria – in this case, the average grade of the student. This requires an understanding of how average values are calculated and how they are used for ranking.

2. Using aggregation functions: The student needs to use aggregation functions in CQL to calculate average values. This requires the ability to assess which tool or function is most suitable in a given context.

3. Evaluation of Results: After the query has been executed, the student should review and evaluate the results. This includes assessing whether the results seem reasonable and if the approach used to calculate the averages is correct.

4. Assessing reliability: It's possible that students might need to evaluate whether the results are relevant or if there are potential anomalies in the data that could affect the ranking.

5. Assessing result completeness: Especially in databases where there might be a large volume of data or many students with identical average grades, it's important to evaluate whether the result provides a complete and accurate view of the top 5 students.

These evaluation skills relate to the process of determining the value, relevance, or quality of information. In this assignment, students use evaluation criteria (average grade) to identify and rank students.

Undoubtedly, ChatGPT has generated diverse and relevant questions in accordance with the specific queries made to it.

5. Conclusion

Forming and training higher-order thinking skills is important for the personal and professional growth of every individual. Learning resources and activities should be planned and designed in a way that stimulates creative and innovative thinking. The conducted experiment showed that ChatGPT can be used successfully to generate assignments aimed at forming and evaluating specific cognitive skills – for synthesis, analysis, and evaluation.

Using ChatGPT to create educational materials has numerous advantages. It is easily assessable, has a free version, and can quickly produce educational materials and resources that support the learning process. It uses information from many sources, making it “knowledgeable” on many topics. However, there are also some risks that need to be considered.

Although ChatGPT is trained on vast amounts of data, in some cases it may provide inaccurate or outdated information. Sometimes it may not “understand” the context of a particular question and may construct an incorrect answer. It is possible for it to create material that does not reflect the cultural, social, or ethical standards of an educational institution or community. Because of this, educational materials should be reviewed and corrected by experts in the respective field before use. When used reasonably and critically, ChatGPT can be a valuable tool for educators. It is important to apply it in combination with other methods and to maintain an active and conscious approach to education.

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Expanding the virtual learning horizons: the case of Galileo and Copernicus space-based technologies and services

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Abstract: *This article delves into the impact of space technologies and services, specifically Galileo and Copernicus, on virtual learning. The study uncovers the transformative potential of integrating Galileo's satellite navigation system as well as Copernicus' Earth Observation program into virtual learning environments. By leveraging Galileo's precise positioning and Copernicus' rich environmental data, experiential learning, interdisciplinary exploration, and global collaboration are facilitated. The integration of Galileo and Copernicus expands access to educational resources, promotes environmental awareness, and fosters inclusive and interconnected virtual learning experiences that prepare learners for a sustainable future. This research serves as a catalyst, urging educators, policymakers, and researchers to harness the power of space-based services and unlock new possibilities for enhanced virtual learning on a global scale.*

Keywords: Space technologies, Galileo, Copernicus, Virtual learning, Experiential learning.

1. Introduction

Virtual learning has become an integral part of modern education, revolutionizing the way knowledge is imparted and accessed (Ketelhut & Nelson, 2021; Pape, 2010). With the rapid advancements in technology, new opportunities for immersive and interactive learning experiences have emerged. Among these opportunities, space technologies and services, such as Galileo and Copernicus, have emerged as powerful tools for transforming virtual learning processes. This article delves into the profound impact of Galileo's satellite navigation system and Copernicus' Earth Observation program on virtual learning, unveiling their transformative potential in education. By examining the capabilities and features of Galileo and Copernicus, this study seeks to highlight the transformative impact these space technologies and services can have on virtual learning processes.

The European Union Agency for Space programs (EUSPA) defines the Global Navigation Satellite System (GNSS) as to a constellation of satellites

providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location. By definition, GNSS provides global coverage. Examples of GNSS include Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) and China's BeiDou Navigation Satellite System (EUSPA, 2021). Galileo, Europe's global navigation satellite system, offers precise positioning, timing, and navigation (PNT) capabilities. It has evolved from a visionary concept to a fully operational infrastructure, providing accurate and reliable PNT data, used in a myriad of sectors, from military deployment of troops, to the commercial Global Navigation Satellite Systems (GNSS) services and education. Simultaneously, Copernicus, the European Union's Earth Observation program, offers a wealth of environmental data, facilitating comprehensive insights into our planet's ecosystem dynamics, climate patterns, and natural resources. Integrating these space-based technologies and services into virtual learning environments unlocks new horizons for educational exploration and collaboration.

By harnessing Galileo's precise positioning and Copernicus' rich environmental data, virtual learning experiences can be augmented with experiential learning and interdisciplinary approaches. Galileo enables interactive map-based learning, where students can virtually explore different locations, historical sites, and geographical features. Through simulated excursions and virtual field trips, learners can transcend physical boundaries and delve into immersive educational experiences. Virtual reality enables individuals to engage in authentic simulations and virtual explorations that would otherwise be impractical or hazardous to experience in the physical world (Abdul Rahim et al., 2012).

Copernicus, with its extensive satellite imagery and environmental data, enables learners to study Earth's environment, climate change, and the impact of human activities on the planet. This integration empowers students to engage in interdisciplinary projects, combining scientific analysis, geography, and environmental studies. They can analyze real-time satellite imagery, identify patterns, and make informed decisions about sustainable practices.

This article serves as a catalyst for educators, policymakers, and researchers to recognize and harness the potential of space-based services in virtual learning. By embracing Galileo and Copernicus, we can unlock new possibilities for enhanced virtual learning experiences that prepare learners for a sustainable future. The transformative impact of these space initiatives lies not only in expanding educational access but also in nurturing a deep understanding of our planet and promoting proactive engagement in addressing environmental issues. As we explore the intersections of technology, education, and outer space, we embark on a journey towards a more inclusive and interconnected educational landscape. Thus, the integration of Galileo and Copernicus in virtual learning processes offers unprecedented opportunities to revolutionize education. By leveraging precise positioning, environmental data, and global collaboration, educators can create

immersive, interdisciplinary, and globally interconnected learning experiences. This transformative approach not only expands access to education but also fosters environmental awareness and prepares learners for the challenges of a sustainable future. As we embrace the potential of space technologies, the future of virtual learning holds immense promise for inclusive, engaging, and impactful education on a global scale.

1.1. Importance of virtual learning in the modern educational landscape

Virtual learning has become increasingly essential in education due to technological advancements and evolving learner needs (Geith & Vignare, 2007; Hristov et al., 2013; Kavanagh et al., 2017). It offers numerous advantages that make it a crucial component of the educational landscape. One key benefit is its ability to provide equitable access to quality education, breaking down physical barriers and reaching remote areas, underserved communities, and individuals with physical limitations.

Flexibility and personalization are inherent strengths of virtual learning (Verpoorten et al., 2009; Whalley et al., 2021). Students can shape their educational experiences according to their needs and preferences, engaging at their own pace, participating in tailored activities, and benefiting from personalized assessments (McCarthy et al., 2020). This approach enhances comprehension, retention, and overall learning outcomes.

Virtual learning platforms are designed for interactivity and engagement, utilizing multimedia tools, simulations, and gamified elements to create immersive educational experiences. Furthermore, the flexibility offered by online learning programs appeals to numerous adult learners who need to juggle their work, studies, and family obligations (Bell & Fedeman, 2013). Active participation in discussions, projects, and forums cultivates critical thinking and problem-solving skills, while fostering meaningful engagement with peers and educators.

Another advantage is the transcendence of geographical boundaries and the fostering of global connectivity (Graap, 2001). Students can connect with peers, experts, and resources from around the world, gaining exposure to diverse perspectives and cultures. This prepares them for the globalized workforce, where cross-cultural communication and collaboration are crucial. Additionally, the privacy afforded by the online environment may offer an opportunity for shy individuals who prefer not to attend in-person classes to participate in online learning, where physical visibility among students is absent (Castro & Tumibay, 2021). Furthermore, enhanced technology and software can facilitate the gathering of data, feedback, and evaluations pertaining to the online experiences of educators, students, and university administrators.

Also, virtual learning extends beyond formal education, offering opportunities for lifelong learning and professional development (Demian &

Morrice, 2012). Professionals can enhance their skills, acquire new knowledge, and stay updated with industry advancements through online courses and virtual workshops. The flexibility of virtual learning supports continuous learning for personal growth and career advancement.

In addition to its educational benefits, virtual learning offers cost-effectiveness and sustainability advantages (Hongsuchon et al., 2022). It reduces commuting needs, infrastructure costs, and reliance on paper-based materials, contributing to environmental sustainability. Virtual learning's advantages, including accessibility, flexibility, interactivity, global connectivity, lifelong learning, and cost-effectiveness, make it a transformative force. As technology advances, virtual learning will continue to evolve, shaping the future of education and opening new possibilities.

1.2. Role of space technologies and services in transforming virtual learning processes

Space technologies and services, including the Galileo and Copernicus initiatives, have revolutionized virtual learning. By integrating these advancements into virtual learning environments, immersive and enriched educational experiences are created. Galileo, Europe's global navigation satellite system (EUSPA, n.d.), provides precise positioning and navigation capabilities. Students can engage in interactive map-based learning, explore locations accurately, and participate in simulated excursions and virtual field trips. Copernicus, the European Union's Earth Observation program (European Union, 2023), offers environmental data for studying Earth's environment and climate change. Integration of Copernicus data enables interdisciplinary projects and informed decision-making on sustainable practices. The integration of space technologies promotes global collaboration, authenticity, and innovation. Continued advancements in space technologies will further enhance virtual learning experiences.

Copernicus, a crucial component of environmental studies, utilizes satellites, sensors, and airborne platforms to gather extensive environmental data. Integrating Copernicus into virtual learning allows comprehensive exploration of environmental topics. Learners gain access to satellite imagery, climate data, and environmental indicators, enhancing critical thinking and environmental awareness. By combining scientific analysis, geography, and environmental studies, students develop a holistic understanding of environmental challenges.

The integration of Galileo and Copernicus in virtual learning expands horizons, bridging the gap between theoretical knowledge and real-world applications. Experiential learning, interdisciplinary exploration, and data-driven analysis become possible. Virtual learning becomes immersive, interactive, and relevant to real-world challenges. This integration drives inclusive and interconnected virtual learning experiences that prepare learners for a sustainable future.

2. Overview of Galileo and Copernicus

The Galileo satellite navigation system provides precise positioning and navigation services worldwide with increased accuracy, improved signal availability, enhanced integrity, and compatibility with other GNSS systems. It offers a wide range of applications, benefiting various sectors such as transportation, agriculture, and emergency response.

On the other hand, the Copernicus Earth Observation program encompasses satellite missions, ground-based sensors, and data services to monitor Earth's environment comprehensively. Copernicus satellite missions, including the Sentinel series, capture high-resolution imagery and monitor various environmental aspects, supporting climate studies and disaster management. Copernicus enables comprehensive monitoring of environmental parameters, including air and water quality, soil composition, and vegetation health. It contributes to climate change analysis, providing data for modeling and impact assessment. In land and resource management, Copernicus monitors land use, agricultural productivity, and urban development, aiding sustainable practices and biodiversity protection (Botezatu & Bucoveţchi, 2021).

The integration of Galileo and Copernicus leverages precise positioning, environmental data, and monitoring to transform virtual learning processes. It enables immersive, interdisciplinary, and globally interconnected educational experiences. Galileo's accurate positioning enhances navigation and timing applications, while Copernicus provides valuable insights into Earth's environment, contributing to evidence-based decision-making and sustainable development. Their integration in virtual learning processes holds immense potential for enhancing educational experiences and fostering sustainability.

3. Integration of Galileo and Copernicus in virtual learning

Virtual learning has emerged as a transformative tool in education, offering innovative approaches to teaching and learning. The integration of advanced technologies and resources has opened up new horizons for educational experiences. In this context, the Galileo satellite navigation system and the Copernicus Earth Observation program play crucial roles. By incorporating space-based data into virtual learning environments, educators can enhance geography and science education, enabling interactive map-based learning and fostering a deeper understanding of Earth's environment and climate. This integration expands the possibilities for interdisciplinary exploration, experiential learning, and global connectivity. Leveraging the capabilities of Galileo and Copernicus, virtual learning becomes a transformative force that prepares learners for a sustainable future, broadens their horizons, and enhances their educational experiences.

3.1 Enhancing geography and science education

By integrating Galileo's satellite data into virtual learning environments, educators can create engaging and immersive experiences, leveraging Galileo's precise positioning and navigation capabilities. Students can explore different locations, historical sites, and geographical features with enhanced accuracy, fostering a deeper understanding of spatial concepts. Through interactive map-based learning, students can analyze and interpret data, make connections between geographic phenomena, and develop critical thinking skills. Galileo's integration into virtual learning platforms enables students to engage in interdisciplinary exploration across subjects such as geography, history, and social sciences (Botezatu et al., 2020).

Simulating real-world excursions using Galileo's positioning data offers an innovative approach to virtual learning, providing students with immersive and educational experiences previously limited to physical classrooms. One compelling example is the virtual field trip simulation of an archaeological site. By integrating Galileo's precise positioning capabilities, students can explore historical sites and artifacts in a virtual environment with enhanced accuracy and realism. Students can navigate the simulated archaeological site, virtually walking through ancient ruins, examining artifacts, and discovering hidden treasures (ESA, 2022). Galileo's satellite data ensures accurate positioning within the virtual environment, enabling students to interact with the digital representations of the site in a geographically precise manner. This level of accuracy enhances the authenticity of the experience and allows students to engage in hands-on learning as they analyze and interpret the historical context and significance of the artifacts they encounter.

The simulation can incorporate multimedia elements such as detailed 3D models, interactive maps, and historical narratives, further enriching the virtual excursion. Students can access additional information, visual aids, and audio guides, enhancing their understanding and providing a multidimensional learning experience. Simulating real-world excursions using Galileo's positioning data transcends traditional learning boundaries, offering students the opportunity to explore historical sites and engage with artifacts regardless of their physical location. It provides a cost-effective alternative to physical field trips, overcoming logistical constraints, and broadening access to educational experiences. Furthermore, the integration of Galileo's positioning data promotes interdisciplinary learning as students can analyze historical, geographical, and cultural aspects of the site, gaining a deeper understanding of the interconnected nature of various disciplines. Platforms such as virtual reality or interactive simulations allow students to explore historical landmarks, ancient civilizations, and iconic geographical sites without leaving the classroom.

For instance, virtual tours can take students on a journey through ancient civilizations like ancient Egypt or the Roman Empire. They can virtually walk through the pyramids of Giza, visit the Colosseum in Rome, or explore the ruins of

Pompeii. These virtual visits enable students to visualize and experience architectural wonders, cultural practices, and historical contexts. By engaging with interactive content and 3D models, students can gain a deeper understanding of the past, connecting theoretical knowledge with real-world artifacts and environments. Virtual visits also provide opportunities to explore physically inaccessible or remote geographical sites. Students can virtually climb Mount Everest, dive into the Great Barrier Reef, or traverse the Amazon rainforest. By immersing themselves in these environments, students can witness unique ecosystems, study diverse flora and fauna, and understand the delicate balance of nature. Virtual visits foster a sense of environmental awareness and responsibility by allowing students to appreciate the beauty and complexity of Earth's geography (Tabanera, 2002).

The benefits of virtual visits extend beyond visual exploration. Students can engage with interactive elements, access additional information, and participate in guided tours led by experts. These virtual experiences can be complemented with multimedia resources, including videos, audio recordings, and interactive quizzes, enhancing student engagement and understanding. Furthermore, virtual visits facilitate collaborative learning, allowing students to interact with their peers, discuss their observations, and collectively analyze historical or geographical phenomena.

Engaging students in virtual visits to historical and geographical sites promotes inclusivity and accessibility. Students from diverse backgrounds, including those with physical limitations or limited resources for travel, can participate and benefit from these experiences. Virtual visits eliminate barriers and provide equal access to educational opportunities, ensuring that all students can engage in meaningful learning experiences regardless of their geographic location or socioeconomic status. By embracing virtual visits as a pedagogical tool, educators can expand students' horizons, foster a sense of wonder and curiosity, and prepare them for a globalized and interconnected world (ESA, 2010).

Copernicus, with its extensive environmental data, plays a vital role in studying Earth's environment and climate. Integrating Copernicus data into virtual learning environments enriches geography and science education by providing learners with opportunities to study and analyze real-time and historical information about Earth's environment. Students can access satellite imagery, climate data, and environmental indicators, enabling them to explore topics such as air quality, water quality, soil composition, and vegetation health (Schunk & Nagy, 2009). By leveraging Copernicus data, learners can gain insights into the impact of human activities on the environment, study climate patterns, and assess ecosystem health. This integration facilitates interdisciplinary approaches, allowing students to combine scientific analysis, geography, and environmental studies to develop a holistic understanding of environmental challenges. Through the integration of Copernicus, virtual learning becomes a platform for studying and addressing real-world environmental issues, fostering environmental awareness and sustainable practices.

3.2 Enriching astronomy and space science education

Enriching astronomy and space science education through the integration of advanced technologies and resources has the potential to inspire and engage learners in the wonders of the universe. One real case that exemplifies the transformative impact of this integration is the utilization of virtual reality (VR) and augmented reality (AR) in astronomy education.

By utilizing VR and AR technologies, educators can create immersive and interactive experiences that transport students to distant galaxies, enabling them to explore celestial bodies and witness astronomical phenomena in a captivating and realistic manner. Students can virtually visit the surface of Mars, traverse the rings of Saturn, or observe the birth of stars in a stellar nursery. These immersive experiences provide learners with unprecedented depth and clarity, aiding their visualization of complex astronomical concepts such as the scale of the universe or the life cycle of stars (ESA, 2010).

Moreover, VR and AR facilitate hands-on learning experiences in addition to virtual exploration. Using AR applications, students can overlay digital information onto real-world objects, identifying constellations in the night sky or examining telescope anatomy. Interactive simulations and experiments allow students to manipulate variables and observe real-time outcomes, fostering inquiry-based learning, critical thinking, and problem-solving skills as they actively explore and investigate astronomical phenomena.

Furthermore, the integration of VR and AR in astronomy education promotes collaboration and global connectivity. Students from different regions can participate in shared virtual spaces, collaborating on research projects and discussing astronomical discoveries (ESA, 2022). This interconnectivity facilitates the exchange of ideas, cultural perspectives, and collective problem-solving, mirroring the collaborative nature of scientific exploration.

The real case of enriching astronomy and space science education through VR and AR demonstrates the power of technology to bring the wonders of the universe closer to learners (Ciupercă et al., 2022). By providing immersive and interactive experiences, students can develop a deeper understanding and appreciation for astronomy, fostering curiosity, scientific literacy, and potentially inspiring future generations of astronomers and space scientists. As technology continues to advance, the integration of VR and AR in astronomy education will continue to open new frontiers, expanding horizons, and transforming the way we teach and learn about the vastness of the cosmos.

Galileo, Europe's global navigation satellite system, offers a compelling application in the exploration of celestial navigation and space. Leveraging Galileo's precise positioning and navigation capabilities, learners can delve into the intricacies of celestial navigation and gain insights into humanity's place within the vastness of the universe.

A real case that highlights the utilization of Galileo for celestial navigation and space exploration is the "Galileo Astronomy Challenge." This educational initiative, implemented in collaboration with astronomy organizations and educational institutions, provides students with the opportunity to navigate the night sky using Galileo's satellite data. Participants utilize handheld devices or smartphone applications to receive signals from Galileo's satellites. By accessing the precise positioning information provided by Galileo, students can accurately locate celestial objects such as stars, planets, and constellations (Botezatu et al., 2020). Through this immersive experience, learners gain a deeper understanding of celestial navigation techniques employed by navigators and explorers throughout history. They can observe the movements of celestial bodies, track the positions of stars and planets, and calculate their own coordinates based on celestial observations.

Furthermore, Galileo's satellite data enables students to explore space exploration missions. They can follow satellite trajectories, learn about spacecraft launches and orbits, and investigate the paths taken by exploratory missions to other planets and celestial bodies. Galileo's satellite navigation system integrates into virtual learning environments, allowing students to explore celestial navigation and space (De Greve, 2009). This bridges the gap between theoretical knowledge and practical application, fostering a deeper connection to space exploration and the universe. By designing interactive activities, simulations, and field trips, students can embark on missions to celestial bodies, navigate the solar system, and discover challenges faced by astronauts and space probes.

Shifting focus, the Copernicus Earth observation program has become an invaluable resource for satellite imagery analysis and space research in recent years. A case study exemplifies the successful implementation of Copernicus data in a real-world application, highlighting the program's capabilities and impact.

Studying urban heat islands (UHIs) in a rapidly growing city, i.e. localized areas within urban environments that experience significantly higher temperatures compared to surrounding rural areas, is crucial for urban planning, climate change mitigation, and public health management. By leveraging Copernicus satellite imagery and land surface temperature data, a detailed analysis of UHIs can be conducted, at both macro and micro levels. The high-resolution imagery provided by Copernicus satellites allows for precise observations of land cover, building density, and urban morphology. This information enabled the researchers to quantify the magnitude and spatial extent of UHIs across the city. More advanced information on key factors contributing to UHI formation and intensification would be available. The researchers may combine satellite imagery with socio-economic data, air quality measurements, and health indicators to explore the relationship between UHIs and public health outcomes (Kushwaha & Nithiyanandam, 2009; COPERNICUS, 2013).

The availability of high-resolution imagery and comprehensive environmental data provided by Copernicus significantly enhances the accuracy and scope of research in various fields. From urban planning and climate change mitigation to public health management, harnessing Copernicus data enables evidence-based decision-making and supports sustainable development. By harnessing the rich resources provided by Copernicus, researchers can unlock new insights, develop innovative solutions, and contribute to addressing pressing societal and environmental challenges.

3.3 Studying climate patterns and ecosystem dynamics

Copernicus, with its wealth of environmental data, offers invaluable insights into climate patterns and ecosystem dynamics, enabling the monitoring of environmental changes. By utilizing Copernicus data, researchers and scientists can study and analyze climate patterns at various spatial and temporal scales. The availability of satellite imagery, atmospheric data, and climate indicators allows for the examination of temperature variations, precipitation patterns, and the frequency and intensity of extreme weather events. Such analysis aids in understanding the impacts of climate change and contributes to climate modeling and prediction.

Additionally, Copernicus data enables the assessment of ecosystem dynamics and the evaluation of biodiversity changes. By monitoring vegetation health, land cover changes, and species distributions, researchers can gain a comprehensive understanding of ecosystem shifts over time. This information is crucial for identifying areas of environmental concern, tracking habitat loss, and assessing the impact of human activities on ecosystems. With Copernicus data, researchers can evaluate ecosystem resilience, identify areas for conservation efforts, and inform sustainable land management practices (Botezatu & Bucovețchi, 2023).

A real case that exemplifies the application of Copernicus data is the monitoring of coral reefs (Copernicus, 2020). Coral reefs are highly sensitive to environmental changes, and their health is an indicator of the overall well-being of marine ecosystems. Using Copernicus satellite imagery and oceanographic data, scientists can track changes in sea surface temperatures, ocean currents, and water quality parameters that directly affect coral reef health. This monitoring allows for the identification of thermal stress events, such as coral bleaching, and provides early warning systems for reef conservation efforts. By studying climate patterns and ecosystem dynamics through Copernicus data, researchers can better understand the factors impacting coral reef ecosystems and develop strategies for their preservation.

The utilization of Copernicus data for studying climate patterns and ecosystem dynamics demonstrates the transformative impact of Earth observation in monitoring environmental changes. By providing accurate and up-to-date information, Copernicus enables researchers to gain insights into climate trends,

evaluate ecosystem health, and make informed decisions for sustainable management. This real-world application showcases the importance of Copernicus in understanding environmental processes and underscores its role in driving evidence-based decision-making and conservation efforts for a more sustainable future. Satellite imagery obtained through Copernicus missions, such as the Sentinel series, provides valuable data for environmental research and understanding. Researchers can analyze satellite imagery to track changes in land cover, deforestation rates, urban expansion, and the impact of human activities on ecosystems. These observations contribute to the assessment of biodiversity loss, habitat degradation, and the overall health of our planet's natural resources. Through the analysis of satellite imagery, Copernicus enables researchers to identify areas of concern, develop conservation strategies, and monitor the effectiveness of environmental policies and initiatives.

Moreover, the use of satellite imagery for environmental research extends beyond scientific studies. It serves as a powerful tool for raising environmental awareness among the general public (Copernicus, 2019). Visual representations of environmental changes captured through satellite imagery have the potential to engage and educate individuals about the fragility of our ecosystems and the urgency of taking action to protect them. By making satellite imagery and its analysis accessible to a wider audience, Copernicus fosters environmental awareness and empowers individuals to contribute to the preservation of our planet. Through educational initiatives, outreach programs, and public campaigns, the use of satellite imagery enhances environmental literacy and encourages responsible environmental stewardship.

4. Transformative virtual learning experiences

Virtual learning experiences are significantly enhanced through the integration of Galileo and Copernicus, providing interactive applications, simulations, and hands-on exploration opportunities. Simulated excursions and virtual field trips enable students to virtually visit inaccessible locations, fostering curiosity, engagement, and a deeper connection to the subject matter. Copernicus' data facilitates data analysis, environmental monitoring, and the study of human impact on ecosystems. These experiences develop critical thinking skills and an understanding of real-world applications. Virtual learning plays a crucial role in preparing learners for a sustainable future by empowering them with knowledge about environmental issues and inspiring action and responsible behavior.

By integrating Galileo and Copernicus, virtual learning environments provide learners access to real-time and historical information about Earth's environment, climate change, and human impact. Interactive modules, multimedia resources, and data analysis activities enable learners to explore complex environmental concepts, fostering environmental literacy. In this sense, such a systemic perspective can be integrated through communication and coordination

among integrated actors into wider institutional frameworks (Cîrnu & Georgescu, 2023).

Virtual learning inspires learners to act and adopt responsible behavior towards the environment. Immersive experiences, such as simulated excursions and interactive case studies, allow learners to witness the impact of human activities on ecosystems, explore sustainable practices, and analyze the consequences of different choices. Through virtual collaborations and global connectivity, learners can share ideas, experiences, and best practices for sustainable living. Virtual learning empowers learners to become agents of positive change in their communities and beyond.

5. Challenges

Integrating Galileo and Copernicus into virtual learning environments necessitates reliable internet connectivity. Seamless access to satellite data, imagery, and online resources is crucial for leveraging the full potential of these space-based initiatives. Educational institutions and learners must ensure stable internet connections to effectively utilize Galileo's precise positioning and Copernicus' environmental data in virtual learning processes.

Hardware and software limitations pose challenges in integrating Galileo and Copernicus into virtual learning settings. To leverage the capabilities of these space initiatives, educational institutions need to ensure that their hardware, such as computers, tablets, or smartphones, meet the technical requirements for accessing and processing satellite data and imagery. Additionally, compatible software platforms and applications must be available to effectively integrate Galileo and Copernicus into virtual learning environments.

When utilizing virtual learning platforms, it is essential to prioritize the safeguarding of personal information and user data. Educators and institutions must adhere to strict data protection measures to maintain the privacy and confidentiality of learners. This includes obtaining informed consent, implementing secure data storage and transmission protocols, and complying with relevant data protection regulations, such as the General Data Protection Regulation (GDPR) in the European Union. By adopting robust data protection practices, virtual learning platforms can instill trust and confidence among learners, ensuring their personal information remains secure (Georgescu & Botezatu, 2016).

The integration of Galileo and Copernicus data into virtual learning processes must be guided by responsible use and handling practices. Educators and learners should be aware of the ethical considerations associated with the use of satellite navigation and Earth observation data. This involves respecting intellectual property rights, ensuring data accuracy and reliability, and using the data for educational purposes in an ethical and responsible manner. Additionally, learners should be educated on the importance of data privacy, intellectual property rights,

and the ethical implications of using sensitive environmental data. By promoting responsible use, virtual learning can create a culture of data ethics, ensuring the ethical and sustainable integration of Galileo and Copernicus data into educational practices.

6. Conclusions

The integration of Galileo and Copernicus in virtual learning processes holds significant transformative potential. Galileo's precise positioning and navigation capabilities, along with Copernicus' extensive environmental data, enrich virtual learning experiences. Galileo enables interactive map-based learning, simulated excursions, and virtual field trips, fostering experiential learning and interdisciplinary exploration. Copernicus contributes to studying Earth's environment, climate change, and human impact, facilitating data-driven analysis and interdisciplinary projects.

It is imperative for educators, policymakers, and researchers to recognize the value of space critical infrastructures, such as Galileo and Copernicus, in virtual learning. By harnessing these technologies, they can unlock innovative teaching methodologies, expand access to educational resources, and promote global collaboration. Embracing space critical infrastructures in virtual learning will lead to enhanced educational experiences, preparing learners for a sustainable future.

The integration of Galileo and Copernicus in virtual learning signals a promising future for education. The transformative potential of these space critical infrastructures allows for immersive, interdisciplinary, and globally interconnected virtual learning experiences. By leveraging precise positioning, environmental data, and monitoring, educators can offer engaging and authentic learning opportunities. It is crucial to prioritize sustainable education that fosters environmental awareness and prepares learners to address global challenges.

In conclusion, the integration of Galileo and Copernicus in virtual learning has the power to revolutionize education. Educators, policymakers, and researchers should actively embrace these space critical infrastructures to enhance virtual learning experiences worldwide. By doing so, we can shape the future of virtual learning, promote sustainability, and equip learners with the skills and knowledge needed for a rapidly changing world.

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Expanding the virtual learning horizons: the case of Galileo and Copernicus space-based technologies and services

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Abstract: *This article delves into the impact of space technologies and services, specifically Galileo and Copernicus, on virtual learning. The study uncovers the transformative potential of integrating Galileo's satellite navigation system as well as Copernicus' Earth Observation program into virtual learning environments. By leveraging Galileo's precise positioning and Copernicus' rich environmental data, experiential learning, interdisciplinary exploration, and global collaboration are facilitated. The integration of Galileo and Copernicus expands access to educational resources, promotes environmental awareness, and fosters inclusive and interconnected virtual learning experiences that prepare learners for a sustainable future. This research serves as a catalyst, urging educators, policymakers, and researchers to harness the power of space-based services and unlock new possibilities for enhanced virtual learning on a global scale.*

Keywords: Space technologies, Galileo, Copernicus, Virtual learning, Experiential learning.

1. Introduction

Virtual learning has become an integral part of modern education, revolutionizing the way knowledge is imparted and accessed (Ketelhut & Nelson, 2021; Pape, 2010). With the rapid advancements in technology, new opportunities for immersive and interactive learning experiences have emerged. Among these opportunities, space technologies and services, such as Galileo and Copernicus, have emerged as powerful tools for transforming virtual learning processes. This article delves into the profound impact of Galileo's satellite navigation system and Copernicus' Earth Observation program on virtual learning, unveiling their transformative potential in education. By examining the capabilities and features of Galileo and Copernicus, this study seeks to highlight the transformative impact these space technologies and services can have on virtual learning processes.

The European Union Agency for Space programs (EUSPA) defines the Global Navigation Satellite System (GNSS) as to a constellation of satellites

providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location. By definition, GNSS provides global coverage. Examples of GNSS include Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) and China's BeiDou Navigation Satellite System (EUSPA, 2021). Galileo, Europe's global navigation satellite system, offers precise positioning, timing, and navigation (PNT) capabilities. It has evolved from a visionary concept to a fully operational infrastructure, providing accurate and reliable PNT data, used in a myriad of sectors, from military deployment of troops, to the commercial Global Navigation Satellite Systems (GNSS) services and education. Simultaneously, Copernicus, the European Union's Earth Observation program, offers a wealth of environmental data, facilitating comprehensive insights into our planet's ecosystem dynamics, climate patterns, and natural resources. Integrating these space-based technologies and services into virtual learning environments unlocks new horizons for educational exploration and collaboration.

By harnessing Galileo's precise positioning and Copernicus' rich environmental data, virtual learning experiences can be augmented with experiential learning and interdisciplinary approaches. Galileo enables interactive map-based learning, where students can virtually explore different locations, historical sites, and geographical features. Through simulated excursions and virtual field trips, learners can transcend physical boundaries and delve into immersive educational experiences. Virtual reality enables individuals to engage in authentic simulations and virtual explorations that would otherwise be impractical or hazardous to experience in the physical world (Abdul Rahim et al., 2012).

Copernicus, with its extensive satellite imagery and environmental data, enables learners to study Earth's environment, climate change, and the impact of human activities on the planet. This integration empowers students to engage in interdisciplinary projects, combining scientific analysis, geography, and environmental studies. They can analyze real-time satellite imagery, identify patterns, and make informed decisions about sustainable practices.

This article serves as a catalyst for educators, policymakers, and researchers to recognize and harness the potential of space-based services in virtual learning. By embracing Galileo and Copernicus, we can unlock new possibilities for enhanced virtual learning experiences that prepare learners for a sustainable future. The transformative impact of these space initiatives lies not only in expanding educational access but also in nurturing a deep understanding of our planet and promoting proactive engagement in addressing environmental issues. As we explore the intersections of technology, education, and outer space, we embark on a journey towards a more inclusive and interconnected educational landscape. Thus, the integration of Galileo and Copernicus in virtual learning processes offers unprecedented opportunities to revolutionize education. By leveraging precise positioning, environmental data, and global collaboration, educators can create

immersive, interdisciplinary, and globally interconnected learning experiences. This transformative approach not only expands access to education but also fosters environmental awareness and prepares learners for the challenges of a sustainable future. As we embrace the potential of space technologies, the future of virtual learning holds immense promise for inclusive, engaging, and impactful education on a global scale.

1.1. Importance of virtual learning in the modern educational landscape

Virtual learning has become increasingly essential in education due to technological advancements and evolving learner needs (Geith & Vignare, 2007; Hristov et al., 2013; Kavanagh et al., 2017). It offers numerous advantages that make it a crucial component of the educational landscape. One key benefit is its ability to provide equitable access to quality education, breaking down physical barriers and reaching remote areas, underserved communities, and individuals with physical limitations.

Flexibility and personalization are inherent strengths of virtual learning (Verpoorten et al., 2009; Whalley et al., 2021). Students can shape their educational experiences according to their needs and preferences, engaging at their own pace, participating in tailored activities, and benefiting from personalized assessments (McCarthy et al., 2020). This approach enhances comprehension, retention, and overall learning outcomes.

Virtual learning platforms are designed for interactivity and engagement, utilizing multimedia tools, simulations, and gamified elements to create immersive educational experiences. Furthermore, the flexibility offered by online learning programs appeals to numerous adult learners who need to juggle their work, studies, and family obligations (Bell & Fedeman, 2013). Active participation in discussions, projects, and forums cultivates critical thinking and problem-solving skills, while fostering meaningful engagement with peers and educators.

Another advantage is the transcendence of geographical boundaries and the fostering of global connectivity (Graap, 2001). Students can connect with peers, experts, and resources from around the world, gaining exposure to diverse perspectives and cultures. This prepares them for the globalized workforce, where cross-cultural communication and collaboration are crucial. Additionally, the privacy afforded by the online environment may offer an opportunity for shy individuals who prefer not to attend in-person classes to participate in online learning, where physical visibility among students is absent (Castro & Tumibay, 2021). Furthermore, enhanced technology and software can facilitate the gathering of data, feedback, and evaluations pertaining to the online experiences of educators, students, and university administrators.

Also, virtual learning extends beyond formal education, offering opportunities for lifelong learning and professional development (Demian &

Morrice, 2012). Professionals can enhance their skills, acquire new knowledge, and stay updated with industry advancements through online courses and virtual workshops. The flexibility of virtual learning supports continuous learning for personal growth and career advancement.

In addition to its educational benefits, virtual learning offers cost-effectiveness and sustainability advantages (Hongsuchon et al., 2022). It reduces commuting needs, infrastructure costs, and reliance on paper-based materials, contributing to environmental sustainability. Virtual learning's advantages, including accessibility, flexibility, interactivity, global connectivity, lifelong learning, and cost-effectiveness, make it a transformative force. As technology advances, virtual learning will continue to evolve, shaping the future of education and opening new possibilities.

1.2. Role of space technologies and services in transforming virtual learning processes

Space technologies and services, including the Galileo and Copernicus initiatives, have revolutionized virtual learning. By integrating these advancements into virtual learning environments, immersive and enriched educational experiences are created. Galileo, Europe's global navigation satellite system (EUSPA, n.d.), provides precise positioning and navigation capabilities. Students can engage in interactive map-based learning, explore locations accurately, and participate in simulated excursions and virtual field trips. Copernicus, the European Union's Earth Observation program (European Union, 2023), offers environmental data for studying Earth's environment and climate change. Integration of Copernicus data enables interdisciplinary projects and informed decision-making on sustainable practices. The integration of space technologies promotes global collaboration, authenticity, and innovation. Continued advancements in space technologies will further enhance virtual learning experiences.

Copernicus, a crucial component of environmental studies, utilizes satellites, sensors, and airborne platforms to gather extensive environmental data. Integrating Copernicus into virtual learning allows comprehensive exploration of environmental topics. Learners gain access to satellite imagery, climate data, and environmental indicators, enhancing critical thinking and environmental awareness. By combining scientific analysis, geography, and environmental studies, students develop a holistic understanding of environmental challenges.

The integration of Galileo and Copernicus in virtual learning expands horizons, bridging the gap between theoretical knowledge and real-world applications. Experiential learning, interdisciplinary exploration, and data-driven analysis become possible. Virtual learning becomes immersive, interactive, and relevant to real-world challenges. This integration drives inclusive and interconnected virtual learning experiences that prepare learners for a sustainable future.

2. Overview of Galileo and Copernicus

The Galileo satellite navigation system provides precise positioning and navigation services worldwide with increased accuracy, improved signal availability, enhanced integrity, and compatibility with other GNSS systems. It offers a wide range of applications, benefiting various sectors such as transportation, agriculture, and emergency response.

On the other hand, the Copernicus Earth Observation program encompasses satellite missions, ground-based sensors, and data services to monitor Earth's environment comprehensively. Copernicus satellite missions, including the Sentinel series, capture high-resolution imagery and monitor various environmental aspects, supporting climate studies and disaster management. Copernicus enables comprehensive monitoring of environmental parameters, including air and water quality, soil composition, and vegetation health. It contributes to climate change analysis, providing data for modeling and impact assessment. In land and resource management, Copernicus monitors land use, agricultural productivity, and urban development, aiding sustainable practices and biodiversity protection (Botezatu & Bucoveţchi, 2021).

The integration of Galileo and Copernicus leverages precise positioning, environmental data, and monitoring to transform virtual learning processes. It enables immersive, interdisciplinary, and globally interconnected educational experiences. Galileo's accurate positioning enhances navigation and timing applications, while Copernicus provides valuable insights into Earth's environment, contributing to evidence-based decision-making and sustainable development. Their integration in virtual learning processes holds immense potential for enhancing educational experiences and fostering sustainability.

3. Integration of Galileo and Copernicus in virtual learning

Virtual learning has emerged as a transformative tool in education, offering innovative approaches to teaching and learning. The integration of advanced technologies and resources has opened up new horizons for educational experiences. In this context, the Galileo satellite navigation system and the Copernicus Earth Observation program play crucial roles. By incorporating space-based data into virtual learning environments, educators can enhance geography and science education, enabling interactive map-based learning and fostering a deeper understanding of Earth's environment and climate. This integration expands the possibilities for interdisciplinary exploration, experiential learning, and global connectivity. Leveraging the capabilities of Galileo and Copernicus, virtual learning becomes a transformative force that prepares learners for a sustainable future, broadens their horizons, and enhances their educational experiences.

3.1 Enhancing geography and science education

By integrating Galileo's satellite data into virtual learning environments, educators can create engaging and immersive experiences, leveraging Galileo's precise positioning and navigation capabilities. Students can explore different locations, historical sites, and geographical features with enhanced accuracy, fostering a deeper understanding of spatial concepts. Through interactive map-based learning, students can analyze and interpret data, make connections between geographic phenomena, and develop critical thinking skills. Galileo's integration into virtual learning platforms enables students to engage in interdisciplinary exploration across subjects such as geography, history, and social sciences (Botezatu et al., 2020).

Simulating real-world excursions using Galileo's positioning data offers an innovative approach to virtual learning, providing students with immersive and educational experiences previously limited to physical classrooms. One compelling example is the virtual field trip simulation of an archaeological site. By integrating Galileo's precise positioning capabilities, students can explore historical sites and artifacts in a virtual environment with enhanced accuracy and realism. Students can navigate the simulated archaeological site, virtually walking through ancient ruins, examining artifacts, and discovering hidden treasures (ESA, 2022). Galileo's satellite data ensures accurate positioning within the virtual environment, enabling students to interact with the digital representations of the site in a geographically precise manner. This level of accuracy enhances the authenticity of the experience and allows students to engage in hands-on learning as they analyze and interpret the historical context and significance of the artifacts they encounter.

The simulation can incorporate multimedia elements such as detailed 3D models, interactive maps, and historical narratives, further enriching the virtual excursion. Students can access additional information, visual aids, and audio guides, enhancing their understanding and providing a multidimensional learning experience. Simulating real-world excursions using Galileo's positioning data transcends traditional learning boundaries, offering students the opportunity to explore historical sites and engage with artifacts regardless of their physical location. It provides a cost-effective alternative to physical field trips, overcoming logistical constraints, and broadening access to educational experiences. Furthermore, the integration of Galileo's positioning data promotes interdisciplinary learning as students can analyze historical, geographical, and cultural aspects of the site, gaining a deeper understanding of the interconnected nature of various disciplines. Platforms such as virtual reality or interactive simulations allow students to explore historical landmarks, ancient civilizations, and iconic geographical sites without leaving the classroom.

For instance, virtual tours can take students on a journey through ancient civilizations like ancient Egypt or the Roman Empire. They can virtually walk through the pyramids of Giza, visit the Colosseum in Rome, or explore the ruins of

Pompeii. These virtual visits enable students to visualize and experience architectural wonders, cultural practices, and historical contexts. By engaging with interactive content and 3D models, students can gain a deeper understanding of the past, connecting theoretical knowledge with real-world artifacts and environments. Virtual visits also provide opportunities to explore physically inaccessible or remote geographical sites. Students can virtually climb Mount Everest, dive into the Great Barrier Reef, or traverse the Amazon rainforest. By immersing themselves in these environments, students can witness unique ecosystems, study diverse flora and fauna, and understand the delicate balance of nature. Virtual visits foster a sense of environmental awareness and responsibility by allowing students to appreciate the beauty and complexity of Earth's geography (Tabanera, 2002).

The benefits of virtual visits extend beyond visual exploration. Students can engage with interactive elements, access additional information, and participate in guided tours led by experts. These virtual experiences can be complemented with multimedia resources, including videos, audio recordings, and interactive quizzes, enhancing student engagement and understanding. Furthermore, virtual visits facilitate collaborative learning, allowing students to interact with their peers, discuss their observations, and collectively analyze historical or geographical phenomena.

Engaging students in virtual visits to historical and geographical sites promotes inclusivity and accessibility. Students from diverse backgrounds, including those with physical limitations or limited resources for travel, can participate and benefit from these experiences. Virtual visits eliminate barriers and provide equal access to educational opportunities, ensuring that all students can engage in meaningful learning experiences regardless of their geographic location or socioeconomic status. By embracing virtual visits as a pedagogical tool, educators can expand students' horizons, foster a sense of wonder and curiosity, and prepare them for a globalized and interconnected world (ESA, 2010).

Copernicus, with its extensive environmental data, plays a vital role in studying Earth's environment and climate. Integrating Copernicus data into virtual learning environments enriches geography and science education by providing learners with opportunities to study and analyze real-time and historical information about Earth's environment. Students can access satellite imagery, climate data, and environmental indicators, enabling them to explore topics such as air quality, water quality, soil composition, and vegetation health (Schunk & Nagy, 2009). By leveraging Copernicus data, learners can gain insights into the impact of human activities on the environment, study climate patterns, and assess ecosystem health. This integration facilitates interdisciplinary approaches, allowing students to combine scientific analysis, geography, and environmental studies to develop a holistic understanding of environmental challenges. Through the integration of Copernicus, virtual learning becomes a platform for studying and addressing real-world environmental issues, fostering environmental awareness and sustainable practices.

3.2 Enriching astronomy and space science education

Enriching astronomy and space science education through the integration of advanced technologies and resources has the potential to inspire and engage learners in the wonders of the universe. One real case that exemplifies the transformative impact of this integration is the utilization of virtual reality (VR) and augmented reality (AR) in astronomy education.

By utilizing VR and AR technologies, educators can create immersive and interactive experiences that transport students to distant galaxies, enabling them to explore celestial bodies and witness astronomical phenomena in a captivating and realistic manner. Students can virtually visit the surface of Mars, traverse the rings of Saturn, or observe the birth of stars in a stellar nursery. These immersive experiences provide learners with unprecedented depth and clarity, aiding their visualization of complex astronomical concepts such as the scale of the universe or the life cycle of stars (ESA, 2010).

Moreover, VR and AR facilitate hands-on learning experiences in addition to virtual exploration. Using AR applications, students can overlay digital information onto real-world objects, identifying constellations in the night sky or examining telescope anatomy. Interactive simulations and experiments allow students to manipulate variables and observe real-time outcomes, fostering inquiry-based learning, critical thinking, and problem-solving skills as they actively explore and investigate astronomical phenomena.

Furthermore, the integration of VR and AR in astronomy education promotes collaboration and global connectivity. Students from different regions can participate in shared virtual spaces, collaborating on research projects and discussing astronomical discoveries (ESA, 2022). This interconnectivity facilitates the exchange of ideas, cultural perspectives, and collective problem-solving, mirroring the collaborative nature of scientific exploration.

The real case of enriching astronomy and space science education through VR and AR demonstrates the power of technology to bring the wonders of the universe closer to learners (Ciupercă et al., 2022). By providing immersive and interactive experiences, students can develop a deeper understanding and appreciation for astronomy, fostering curiosity, scientific literacy, and potentially inspiring future generations of astronomers and space scientists. As technology continues to advance, the integration of VR and AR in astronomy education will continue to open new frontiers, expanding horizons, and transforming the way we teach and learn about the vastness of the cosmos.

Galileo, Europe's global navigation satellite system, offers a compelling application in the exploration of celestial navigation and space. Leveraging Galileo's precise positioning and navigation capabilities, learners can delve into the intricacies of celestial navigation and gain insights into humanity's place within the vastness of the universe.

A real case that highlights the utilization of Galileo for celestial navigation and space exploration is the "Galileo Astronomy Challenge." This educational initiative, implemented in collaboration with astronomy organizations and educational institutions, provides students with the opportunity to navigate the night sky using Galileo's satellite data. Participants utilize handheld devices or smartphone applications to receive signals from Galileo's satellites. By accessing the precise positioning information provided by Galileo, students can accurately locate celestial objects such as stars, planets, and constellations (Botezatu et al., 2020). Through this immersive experience, learners gain a deeper understanding of celestial navigation techniques employed by navigators and explorers throughout history. They can observe the movements of celestial bodies, track the positions of stars and planets, and calculate their own coordinates based on celestial observations.

Furthermore, Galileo's satellite data enables students to explore space exploration missions. They can follow satellite trajectories, learn about spacecraft launches and orbits, and investigate the paths taken by exploratory missions to other planets and celestial bodies. Galileo's satellite navigation system integrates into virtual learning environments, allowing students to explore celestial navigation and space (De Greve, 2009). This bridges the gap between theoretical knowledge and practical application, fostering a deeper connection to space exploration and the universe. By designing interactive activities, simulations, and field trips, students can embark on missions to celestial bodies, navigate the solar system, and discover challenges faced by astronauts and space probes.

Shifting focus, the Copernicus Earth observation program has become an invaluable resource for satellite imagery analysis and space research in recent years. A case study exemplifies the successful implementation of Copernicus data in a real-world application, highlighting the program's capabilities and impact.

Studying urban heat islands (UHIs) in a rapidly growing city, i.e. localized areas within urban environments that experience significantly higher temperatures compared to surrounding rural areas, is crucial for urban planning, climate change mitigation, and public health management. By leveraging Copernicus satellite imagery and land surface temperature data, a detailed analysis of UHIs can be conducted, at both macro and micro levels. The high-resolution imagery provided by Copernicus satellites allows for precise observations of land cover, building density, and urban morphology. This information enabled the researchers to quantify the magnitude and spatial extent of UHIs across the city. More advanced information on key factors contributing to UHI formation and intensification would be available. The researchers may combine satellite imagery with socio-economic data, air quality measurements, and health indicators to explore the relationship between UHIs and public health outcomes (Kushwaha & Nithiyanandam, 2009; COPERNICUS, 2013).

The availability of high-resolution imagery and comprehensive environmental data provided by Copernicus significantly enhances the accuracy and scope of research in various fields. From urban planning and climate change mitigation to public health management, harnessing Copernicus data enables evidence-based decision-making and supports sustainable development. By harnessing the rich resources provided by Copernicus, researchers can unlock new insights, develop innovative solutions, and contribute to addressing pressing societal and environmental challenges.

3.3 Studying climate patterns and ecosystem dynamics

Copernicus, with its wealth of environmental data, offers invaluable insights into climate patterns and ecosystem dynamics, enabling the monitoring of environmental changes. By utilizing Copernicus data, researchers and scientists can study and analyze climate patterns at various spatial and temporal scales. The availability of satellite imagery, atmospheric data, and climate indicators allows for the examination of temperature variations, precipitation patterns, and the frequency and intensity of extreme weather events. Such analysis aids in understanding the impacts of climate change and contributes to climate modeling and prediction.

Additionally, Copernicus data enables the assessment of ecosystem dynamics and the evaluation of biodiversity changes. By monitoring vegetation health, land cover changes, and species distributions, researchers can gain a comprehensive understanding of ecosystem shifts over time. This information is crucial for identifying areas of environmental concern, tracking habitat loss, and assessing the impact of human activities on ecosystems. With Copernicus data, researchers can evaluate ecosystem resilience, identify areas for conservation efforts, and inform sustainable land management practices (Botezatu & Bucovețchi, 2023).

A real case that exemplifies the application of Copernicus data is the monitoring of coral reefs (Copernicus, 2020). Coral reefs are highly sensitive to environmental changes, and their health is an indicator of the overall well-being of marine ecosystems. Using Copernicus satellite imagery and oceanographic data, scientists can track changes in sea surface temperatures, ocean currents, and water quality parameters that directly affect coral reef health. This monitoring allows for the identification of thermal stress events, such as coral bleaching, and provides early warning systems for reef conservation efforts. By studying climate patterns and ecosystem dynamics through Copernicus data, researchers can better understand the factors impacting coral reef ecosystems and develop strategies for their preservation.

The utilization of Copernicus data for studying climate patterns and ecosystem dynamics demonstrates the transformative impact of Earth observation in monitoring environmental changes. By providing accurate and up-to-date information, Copernicus enables researchers to gain insights into climate trends,

evaluate ecosystem health, and make informed decisions for sustainable management. This real-world application showcases the importance of Copernicus in understanding environmental processes and underscores its role in driving evidence-based decision-making and conservation efforts for a more sustainable future. Satellite imagery obtained through Copernicus missions, such as the Sentinel series, provides valuable data for environmental research and understanding. Researchers can analyze satellite imagery to track changes in land cover, deforestation rates, urban expansion, and the impact of human activities on ecosystems. These observations contribute to the assessment of biodiversity loss, habitat degradation, and the overall health of our planet's natural resources. Through the analysis of satellite imagery, Copernicus enables researchers to identify areas of concern, develop conservation strategies, and monitor the effectiveness of environmental policies and initiatives.

Moreover, the use of satellite imagery for environmental research extends beyond scientific studies. It serves as a powerful tool for raising environmental awareness among the general public (Copernicus, 2019). Visual representations of environmental changes captured through satellite imagery have the potential to engage and educate individuals about the fragility of our ecosystems and the urgency of taking action to protect them. By making satellite imagery and its analysis accessible to a wider audience, Copernicus fosters environmental awareness and empowers individuals to contribute to the preservation of our planet. Through educational initiatives, outreach programs, and public campaigns, the use of satellite imagery enhances environmental literacy and encourages responsible environmental stewardship.

4. Transformative virtual learning experiences

Virtual learning experiences are significantly enhanced through the integration of Galileo and Copernicus, providing interactive applications, simulations, and hands-on exploration opportunities. Simulated excursions and virtual field trips enable students to virtually visit inaccessible locations, fostering curiosity, engagement, and a deeper connection to the subject matter. Copernicus' data facilitates data analysis, environmental monitoring, and the study of human impact on ecosystems. These experiences develop critical thinking skills and an understanding of real-world applications. Virtual learning plays a crucial role in preparing learners for a sustainable future by empowering them with knowledge about environmental issues and inspiring action and responsible behavior.

By integrating Galileo and Copernicus, virtual learning environments provide learners access to real-time and historical information about Earth's environment, climate change, and human impact. Interactive modules, multimedia resources, and data analysis activities enable learners to explore complex environmental concepts, fostering environmental literacy. In this sense, such a systemic perspective can be integrated through communication and coordination

among integrated actors into wider institutional frameworks (Cîrnu & Georgescu, 2023).

Virtual learning inspires learners to act and adopt responsible behavior towards the environment. Immersive experiences, such as simulated excursions and interactive case studies, allow learners to witness the impact of human activities on ecosystems, explore sustainable practices, and analyze the consequences of different choices. Through virtual collaborations and global connectivity, learners can share ideas, experiences, and best practices for sustainable living. Virtual learning empowers learners to become agents of positive change in their communities and beyond.

5. Challenges

Integrating Galileo and Copernicus into virtual learning environments necessitates reliable internet connectivity. Seamless access to satellite data, imagery, and online resources is crucial for leveraging the full potential of these space-based initiatives. Educational institutions and learners must ensure stable internet connections to effectively utilize Galileo's precise positioning and Copernicus' environmental data in virtual learning processes.

Hardware and software limitations pose challenges in integrating Galileo and Copernicus into virtual learning settings. To leverage the capabilities of these space initiatives, educational institutions need to ensure that their hardware, such as computers, tablets, or smartphones, meet the technical requirements for accessing and processing satellite data and imagery. Additionally, compatible software platforms and applications must be available to effectively integrate Galileo and Copernicus into virtual learning environments.

When utilizing virtual learning platforms, it is essential to prioritize the safeguarding of personal information and user data. Educators and institutions must adhere to strict data protection measures to maintain the privacy and confidentiality of learners. This includes obtaining informed consent, implementing secure data storage and transmission protocols, and complying with relevant data protection regulations, such as the General Data Protection Regulation (GDPR) in the European Union. By adopting robust data protection practices, virtual learning platforms can instill trust and confidence among learners, ensuring their personal information remains secure (Georgescu & Botezatu, 2016).

The integration of Galileo and Copernicus data into virtual learning processes must be guided by responsible use and handling practices. Educators and learners should be aware of the ethical considerations associated with the use of satellite navigation and Earth observation data. This involves respecting intellectual property rights, ensuring data accuracy and reliability, and using the data for educational purposes in an ethical and responsible manner. Additionally, learners should be educated on the importance of data privacy, intellectual property rights,

and the ethical implications of using sensitive environmental data. By promoting responsible use, virtual learning can create a culture of data ethics, ensuring the ethical and sustainable integration of Galileo and Copernicus data into educational practices.

6. Conclusions

The integration of Galileo and Copernicus in virtual learning processes holds significant transformative potential. Galileo's precise positioning and navigation capabilities, along with Copernicus' extensive environmental data, enrich virtual learning experiences. Galileo enables interactive map-based learning, simulated excursions, and virtual field trips, fostering experiential learning and interdisciplinary exploration. Copernicus contributes to studying Earth's environment, climate change, and human impact, facilitating data-driven analysis and interdisciplinary projects.

It is imperative for educators, policymakers, and researchers to recognize the value of space critical infrastructures, such as Galileo and Copernicus, in virtual learning. By harnessing these technologies, they can unlock innovative teaching methodologies, expand access to educational resources, and promote global collaboration. Embracing space critical infrastructures in virtual learning will lead to enhanced educational experiences, preparing learners for a sustainable future.

The integration of Galileo and Copernicus in virtual learning signals a promising future for education. The transformative potential of these space critical infrastructures allows for immersive, interdisciplinary, and globally interconnected virtual learning experiences. By leveraging precise positioning, environmental data, and monitoring, educators can offer engaging and authentic learning opportunities. It is crucial to prioritize sustainable education that fosters environmental awareness and prepares learners to address global challenges.

In conclusion, the integration of Galileo and Copernicus in virtual learning has the power to revolutionize education. Educators, policymakers, and researchers should actively embrace these space critical infrastructures to enhance virtual learning experiences worldwide. By doing so, we can shape the future of virtual learning, promote sustainability, and equip learners with the skills and knowledge needed for a rapidly changing world.

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Anti-fraud protection in learning outcomes assessment: from didactic requirements to technological solutions

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Abstract: *The present research turns out to be a theoretical study with methodological and applied accents in the field of educational sciences, as also the professional training of future ICT specialists. The author discusses the problem of educational fraud, examining the phenomenon from a notional, social perspective through the analysis of specialized literature related to the announced topic, here several areas are outlined that intersect and influence each other, such as: (A). educational fraud, cheating, plagiarism, but also (B). the solutions - didactic and technological - are analyzed and proposed for use in order to prevent, reduce, potentially and eliminate the phenomenon of fraud from educational practice, especially from the didactic context of the university environment.*

Keywords: Educational fraud, Digital anti-fraud tools, Methodological anti-fraud tools.

1. Introduction

Periodically, teachers who interact with their students at various stages of schooling and / or professionalization are faced with evidence of fraud acts able to attest the presence and / or quality of skills possessed by students who intend to confirm and / or certify certain knowledge, abilities corresponding to a given field of study (thematic and / or professional area, academic subjects, study program, etc.) and / or a qualification level.

Probably, there are no such types of teachers (primary and / or high schools' teachers; university teaching staff, beginning with mentors, assistants, and lecturers, until the holders of the most notorious scientific and didactical titles in the academy) who have not encountered at least once the phenomenon of fraud and cheating behavior among students.

The purpose of this article is to describe the possibilities of anti-fraud protection through the lens of the analysis of the fraud phenomenon in the assessing process of the skills acquired by the learner during his studies and also to inform the didactic and scientific community about the set of technological tools capable to ensure the protection against educational fraud.

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In the context of the announced goal, the following objectives were formulated: (1). A brief description of the phenomenon of fraud in education from a conceptual perspective; (2). Analysis of the term fraud in education from an ethical perspective, in particular through the prism of the principles formulated by the Council of Europe for the Ethics, Transparency and Integrity Platform (ETINED); (3). Analysis of specialized literature regarding the phenomenon of fraud in education from the perspective of didactic activities related to the evaluation and measurement of skills obtained by the learner with the aim of diversifying evaluation strategies, but also increasing their objectivity; (4). Presentation of the methodological aspects of anti-fraud protection methods applicable in education; (5). The review of technological anti-fraud protection tools, applicable, but also already used in education; (6). The phrasing of conclusions related to this research.

2. The phenomenon of educational fraud (EF)

2.1 Conceptual and ethical context

As a rule, the fraud and misleading behavior of the learner is associated with a formal educational setting, but it can also extend to other situations related to the process of assessment/measuring / proving the competencies of the potential applicant(s) for the particular jobs: either within the various contests with the aim of occupying certain positions; admission to another level of studies, professional activity; and also for participation in various competitions with the aim of determining eventual, the best, winners.

Regardless of obtaining which facilities or access to certain goods, **fraud, and deception is the act that deprives the one who deserves it** (in this role can be anyone, a natural and/or legal person represented by any public or private institution, sometimes even by the state itself) **of something valuable**.

Speaking of a formal institutional educational framework, we refer to all educational organizations, whether public or private, recognized by the authorities of a country that operate in the field of education and provide services related to the declared field within institutionalized, intentional, and planned limits.

Currently, the formal institutional educational framework of a country consists, for the most part, of initial and general education institutions, educational institutions for beneficiaries with special needs, and institutions that offer special educational programs, these being part of the field of adult education, but and vocational education institutions.

The latter are also recognized as components of professional education (Tertiary education, starting with level 3-4 ISCED and ending with level 5-7 of studies, these being usually delivered by universities), a fact defined in accordance with the International Standard Classification of Education ISCED 2011 issued by

The UNESCO Institute for Statistics (UIS) (UNESCO Institute for Statistics, 2012). There is also a dedicated term for frauds tangential to educational processes/activities. This term is "Educational Fraud" (EF), defined by the Council of Europe for Ethics, Transparency, and Integrity Platform (ETINED).

In the determination given by ETINED, EF is associated with behavior or action occurring in the field of education, intended to deceive and obtain an unfair advantage. Correspondingly, in the ETINED's view, EF could include more activities such as:

- A. The activities of diploma, accreditation, visa, and essay bank factories, etc.;
- B. Impersonation by performing in whole or in part any work or assessment required as part of a program in place of an enrolled student;
- C. Illegal or unregulated use of authentic documents;
- D. Copying the learning results to the assessment tests (of different levels and in various didactic contexts);
- E. Plagiarism;
- F. Producing or using falsified, plagiarized, or counterfeit documents;
- G. Offering unrecognized or unaccredited qualifications with intent to defraud another.

In our article, we are going to discuss more regarding the aspects that can serve as solutions to the problems contained in points B, D, and E. These are elements that are directly within the scope of education sciences, general and / or particular didactics; are embedded as some educational management components (Burlacu, 2022d), and also as issues related to the process of managing the technical and technological infrastructure to secure the contents of evaluation/measurement/markings of learning results.

The Platform for Ethics, Transparency, and Integrity of the Council of Europe (ETINED) delivered a series of rules called "ETINED Principles" which would be followed and promoted in accordance with its mandate. The "ETINED Principles" authors were based on the idea that **quality education should only be achieved when educational fraud will also be effectively addressed**. This was a goal forwarded when issuing the "ETINED Principles".

In other words, the "ETINED Principles" will be real to apply if all relevant sectors of society adhere fully to a set of fundamental ethical principles, both in public and professional life, while being based on legal norms and structures such as the development, integration, and support of the culture of " [...] democracy and participation based on the principles of ethics, transparency, and integrity in education" (UNESCO Institute for Statistics, 2012). So, one of the tools able to support the promotion of quality education is the fight against educational fraud.

2.2 Review of the specialized literature: the dimensions of the EF problem

Scientific articles that discuss various aspects related to the phenomenon of educational fraud address a wide spectrum of subjects, some of which outline new sides of the stated problem, others come with certain didactic solutions either of purely methodological content or with technological implications, but all being characterized through a series of operationalization modalities that would allow the easy application of these ideas in practice. In particular, we consider it worth mentioning the following topics related to the given research problem:

I. The aspects associated with the methodology of organizing and carrying out the assessment process of the learning outcomes of students in various disciplines, but also through the application of various strategies, methods, and/or techniques, such as general and particular didactics:

- Computer Science and professional training of future ICT specialists (Burlacu, 2016);
- The assessment of the learning progress during optional courses in the curricular area of Romanian language and literature through projects (Cartaleanu, 2017) and test-type tests (Cartaleanu, 2018);
- The teaching-learning-assessment of the subject Chemistry by applying interactive methods, but also by means of eLearning techniques and tools, including the Moodle platform utility (Melentiev, Calmuțchi & Cerbușca, 2021).

II. The analysis of the possibilities of developing and implementing innovative strategies for evaluating the learner's skills, these being based on the diversification of evaluation methods and procedures, as well as capitalizing on their potential (Burlacu, 2022a; Burlacu, 2022c).

- Reflecting on the theoretical benchmarks of some methods and procedures able to support the teaching staff in building a modern assessment strategy of learning outcomes of the learner on the example of the specific didactic context of the study programs with the specializations in the field of Computer Sciences and ICT (Burlacu, 2016; Burlacu, 2022c);
- Description of a formative assessment tool based on criteria and descriptors that could be implemented within the educational activities specific to seminar classes within the study programs of specializations with professionalization in the field of Computer Science and ICT, but not only (Burlacu, 2021c).

III. The assessment of technology-assisted learning outcomes (Balmus & Burlacu, 2017; Burlacu, 2020a; Burlacu, 2020b; Burlacu, 2022b). Given the direction of research is represented by studies that touch on the side of digital

transformations (Burlacu, 2021d; Burlacu, 2021e) that all of us are traveling through, as the actors who design, create, and implement the changes. And, above us, as members of society who go across the torrent of metamorphoses of the digital age—related to the changes in the educational process (Burlacu, 2022c; Burlacu, 2022d).

- The ways of creative assessment, either assisted by technology or organized and carried out with the aim of developing skills that generate innovative ideas (Burlacu N., 2022a) and are sustainable and/or have the potential to train future generations of responsible people, able to think critically and strategically, as well as to act rationally (Burlacu & Irimiciuc, 2018; Burlacu, 2022c).

IV. Works that debate some forms of educational fraud phenomenon, such as plagiarism, and also some software solutions for checking plagiarism (Burlacu & Irimiciuc, 2017; Burlacu, 2022a);

V. The use of LMS platforms for educational purposes, obviously also to evaluate the skills acquired throughout the studies: capitalizing on the actual tools available on Moodle (Deinego, 2016; Burlacu, 2021a; Burlacu, 2021b) and/or virtual classes (Burlacu, 2020a).

3. Anti-fraud protection methods

3.1 Methodological aspects of anti-fraud protection

Obviously, it is insufficient to talk to students about undesirable behaviors during assessment tests, but also their consequences. Although each educational institution reflects the given aspect in its internal regulations, regardless of whether or not there is a code of ethics that establishes the attitude towards such actions, as a rule, the teaching staff also does this there.

Every member of the teaching staff, in his/her turn, was once a student. Moreover, since he/she was passing along the professional training through multiple assessments, exams, checks, and confirmations, today's teacher has encountered at least one such case of fraud in evaluation tests. Does not matter what kind and/or level of studies it was about, and it is not also important about what type of status he/she was in when these happened: he/she could be in the position of a student/trainee, or in the position of a teacher already.

As our basic purposes in the present material are: (A). The analysis of the fraud phenomenon in the assessment during certifications and/or colloquiums, tests and/or passing exams, and the completion of a discipline (either school or university, etc.); (B). The description of some technological tools to prevent the phenomenon of copying, plagiarism, and/or any other kind of deception that would devalue and/or reduce to zero the credibility and authenticity of the learning results.

We would like to mention that, certainly, there are also methodological solutions for designing, structuring, developing, and applying assessments so that they are less exposed to the risk of fraud. Broadly speaking, among the respective measures we could list the following:

- **How to construct/formulate the questions in the sheet/form/evaluation grid.** Here we mean that it should be conceptualized in such a way that from the start will exclude the student's need to search/find the answer on the Internet so that the correct answer is trivially copied and placed in the given assessment place and presented as his own. Resulting of this approach, the items formulated for a possible assessment test of the learning outcomes should contain complex and creative components (even in the case of exact sciences). So that the given answer would reflect the capacity of analysis, synthesis, generalization, and deduction of the evaluated student. It is clear, that the development of such assessment items also requires a higher degree of competence, creativity, and dedication from the teacher.

It is easier to make superficial test sheets that a priori do not have the potential to measure the depth and quality of the skills, knowledge, and abilities possessed by the student, and also to confirm the veracity and/or belonging of the particular answer to the evaluated learner. Without a doubt, if the assessment and/or tests are more standardized, the answer given by the student, will not bear the individual imprint of him/her. Only argumentative and/or open-text answers, essays, and code design in a programming language will bring clarity to the originality of the answer, but also of the assessment itself.

- **The developing of unique assessments for each student.** There are several scenarios here. The uniqueness of the assessment variant can be implemented either by developing an X number of test variants, equal to the number of students to be evaluated; or by diversifying/customizing only a certain part of the test with an obvious application content.

For example: When we are talking about the real sciences, only the problem(s) proposed to be solved within the practical task can be different from one variant to another variant. Providing that the practical task will reflect the same degree of complexity, and also will test potentially the same skills of each learner. In the case when exist a few assessment variants should be distinct at least the operational values, and/or some problem statement aspects, and/or some content of the initial template of the assessment grid.

- **Carrying out identity verification of the assessed.** The given procedure is also called the identity authentication process and consists of taking measures to ensure that the student who wrote the answers is also the student who will take the grade. Physical supervision of the classroom by the teacher and his assistants (including surveillance through the camera) also is opportune here. If the exam is online, digital solutions can be used to perform two-factor authentication (2FA) when accessing the system and entering the teaching-learning-assessment platform.

2FA is a security system that requires two separate, distinct ways of identification in order to access something (in educational needs it can be, as in our case, the teaching-learning-assessment platform). Usually, the first factor is a password and the second commonly includes a text with a code sent to the user's and/or learner's smartphone. In circumstances requiring increased security levels, the given 2FA systems can include the biometrics data scan such as the user's fingerprint, face, or retina.

- **Assessment Course: Fraud Prevention by Intervening in the Process of the Assessment.** If there are suspicions that the assessment is fraudulent and/or there are signs of undesirable student behavior, the assessment test (digital grid or paper) can be removed from final verification with or without canceling what was written, and the student can be penalized.

There are numerous reports about fraud cases and deception discovered during the assessments carried out in reputable educational institutions (public and private schools, colleges, and universities) in the international mass media sources. The reflected of the international press's occurrences ended with the sending down of the students who committed these violations.

3.2 Technological anti-fraud protection tools

The fact is that currently there are technological tools that could reduce and / or eliminate actions related to the fraud phenomenon of the learner in the world.

Conventionally speaking these are of two kinds: (1). Hardware, and also (2). Software.

From the hardware category, we refer to the possibilities of external supervision of the evidence-supporting process, the one that takes place under the video cameras, as is happening at the baccalaureate sessions in the Republic of Moldova beginning in 2012. We will talk about a few software anti-fraud protection solutions.

3.2.1 Mobile authentication apps

These kinds of applications (see Table 1) offer the connecting possibility to various online accounts, as well as websites through 2FA, or even multi-factor authentication.

Table 1. Mobile Multi-factor Authentication Apps

ON	Application Description (App Name & Producer)
1.	<i>Duo Mobile App; Cisco; USA</i>
The application is intended for enterprise users who deserve the software development process. Given product has proposed a set of innovative	

	business organization features, especially, (A.) the multi-user deployment and provisioning options and (B.) one-tap push authentication. The last one is a mechanism that responds to a single tap in comparison with usually used one-time passcodes. Duo Mobile backups can be performed using: Google Drive for Android and/or iCloud KeyChain for iPhone.
2.	<i>Google Authenticator; Google; USA</i>
	The given application is a basic one with additional possibilities for its own services, such as Microsoft Authenticator. Google Authenticator does not offer an online backup for account codes, although the user can import them from an old phone or another digital device to a new one. It should be mentioned that there is currently no Apple Watch app for Google Authenticator.
3.	<i>Microsoft Authenticator; Microsoft; USA</i>
	Microsoft Authenticator incorporates strong password generation and lets you sign in to Microsoft accounts with the push of a button. The app also allows educational organizations and workplaces to register users' devices. In the case when the user adopts this app, it should make sure to enable account recovery. That way, when the user gets a new device, he / she'll see a recovery option by signing in to his Microsoft account, providing more steps of verification. The user can request to unlock his/her phone with a PIN or biometric verification to see the codes. Password management options can be found in a separate tab at the bottom. Also is possible to sync with the user's Microsoft account associated with the alternative authenticator, and then he/she would see own logins saved and synced, for example, in the Edge browser. There is one problem (and it's an Apple lock-in problem) here if a user backs up to iCloud, you can't transfer your saved MFA accounts to an Android device, even though this is the case with most authenticators that offer cloud backup.
4.	<i>LastPass Authenticator (used for iPhone); GoTo, formerly LogMeIn; USA</i>
	The LastPass Authenticator is separate from the LastPass password manager, although it does offer some interaction with the password manager. Installing LastPass Authenticator is a breeze, and if the user already has an MFA-enabled LastPass account, he/she can easily authorize LastPass by tapping a push notification. Also, once the app is set up with the user's LastPass account, it's easy to back up the login accounts to the LastPass vault, which optimizes the process of data transfer to a new phone.
5.	<i>Twilio Authy; Twilio; USA</i>
	One of Twilio Authy's big advantages is the encrypted cloud backup. Nevertheless, it is worrying that the analyzed app can add up another phone using "a PIN code sent-a call or an SMS", which is able to open in a new window. There's an extra option to enter a private password or

passphrase that the given product uses to encrypt login information for your cloud accounts.

The password is known only to the user, so if he/she loses it, this app will not be capable of recovering the account. Certainly, it means that authorities cannot force Authy owners and/or developers to unlock users' accounts. Unlike the other products with similar functions, described in the present paper, the Authy app requires the user's phone number when he/she first configures it. This requirement is the best solution for the majority of users as they would prefer the app to treat their phones as anonymous hardware pieces. Moreover, some experts have suggested that asking for a phone number opens the app up to SIM-swapping fraud. The Authy Help Center proposes ways to mitigate the vulnerabilities, but some beneficiaries choose to work more with authentication apps made by other corporations. The Apple Watch app version has been developed for those devoted users who need and plan to use it in any case.

Authenticator Apps like the ones listed above - Authy, Google Authenticator, and Microsoft Authenticator represent cyber security ways. The use of such application would ensure the protection of the user's identity and/or his / her reputation.

Because in our case, we are talking about the assessment process of the learning outcomes and/or about the final decision during a competition, etc. which is intended to confirm, and then certify the eligibility of the assessed candidate for a possible position that requires a certain level of competence and/or entry into possession of a diploma for the successful completion of a course and/or of the study program, etc. we adhere to the opinions of cybersecurity and GDPR (General Data Protection Regulation) policy experts who confidently recommend these digital tools, including for educational and anti-fraud purposes.

3.2.2 Kiosk mode analysis: functionality and usability

Kiosk Mode is a feature, mostly provided to users of a range of operating systems such as Windows, Linux, Ubuntu, and Mac.

This mode can be characterized as a digital tool that enables the smart display of an application in a full-screen mode on a secured device. This function exists for several versions of browsers. Thus, some are able to run Google Chrome, Microsoft Edge, and Mozilla Firefox.

The Kiosk mode configuration provides the user's computing system with a protected and focused browsing environment where corporate users, such as educational institutions – colleges and universities; companies in various social, economic, and industrial sectors could: (A). increase the productivity of employees and beneficiaries and/or (B). streamline the user experience by providing secure connections to implement host business resources.

Among the beneficial characteristics of the implementation of the Kiosk mode in didactics are considered:

I. Increasing the assessor's concentration on digital content *that can be both learning-teaching and assessment of the learning objectives.* Increasing the user's focus is achieved by restricting the ability to navigate to websites and/or web applications with certain contents. In the case of employees and not students, it can be used to reduce the possibility of distracting employees from professional activities during working hours; while in the case of students to eliminate, and reduce the consultation of didactic contents for the purpose of copying and cheating on assessment tests.

II. Increasing the level of cyber security. *Kiosk mode prevents users from accessing unauthorized Web locations and/or intentionally or unintentionally changing system settings.* The Kiosk module provides a secure browsing environment, protecting: (A). The sensitive information (commercial, and also non-commercial, but which should not be disclosed; in our case, this could be - the contents of the evaluation sheets and or the bank of items); (B). The computer system against malware and/or theft of personal and or commercial data.

III. Provides the user with a relatively simple interaction experience *during intuitive browsing sessions, transforming the virtual workspace into an ideal protected area for both ICT professionals and other types of users.* The Kiosk mode users will manipulate readable, highly functional, unambiguous menus. It means the given menus will not create any misunderstanding regarding the action that will be produced after activating the menu command by the user. To rephrase it, users won't feel like they're navigating through a maze of menus, which will allow them to not worry about causing accidental actions.

IV. It showcases branding and customization options to companies and educational institutions that use it. Kiosk mode allows host institutions that choose to use the tool to tailor their browsing experience to their specific needs. It allows customization of the web location landing page: (A). with or without displaying the institution's brand with or without (B). to provide information regarding the services it can offer; (C). thus, strengthening the potential for brand identity and improving user engagement.

It is certain the use of the Kiosk mode promotes concentration and improves the general productivity of users, but it also diminishes. Also is proven the Kiosk mode reduces to zero the cheating possibility on assessments which aim the measuring the skills and knowledge acquired by students. This was the reason for the integration of the given mode in the Learning Platforms or course management system (CMS), such as Moodle.

In our opinion, both types of analyzed digital anti-fraud tools - 2FA-type applications and Kiosk mode facilities for Web applications - have a broad spectrum of valuable features. We consider that these are able to improve multiple

didactic aspects not only in the context to ensure anti-fraud protection during assessments of learning outcomes. We believe that the described technological solutions also have the potential to increase the quality of the learner's acquisition of the assimilated material. Also, these may aid the student to produce in more depth reflections (exposed within the assessment activities), by creating an appropriate individual psychological and emotional comfort.

Using the solutions listed above, the teacher will not have to be the guardian of the assessed student, and the student could be sure that the inviolability of his identity will be respected; and the answers given by him during the evaluation will be measured and quantified in an impartial and standardized way (it means the same evaluation criteria will be applied as for his other colleagues during the assessment of learning outcomes).

4. Conclusions

The experience of combining several digital tools, such as those described in this article - of authentication applications that eliminate the possibility of unauthorized access to certain educational contents and/or Web locations with the use of Kiosk mode, including in the Moodle system - substantially reduces, and in some places, it even eliminates situations of fraud in the assessment of the learning objectives.

It is worth mentioning that such practices are implemented at the Technical University of Moldova. In particular, the accessing method of the available online several institutional microservices is achieved through double authentication (2FA) for all categories of users, from students and teaching staff to employees of the auxiliary, non-teaching staff, and also the administrative staff.

As for the use of the Kiosk mode, usually, it is personally configured by the teacher and/or Moodle course creator, as well as used for periodic, current, and/or final assessment activities that can be organized both online and in mixed - these are the facts that happen.

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On the development of educational resources for smart industrial manufacturing teaching and learning

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Abstract: *Smart industrial manufacturing systems development is based on an efficient education of manufacturing engineers that integrates advanced technologies (e.g. related to Industry 4.0). From the academic education point of view, an important issue that need to be addressed when developing e-learning platforms or different types of tutoring systems for computer aided learning (such as distance learning or online learning) refers to educational resources identification, design, and implementation. A literature review in this area reveals different types of educational resources as for example: theoretical resources (e.g. course modules), practical resources (e.g. laboratory or seminar modules), ontologies, software tools, educational applications, demonstrators, and simulations. The paper presents methodological issues associated with the development of educational resources for smart manufacturing teaching and learning. Also, some educational resources, a prototype ontology and some simulations for industrial manufacturing are discussed.*

Keywords: Educational resource, Smart manufacturing, Learning process, Ontology, E-learning.

1. Introduction

The new software and hardware technologies that are or will be integrated in modern industrial manufacturing systems (more efficient and customer-centered) based on Industry 4.0 require the development of specific educational resources for an efficient education of future manufacturing engineers. Different types of educational resources need to be included in computer-based education systems. Examples of such types of resources are: course modules, laboratory modules, ontologies, software tools, applications, demonstrators, and simulations. Engineering education is based on laboratory work, thus, either real-world laboratories (directly or remotely accessed), or simulated/virtual laboratories are essential educational resources. Moreover, theoretical notions as well as practical aspects (given, for example, by simulations, demonstrations) should be basically given by a domain ontology that explains manufacturing fundamental concepts and the relations between them. A methodology for the identification, design and implementation of the educational resources for smart manufacturing teaching and learning is proposed in this paper. A case study of applying the methodology for a smart manufacturing system development is presented.

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It is important to highlight that laboratory work (simulated, virtual or real-world) in the industrial manufacturing domain is fundamental for the success of future manufacturing engineers. Thus, simulations and demonstrators are essential for their education. An example is given by the simulation of a flexible production line (see e.g. (Stan & Oprea, 2022)) which is a basic educational resource for a manufacturing engineer working in an enterprise.

An important remark related to smart manufacturing education is that the fourth industrial revolution based on Industry 4.0 that incorporates smart technology, artificial intelligence and robotics, has a correspondent type of learning approach given by Education 4.0 that has four core components as described in (Miranda et al., 2021): competencies, learning methods, information and communication technologies, and infrastructure. The learning outcome in Education 4.0 is training of key soft and hard competencies using online sources and a student-centered approach, where the student has an active role.

The paper is organized as follows. Section 2 presents briefly a literature review on selected educational resources/systems in the manufacturing domain and proposes a general methodology for the development of some educational resources for smart manufacturing. A case study is described in Section 3 focusing on some educational resources that were developed for industrial smart manufacturing such as a prototype ontology and simulations. The final section concludes the paper and highlights future works.

2. Manufacturing education

2.1 Literature review

Modern manufacturing systems are currently named as intelligent or smart, both terms being similar but not identical. In general, smart manufacturing refers to the use of smart/intelligent technology (e.g. smart sensors, cloud computing, digital twin) while intelligent manufacturing is based on artificial intelligence and machine learning. A comparative review is detailed in (Wang et al., 2021).

A set of recently reported educational systems or educational resources (e.g. demonstrators, simulators, methodologies, reviews) developed for the manufacturing domain were selected and we present a synthesis of them.

A demonstrator for engineering education in the area of digital manufacturing is presented in (Keaveney et al., 2021). The authors provide details related to the design and implementation of such a demonstrator that is a valuable educational resource for students that will be future manufacturing engineers.

A systematic literature review on training simulators for manufacturing processes such as welding, assembling and soldering is presented in (Knoke and Thoben, 2021). The authors analyzed also the applicability of the simulators.

A material flow design methodology for flexible manufacturing systems is proposed in (Florescu & Barabas, 2020). The main purpose of the methodology is to generate the optimal architecture of the manufacturing system. The authors used Tecnomatix Plant Simulation 15 software developed by Siemens.

The use of ontologies in smart manufacturing is discussed in (Shilov et al., 2020). The authors present a framework for ongoing study of planning and control based on ontology for smart manufacturing systems.

A core ontology that conceptualizes theoretical knowledge associated to production equipment monitoring, diagnosis and forecasting according to Industry 4.0 is introduced in (Vlasenko et al., 2022). A set of terms and relationships were identified, defined and characterized for the description of equipment state during the manufacturing process.

An example of ontology for manufacturing systems developed according to Industry 4.0 is described in (Ramírez-Durán et al., 2020). The authors designed with NeOn methodology and implemented in Protégé, ExtruOnt, an OWL ontology for the description of an extruder machine.

A recent article (Jing et al., 2022) that tackles education sustainability for intelligent manufacturing in the context of current developments in the domain of artificial intelligence (focusing on machine learning, deep learning) provides a detailed analysis of the published literature. The analysis performed by the authors is an educational resource related to the evolution of the manufacturing domain focusing on the use of artificial intelligence in manufacturing during the period 1979-2021.

The development of educational laboratories under Education 4.0 approach is tackled in (Cordero-Guridi, 2022). Virtual and digital technologies were applied for the design and implementation of an automotive manufacturing laboratory according to the guidelines of ISO/IECTR 23842-1 standard.

Remote and virtual laboratories developed for mechanical engineering education are discussed in (Grodzki et al., 2018).

A remote laboratory for online smart manufacturing education developed at a German university is presented in (Terkowsky et al., 2019). The authors analyse the suitability of a remote experiment for smart manufacturing competencies teaching by using a modern engineering Education 4.0 laboratory.

The use of suitable software packages for the simulation of production lines in engineering education is analysed in (Rostkowska, 2014). The author evaluated three programs: Arena, FlexSim and Tecnomatrix Plant Simulator. Depending on the specific industry as well as on course goals it is selected the suitable program.

An important paradigm that was introduced in manufacturing education is connected to the Teaching Factory concept (Mavrikios et al., 2013) that integrates support for the “knowledge” workers in the future factories. Actually, it integrates

learning and working environments, academic and industrial organizations, providing novel long-life learning schemes for the last achievements in technology, tools and techniques for an efficient industrial production. The teaching factory network viewed as a new collaborative form of education in manufacturing is presented in (Mavrikios et al., 2019). In such a network, academia and industry are connected providing specialized educational resources.

From the brief literature review that was presented, we can conclude that the main educational resources that are proper for a practical manufacturing education are: demonstrators, simulations, educational laboratories, manufacturing software, ontologies, case studies, reviews etc. Also, more of the latest educational resources that were reported in the literature were developed according to Industry 4.0 for smart/intelligent manufacturing systems.

2.2 General methodology for manufacturing educational resources development

The main steps of the general methodology for developing educational resources for smart manufacturing education are given as follows:

General Methodology for course educational resources development (Course_EduRes)

Input: course type, course level, course goals - smart manufactory, type of industry

Output: educational resources for teaching and learning (EduRes_Teach and EduRes_Learn)

1. Identify the *educational resources* that are necessary for the course teaching/learning
2. Design the educational resources that were identified for teaching and learning
 - 2.1 Design the *course domain ontology/ontologies* with basic and advanced terms and relations
 - 2.2 Design educational resources for a laboratory work (simulators, demonstrators)
 - 2.3 Design some educational applications (case studies)
3. Implementation of the educational resources that were designed at step 2
 - 3.1 Ontology/ontologies implementation
 - 3.2 Simulators and demonstrator's implementation
 - 3.3 Implement the educational applications (case studies)
4. Testing the educational resources that were implemented at step 3
 - 4.1 Testing the prototype ontology
 - 4.2 Testing the simulators, demonstrators and educational applications

4.3 Evaluation of the tested educational resources from teacher/learner viewpoint

5. Return EduRes_Teach, EduRes_Learn

The main types of educational resources that can be used for smart manufacturing teaching and learning are shown in Fig. 1.

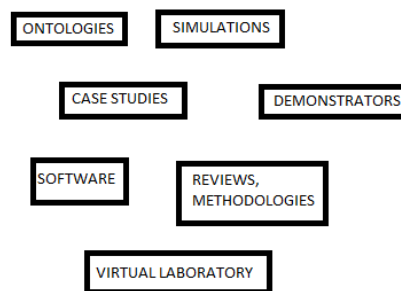


Figure 1. Main types of educational resources for smart manufacturing

During the first step of the methodology the educational resources that are necessary for smart manufacturing course teaching and learning are identified, for a specific type of industry, according with the course goals and level. For example, a general ontology for manufacturing and more ontologies (for equipment/machine, production lines, type of industry, smart/intelligent manufacturing etc), demonstrators (industry specific manufacturing process demonstrator), simulators (flexible production line simulator), and industry specific case studies.

In the next two steps, the educational resources identified in step 1 are designed and implemented with specific methodologies and software. Finally, the educational resources that were developed are tested and evaluated by teacher and students.

3. Case study: educational resources for smart manufacturing systems

3.1 A prototype ontology

The main educational resource that we propose for smart manufacturing education is a prototype ontology that we have developed in Protégé 4.3, Onto-EduSmartManufact 1.0. The ontology includes basic terms (such as process, task, machine, robot, assembly robot, welding machine, production line, flexible production line) and advanced terms related to smart and intelligent manufacturing (e.g. predictive maintenance, data analytics, digital twin, cloud computing, artificial intelligence, machine learning, deep learning). Also, we have added terms related to manufacturing software (including software for modelling and simulation) that is used for the implementation of demonstrators, simulators and various real-world case studies.

We have included in the ontology a set of terms for learning methods. Figure 2 shows the taxonomy for learning methods proper in smart manufacturing education.

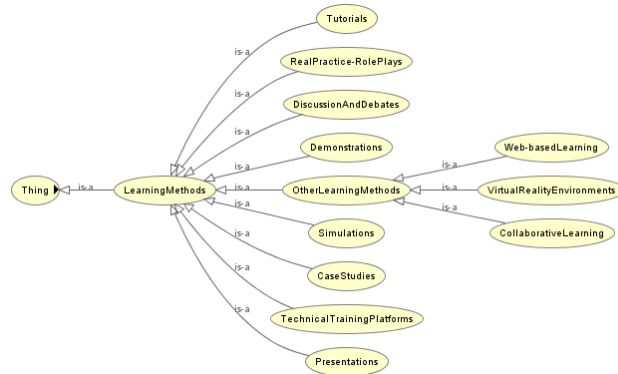


Figure 2. The learning methods taxonomy

Figure 3 presents some terms specific to control in case of smart manufacturing that were included in the prototype ontology. For example, the quality control of a product can be made either by visual inspection (with a camera and image processing and recognition module) or by vibration analysis.

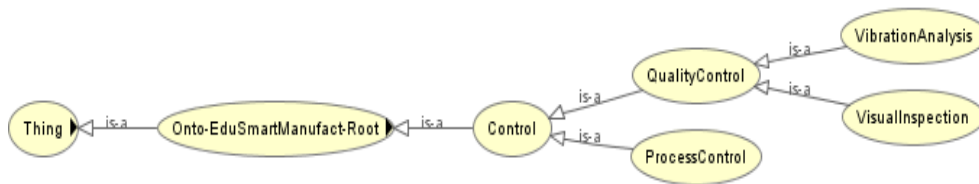


Figure 3. The control taxonomy

As in smart manufacturing, robots are important components, we have included in the prototype ontology some types of robots, as e.g. assembly robot, welding robot and painting robot. In figure 4 it is depicted the robot taxonomy.

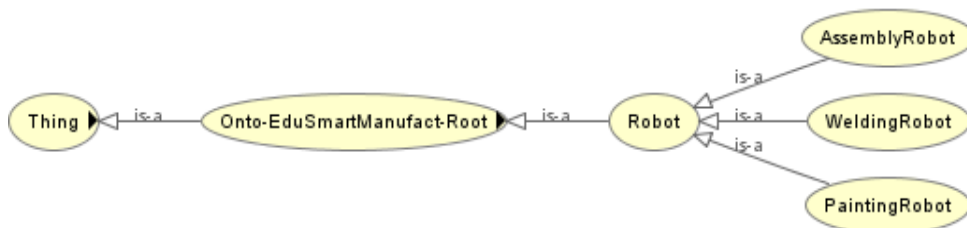


Figure 4. The robot taxonomy

An important issue that is tackled by smart manufacturing is that of equipment maintenance approach. In Figure 5 is shown the taxonomy of the maintenance concept.

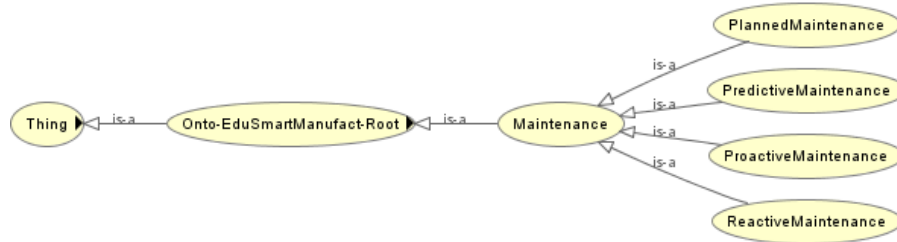


Figure 5. The maintenance taxonomy

Figure 6 shows the main types of processes that were considered in the prototype ontology. Examples of concepts from this taxonomy are packaging process, sorting process, assembling and welding.

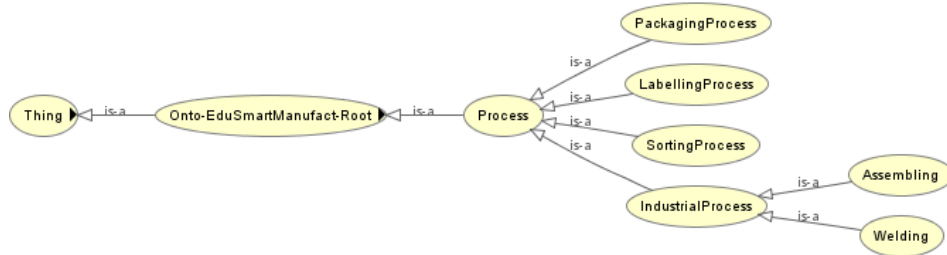


Figure 6. The process taxonomy

Finally, figure 7 depicts the taxonomy for manufacturing software that can be used for modelling, simulation and development of smart manufacturing systems.



Figure 7. The manufacturing software taxonomy

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graph LR
    Thing -- is-a --> OntoEduSmartManufactRoot[Onto-EduSmartManufact-Root]
    OntoEduSmartManufactRoot -- is-a --> ArtificialIntelligence
    ArtificialIntelligence -- is-a --> KnowledgeBasedSystem
    ArtificialIntelligence -- is-a --> CaseBasedReasoning
    ArtificialIntelligence -- is-a --> DataMining
    ArtificialIntelligence -- is-a --> ComputationalIntelligence
    ComputationalIntelligence -- is-a --> ArtificialNeuralNetworks
    ComputationalIntelligence -- is-a --> FuzzyLogic
    ComputationalIntelligence -- is-a --> GeneticAlgorithms
    ExpertSystem -- is-a --> KnowledgeBasedSystem
  
```

Summarizing, each basic or advanced concept from the prototype ontology is defined and characterized by attributes with specific constraints, and relations with other concepts. Apart from the taxonomic relations (*is_a*, *a_kind_of*), other relations such as *has*, *part_of*, *component_of*, and various domain specific relationships are included.

3.2 Simulators

Examples of simulations that can be developed by teachers for course preparation and by students for practical applications development are flexible production line modelling with PetriNets and simulation with Matlab-Simulink, and demonstrators for different types of machines or robots that execute some manufacturing tasks. For example, a virtual learning simulator for product manufacturing implemented with PetriNets was presented in detail in (Stan and Oprea, 2022). In this case, the educational resource that was developed, a simulator of a flexible bottling production line composed of a number of five main workstations, will help students to better understand the manufacturing process. A recent example of flexible manufacturing system simulation with FlexSim software (Gelenbe and Guennouni, 1991) is provided in (Azarian et al., 2021). This example can be used as an educational resource to show the cases of machine failure when reconfigurable machines are used in order to compensate the production loss of a specific production line. Students can learn how to improve the performance of a manufacturing process to have a better reaction to unexpected events occurring in the production line.

4. Conclusions

This paper presented a general methodology for developing educational resources for smart manufacturing systems and a prototype OWL ontology, Onto-EduSmartManufact 1.0, implemented in Protégé that can be used as an educational resource for teaching and learning smart manufacturing.

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TASMANIAN: Virtual lab software platform for teaching functional programming

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Abstract: *The need for efficient and interesting platforms that teach difficult programming paradigms is expanding quickly in the contemporary programming education environment. The full TASMANIAN platform described in this paper is created to make it easier to teach and master functional programming theoretical concepts and practical implementations. The platform, known as "TASMANIAN," uses interactive coding exercises, dynamic visualizations, and a user-friendly interface to overcome the difficulties of teaching functional programming.*

The main goal of the work is to present the TASMANIAN architecture, to underline its importance to students as an immersive learning experience that actively involves them into coding problems. The platform includes elements like a Coding Playground, Challenge Engine, Interactive Visualizations, and Modules focused on fundamental concepts in functional programming. Together, these elements give students the opportunity to practice pattern matching, experiment with functional data structures, and understand the subtleties of monadic composition.

Keywords: Functional Programming, Haskell, F#, F Sharp, Scala, Programming, Education, Virtual Lab.

1. Introduction

The field of programming education is constantly changing, necessitating creative methods for efficiently introducing complex programming concepts. Functional programming stands out among these paradigms for emphasizing immutability, higher-order functions, and compact code. Immersive and interactive platforms play a critical role as educators work to close the gap between theory and practice.

The TASMANIAN platform represents in our vision an important added value to programming education that is presented in this paper. To make functional programming principles easier to teach and learn, TASMANIAN was created. With

its dynamic visuals, interactive coding challenges, and user-friendly interface, TASMANIAN provides a stimulating environment that enables students to not only comprehend but also put functional programming principles into practice.

The rise of functional programming as a career field highlights the significance of strong educational resources. Traditional techniques frequently have trouble communicating both abstract ideas and real-world applications at once (Dobhal et al., 2023). By giving students a platform that combines theoretical instruction with direct hands-on experience, TASMANIAN overcomes this difficulty. TASMANIAN promises to provide students a thorough understanding and practical mastery of this paradigm by allowing them to experiment with functional programming ideas in real-time (Angione et al., 2023).

The importance of good instructional resources is brought home by the growth of functional programming as a career sector. Traditional methods sometimes struggle to convey both abstract concepts and their practical applications simultaneously (Zampetti et al., 2022). TASMANIAN gets around this problem by providing students with a platform that blends theoretical training with immediate hands-on practice. By enabling real-time experimentation with functional programming concepts, TASMANIAN promises to provide students a complete knowledge and practical mastery of this paradigm (Asakawa et al., 2022).

1.1 The future of functional programming

As technology landscapes change and programming paradigms advance, the future of functional programming promises intriguing possibilities. Future developments in functional programming may be influenced by the following major trends and directions:

- *Functional programming* ideas are likely to find their way into popular programming languages as they gain in popularity and understanding. Possible hybrid programming languages that support a wider range of programming requirements include both imperative and functional programming elements (Zampetti et al., 2022).
- *Parallel and concurrently programming* is possible thanks to functional programming's intrinsic emphasis on immutability and the absence of side effects. Functional programming may become the method of choice for dealing with concurrent issues as the demand for effective utilization of multi-core computers and distributed systems grows (Asakawa et al., 2022).
- Building *responsive and interactive applications* is becoming more popular thanks to functional reactive programming (FRP). To handle changing state over time, it makes use of functional programming principles. FRP may become a key strategy as user interfaces become more intricate and engaging (Borsatti et al., 2022).

- *Domain-Specific Languages (DSLs)*. The expressiveness and composability of functional programming make it suited for the development of DSLs. By offering specialized abstractions for problem domains, these languages can increase developer productivity and code readability (Bhat et al., 2022).
- *Data-centric subjects like machine learning and data science* are ideally suited to functional programming's emphasis on data transformations and composability. Functional programming libraries and tools may become more prevalent, especially those made specifically for analyzing and manipulating data (Zhang et al., 2022).
- *Cloud computing and serverless computing*. The serverless computing approach is consistent with the functional programming principles of immutability and statelessness. Building scalable, event-driven serverless applications might be a good fit for functional programming languages (Parham-Mocello et al, 2022).
- *Type Systems and Tooling*. It's expected that advanced type systems will continue to be incorporated, as seen in languages like Haskell. Enhanced type systems can detect problems at build time, resulting in codebases that are more dependable and maintainable. Functional languages may also become easier for developers to use with better tooling and IDE support (Izuta et al., 2021).
- *Education and Training*. Education and training resources will increase as the need for functional programming abilities rises. A greater pool of qualified functional programmers will be produced because of online courses, tutorials, and interactive platforms (Maguerra et al., 2021).

Functional programming has a bright future ahead of it in many areas, from general use to niche applications. Because of its focus on modularity, immutability, and composability, it is well-suited for addressing the issues of contemporary software development, making it a useful and influential programming paradigm for years to come (Asakawa et al., 2022).

1.2 Paper contributions

The paper brings important contributions to the field of how functional programming can be taught at classes by introducing the TASMANIAN Virtual Lab Software Platform. These contributions can be summarized as follows:

- *Innovative Learning Environment*. The paper introduces a novel learning environment, TASMANIAN, designed to teach functional programming concepts. This platform offers an interactive, immersive, and hands-on approach to learning, enabling students to actively engage with

functional programming principles.

- *Effective Pedagogical Tool.* TASMANIAN addresses the challenge of teaching abstract programming paradigms by providing interactive coding challenges, dynamic visualizations, and instant feedback mechanisms. These features enhance comprehension and retention of functional programming concepts.
- *Bridge between Theory and Practice.* The platform's combination of theoretical explanations and practical exercises bridges the gap between theoretical understanding and real-world application. Students can not only grasp the theory but also immediately apply it in a controlled coding environment.
- *Comprehensive Content.* TASMANIAN covers a range of functional programming topics, including functional data structures, pattern matching, monadic composition, and more. Its modular design allows learners to progress from fundamental concepts to advanced topics in a structured manner.
- *Immediate Feedback and Analytics.* TASMANIAN's Feedback and Analytics module provides students with instant feedback on code correctness, promoting an iterative learning process. The platform's analytics capabilities offer insights into performance metrics, enabling learners to track their progress over time.
- *Promising Tool for Educators.* For educators, TASMANIAN presents a powerful tool to facilitate the teaching of functional programming concepts.
- *Real-World Relevance.* By providing an environment for experimentation and application, TASMANIAN helps students understand the practical implications of functional programming.

TASMANIAN can dramatically improve the learning process and mastery of functional programming principles by addressing the difficulties of teaching abstract topics, encouraging engagement, and offering right away application opportunities.

2. Background and motivation

With an emphasis on immutability, higher-order functions, and declarative coding, functional programming has become a potent paradigm. Although its advantages are generally known, teaching functional programming ideas successfully is still difficult. Traditional methods frequently have trouble bridging the gap between theoretical knowledge and real-world application.

Innovative strategies that enable students to not only conceptually

understand these concepts but also experience their implementation in real-world circumstances are needed to address these issues. Instructors are looking for teaching resources that offer dynamic interactivity, immediate feedback, and engagement incentives so that students may develop a solid foundation in functional programming.

The *goal of this work* is to present a remedy that fills the gap between theoretical understanding and hands-on training in functional programming education. By developing an engaging and interactive learning environment, the proposed TASMANIAN platform aims to improve the way functional programming is taught. We shall examine TASMANIAN architecture, attributes, advantages, and prospective influence on the area of programming instruction in the parts that follow. The goal of TASMANIAN is to make functional programming approachable, engaging, and transformative for students of all levels by addressing the drawbacks of conventional teaching techniques and utilizing the benefits of interactive learning.

3. TASMANIAN: Virtual Lab Software Platform

TASMANIAN is a cutting-edge Virtual Lab Software Platform created to transform the way functional programming principles are taught and learned. Students and developers alike may actively engage with the concepts and techniques of functional programming thanks to its dynamic and immersive environment.

The platform (see Figure 1) is composed from 14 modules.

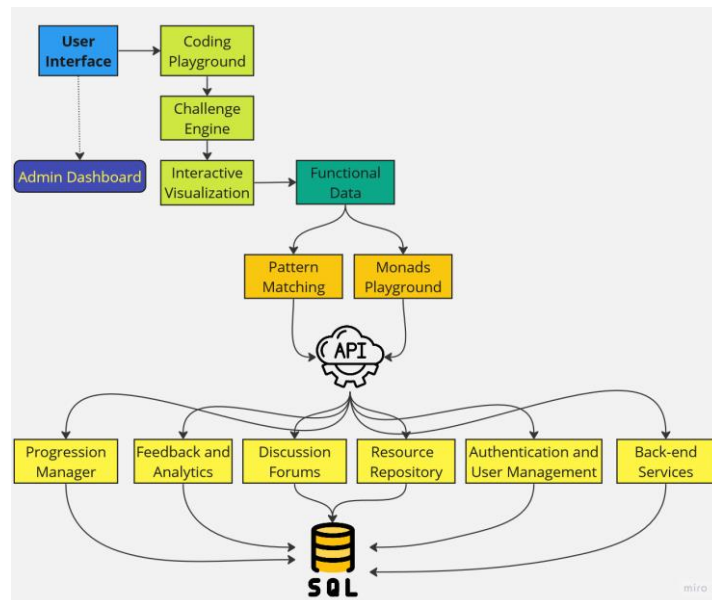


Figure 1. TASMANIAN Platform

These modules are described as follows:

- *Coding playground.* The novel approach of TASMANIAN platform is created to transform the way functional programming principles are taught and learned. It functions as an interactive and immersive environment that enables students, whether they are developers or students, to engage actively with the ideas and techniques of functional programming.
- *Challenge engine.* The module provides interactive coding problems, is essential to TASMANIAN's effectiveness. The challenges include a wide spectrum of functional programming principles and complexity levels, allowing students to develop their skills over time.
- *Interactive Visualizations.* To show abstract ideas, data changes, and code execution, TASMANIAN uses dynamic visuals. Visualizations give consumers a visual depiction of how functional programming functions, which aids in their understanding of complicated concepts.
- *Functional Data Structures Module.* Students of this module can construct and modify useful data structures including lists, trees, and maps. With these structures, students can test how immutability affects data management.
- *Pattern Matching Simulation.* TASMANIAN provides a simulator that enables students to practice pattern matching on different data types to make learning pattern matching easier. It aids students in understanding the complexities of disassembling and comparing data structures.
- *Monads Playground.* The module provides a controlled environment for students to experiment with monads and understand their role in managing side effects. Students can explore monadic transformations and compositions.
- *Progression Manager.* The module is responsible for tracking the student progress and recording the achievements obtained by student. Also, it has the possibility to unlock new challenges based on completion.
- *Feedback and Analytics.* The student after he perform his exercises and uploads its source code, the module will generate feedback based on the code correctness. Within this module we will have the possibility to collect student data for performance analysis.
- *Discussion Forums.* This is an essential space for students where they can ask questions, share solutions, and interact with other students and instructors.
- *Resource Repository.* Responsible for storing additional learning

materials, tutorials, and bibliography/references sources links. The repository will help in enhancing the student learning experience.

- *Authentication and User Management.* The module is dedicated for handling student registration, login, and profiles. The individual progress will be tracked and personalized content is offered to the student.
- *Database.* Within database will store user profiles, progress, and different amount of data specific to student achievements. The database will help in supporting tracking and analytics.

4. Key features and benefits

TASMANIAN includes a variety of interactive tools to improve learning and increase understanding of functional programming ideas.

Personalized learning paths and rapid feedback are two significant interactive features: *Instant Feedback.* TASMANIAN gives immediate feedback regarding the effectiveness and correctness of user-written code. In the platform's coding environment, TASMANIAN displays syntax issues, logical errors, and areas for optimization as students write and run code. Students may immediately recognize and remedy mistakes because to the instant feedback method, which encourages self-correction and experimentation-based learning. *Personalized Learning Paths.* TASMANIAN uses adaptive algorithms to evaluate the proficiency and learning progress of students. The platform customizes the learning experience for each user based on initial assessments and performance on coding challenges. Students are neither too nor underchallenged since challenges and content are offered that match their level of skill. TASMANIAN dynamically modifies the difficulty of challenges as students improve and show mastery, enabling ongoing skill development.

Dynamic visualizations are extremely important for improving understanding of abstract ideas, especially while learning functional programming. *How do they accomplish this?* The answer can be summarized through the followings: *Concrete representation of abstract ideas* - functional programming principles that would otherwise be abstract and difficult to understand are given a concrete, visual representation through dynamic visualizations. They can, for instance, demonstrate how data transformations take place within a functional pipeline, which will help students better understand how functions manipulate data step by step. *Immediate feedback* - visualizations provide real-time feedback by displaying how data or program state changes while code is executed. Students may immediately observe the results of their code, strengthening the relationship between the code and its effects. *Intuitive understanding* - by providing functional programming principles in an interactive, graphical way, visualizations assist students in developing an intuitive understanding of them. Students may "see" how

functions relate to data, how immutability is upheld, and how pattern matching breaks down intricate structures. *Conceptual mapping* - visualizations create a visual map of relationships between various components of functional programming. They illustrate how functions can be composed, how data flows through pipelines, or how recursion operates, helping learners connect the dots between abstract ideas. *Experimentation and exploration* - Experimentation is encouraged by dynamic visualizations. Students can update the code and see how the changes affect the data and outcomes. Students can test theories and investigate variants because of this experimentation, which promotes active learning and curiosity. *Error Identification* - error identification is facilitated by visualizations. The visual depiction allows learners to identify abnormalities or unexpected behaviors, which helps with debugging and problem-solving. *Contextual learning* - visualizations provide context to code snippets. Learners can see the bigger picture of how functions fit into the functional programming paradigm. This contextual understanding is particularly valuable when transitioning from imperative to functional programming. *Engagement and retention* - visualizations are inherently engaging. They break the monotony of text-based learning and can increase retention of complex ideas. Learners often find visual content more memorable and motivating.

5. Case study

We will consider the following case study: Teaching functional programming ideas to a wide collection of students, ranging from novices to experienced programmers, was a regular challenge for the computer science department at a university. They are looking up for a solution that could reconcile theory and practice while considering a range of skill sets.

To teach functional programming, the department chose to incorporate, into their curriculum, the TASMANIAN as a virtual lab software platform. For students enrolled in functional programming classes, TASMANIAN is available as an optional resource which will have the following benefits:

- *Accessibility for all skill levels.* The customized learning routes offered by TASMANIAN should be quite helpful. Beginner students will be given foundational exercises to complete, while more seasoned students were given access to advanced courses. All students were able to use the platform at their own speed and skill level because to its versatility.
- *Interactive learning and immediate feedback.* The coding environment and the fast feedback features were quite popular with the students. They might play with the ideas of functional programming while getting prompt direction. Students were inspired to actively contribute and refine their code because of the interaction, which led to a deeper comprehension of the ideas.

- *Visualizing abstract concepts.* Dynamic graphics created by TASMANIAN were helpful in making abstract concepts clear. Students can see how data moved via functional pipelines, how functions changed data, and the advantages of immutability. Students were able to relate theory to practical situations with the use of visualizations, which made functional programming more understandable.
- *Collaborative learning.* Peer-to-peer learning was made possible via the discussion boards in TASMANIAN. Students are having the possibility to post queries, exchange knowledge, and work together to solve difficult challenges.
- *Improved learning outcomes.* In functional programming courses, students who are regularly using TASMANIAN showed enhanced learning outcomes. Their comprehension of fundamental ideas like monads, pattern matching, and recursion was much improved. To achieve these successful results, the platform's real-time feedback and tailored learning paths were key factors.
- *Instructor insights.* Instructors will be able to observe that students who participated in TASMANIAN showed greater confidence in their ability to apply functional programming ideas to projects and tasks for their courses.

The department's problem of teaching functional programming to a diverse student group will be successfully met through TASMANIAN. The learning process will be improved by its adaptability, interaction, visualizations, and community involvement. The platform will help students to better understand complex ideas while also boosting their self-confidence and performance in functional programming classes.

6. Future research directions

As future research directions, we will focus on including other modules such as the ones described below, focusing on developing applications for IoT, Edge Computing, Functional Programming for Quantum Computing, formal verification, and program analysis and much more.

The following future research directions for TASMANIAN platform are considered genuine and with a considered added value for such platform. These are: advanced functional programming paradigms, formal verification and program analysis, concurrency and parallelism in functional programming, human-computer interaction (HCI), functional programming for IoT and Edge Computing, functional programming for machine learning, functional programming for quantum computing, and functional programming for education. A partnership with industry will be required as well for providing real-world applications.

7. Conclusion

The paper introduces TASMANIAN a Virtual Lab Software Platform meant to transform functional programming idea teaching and learning. The following is a summary of the paper's main ideas and contributions:

It is impossible to overstate the importance of TASMANIAN in the field of functional programming education. It offers a revolutionary answer to the persistent problems with teaching abstract ideas. Functional programming wish to be more approachable and interesting for learners of all backgrounds because to the platform's interactive features, tailored learning routes, instant feedback systems, and visualizations.

TASMANIAN gives instructors the tools they need to close the gap between theory and application so that students may not only comprehend but also successfully apply the concepts of functional programming. Its capacity to influence the future of programming education is highlighted by its effectiveness in enhancing learning outcomes, which has been proven by case studies.

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A multimodal interaction solutions. “The Way” for educational resources

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Abstract: *This paper examines the implementation of multimodal interaction solutions emphasizing education and explores the potential of these solutions for improving learning outcomes. The paper presents a detailed analysis of the developments and advancements in multimodal interaction solutions specifically designed for educational contexts, including the use of natural user interfaces, virtual and augmented reality, voice, gesture and touch interaction, smart eye, and affective and intelligent tutoring systems. The paper also discusses the benefits and challenges associated with the implementation of these solutions, as well as future directions for research and development, multimodal interaction solutions cannot longer be seen as “a way”, they must be “the way”. What do we already have? What do we have and do not use? What are the benefits of this solution? Those are questions we are answering in this paper.*

Keywords: Multimodal interaction, Virtual reality, Augmented reality, Voice interaction, Gesture and touch interaction, Smart eye, Affective, intelligent tutoring systems.

1. Introduction

Technology has progressed to the point that it is possible to use a variety of different methods to achieve the same objective. This is true in many areas, from transportation to communication, and it is also true in the world of problem-solving. Multimodal solutions are a way for individuals and organizations to combine different approaches to achieve a single desired outcome. Multimodal interaction solutions are gaining popularity rapidly within the education sector.

The primary objective of these solutions in education is to offer students a highly immersive and interactive learning experience that is engaging and effective. They are used to combine several types of media, such as text, audio, video, and graphics, to create a more immersive learning environment (Chen et al., 2018), by combining these distinct types of media, students can better understand and retain the material they are learning. Also, they are used in a variety of educational settings, including traditional classrooms, online courses, and virtual classrooms (Medina, 2021).

The incorporation of multimodal interaction solutions can contribute to the establishment of a highly captivating and interactive learning environment, thereby fostering student motivation and heightened engagement with the subject matter. Multimodal interaction solutions can help to reduce the amount of time needed to complete a course, as students can access the material more quickly and easily. What do we already have? What do we have and do not use? What are the benefits of this solution? Those are questions we are answering in this paper, where, we are also discussing the several types of multimodal interaction solutions used in education (Munteanu et al., 2017), and the challenges associated with implementing them. Furthermore, we are exploring the possibilities of utilizing multimodal interaction solutions to foster dynamic and immersive learning environments that captivate and involve learners effectively.

2. A view about multimodal interaction solutions

Multimodal interaction solutions are technologies that enable individuals to actively engage with digital content using multiple input and output modalities. Examples of multimodal interaction solutions include voice recognition, gesture recognition, facial recognition (visual, auditory, tactile, and/or cognitive), and augmented reality (Sugumaran, Sreedevi & Xu, 2022). Visual modes might include images, diagrams, graphs, and text, while auditory modes could involve spoken words, music, or sound effects. Tactile modes could involve physical objects, while cognitive modes might involve problem-solving strategies or creative thinking. This paper will present several types of multimodal solutions and how they have been used to create effective solutions, particularly in Education.

Voice-Enabled Assistants (Intelligence n.d.) have gained tremendous popularity in recent years, becoming an integral part of our daily lives. These digital companions, powered by sophisticated natural language processing (NLP) algorithms, listen to user commands, and respond with relevant information or actions. Voice-activated assistants such as Amazon Alexa, Apple Siri, and Google Assistant have seamlessly integrated into our lives, effortlessly understanding our verbal commands, and providing virtual assistance.

Gesture Recognition (Encyclopedia, n.d.) has taken interactive technology to a new level, allowing users to interact with devices through hand movements, body gestures, or facial expressions. These systems use advanced sensors and cameras to detect and interpret gestures accurately. Immersive gaming consoles like Microsoft Xbox Kinect have capitalized on gesture recognition technology, enabling players to control games through intuitive body movements. Similarly, smartphones with gesture-based controls offer users a touch-free alternative for tasks like answering calls or navigating through applications.

Touch and Haptic Feedback (See, Choco & Chandramohan, 2022) have transformed the way we interact with our devices, making it more tactile and engaging. Touchscreen technology has become a standard feature in smartphones,

tablets, and many other devices, empowering users with the ability to tap, swipe, pinch, and zoom to interact with content effortlessly.

Augmented Reality (AR) and Virtual Reality (VR) technologies (Xiong et al., 2021) have opened up new possibilities for multimodal interactions. AR overlays digital information onto the real-world environment, enabling users to interact with a combination of voice commands, gestures, and visual cues. On the other hand, VR immerses users entirely into virtual environments, where they can interact with objects using hand controllers and voice commands, blurring the line between the real and digital realms.

At the forefront of cutting-edge interaction solutions are Brain-Computer Interfaces (BCI) (Gonfalonieri, 2020). Although still in the early stages of development, BCIs hold immense promise for the future. By establishing a direct communication link between the human brain and external devices, these interfaces enable users to interact and control technology using their thoughts.

Natural Language Interfaces (World Wide Web Consortium, n.d.) empower users to interact with technology using everyday language, making interactions feel more human-like and conversational. These interfaces go beyond simple voice commands and cater to more complex queries and responses.

In collaborative environments, Multi-Touch Tabletops (Niu, McCrickard & Nguyen 2016) have gained popularity, facilitating interactive group work and presentations. These large touch-sensitive displays enable multiple users to interact simultaneously, making them ideal for brainstorming sessions, interactive exhibits, and educational settings.

Eye-Tracking Interfaces (Bitbrain, n.d.) offer a hands-free and natural way to interact with technology. These systems use specialized sensors to track a user's eye movements, allowing them to control devices and interact with content without the need for physical touch or speech.

Wearable Technology has integrated multimodal interaction features into our everyday accessories. Smartwatches, fitness trackers, and other wearables combine touch, voice, and gesture-based inputs to provide users with a seamless and versatile interaction experience. These devices enable users to check notifications, track health metrics, and control connected devices with ease.

3. Companies who develop multimodal interaction solutions

Companies that develop multimodal interaction solutions are at the forefront of revolutionizing the way humans interact with technology. These innovative organizations harness cutting-edge technologies like natural language processing, speech recognition, gesture tracking, and artificial intelligence to create seamless and intuitive user experiences. By integrating multiple modes of communication, such as voice commands, touch, and gestures, these companies empower users to

interact with devices and applications in a more natural and immersive manner. Here are some examples of these companies:

1. Sensory (Sensory, n.d.): Sensory is a technology company that specializes in AI-based facial and speech recognition, biometrics, and embedded machine learning technologies. They offer a suite of tools designed to make user experience (UX) more intuitive and secure. Their solutions are used in a variety of industries, including automotive, banking, healthcare, and consumer electronics.
2. Affective (Affective, n.d.): Smart Eye has extended the utilization of Affective Emotion AI technology by introducing novel conversational engagement metrics. These metrics offer enhanced insights into consumer responses by analysing facial expressions in qualitative online research studies.
3. Inbenta (Inbenta, n.d.): Conversational AI with ZERO training required. It builds conversational experiences with patented Neuro-Symbolic AI 4-in-1 platform. It powers interactions with customers and employees giving answers to the most complex questions. In fact, it helps but sometimes provides predictable answers.
4. eGain (eGain, n.d.): eGain Corporation, previously known as eGain Communications Corporation, is a California-based cloud-based software company headquartered in Sunnyvale. The company specializes in delivering customer service, knowledge management, and analytics applications that businesses leverage to effectively serve and engage with their customers, ultimately driving sales and enhancing customer experiences.
5. Interactions (Interactions, n.d.): The company is privately owned and specializes in developing and offering hosted Virtual Assistant applications. These applications equip businesses with the capability to provide automated natural language communications for their enterprise customer care services. With these solutions in place, businesses can enhance their customer care operations by enabling seamless and automated interactions with their customers.

4. Popular multimodal interaction solutions. Voice recognition

Voice recognition technology has emerged as one of the most popular multimodal interaction solutions, revolutionizing the way we interact with devices and services. With the ability to convert spoken language into text or actionable commands, voice recognition has become a ubiquitous feature in our daily lives. This cutting-edge technology enables users to perform tasks, access information, and control various devices using natural spoken language, making interactions more seamless and user-friendly. From virtual assistants like Amazon Alexa and Apple Siri to voice-enabled applications and smart home devices, voice recognition has found widespread adoption across different industries, empowering users with hands-free and intuitive communication with technology.

1. Google Assistant (Google, n.d.) is a virtual voice-enabled assistant developed by

Google. It serves as your own personal digital companion, designed to help with various tasks and answer questions using natural language understanding.

2. Amazon Alexa (Amazon, n.d.) is a versatile virtual voice assistant developed by Amazon. Serving as the core of Amazon's smart speakers and smart displays, Alexa is designed to make life easier by responding to voice commands and carrying out a wide array of tasks.

3. Apple Siri (Apple, n.d.) is an intelligent virtual assistant developed by Apple Inc. and is an integral part of their iOS devices, macOS, Apple Watch, and HomePod. Siri is designed to assist users with a wide range of tasks and queries through voice commands and natural language understanding. As a default virtual assistant on Apple devices, Siri offers a seamless hands-free experience, allowing users to perform various tasks with just their voice.

4. Cortana (Microsoft, n.d.) developed by Microsoft, is a powerful and versatile personal productivity assistant designed to assist users across various Microsoft platforms and devices. Named after the AI character from the "Halo" video game series, Cortana provides users with a range of capabilities through natural language interactions and adaptive learning. As a default assistant on Windows 10 devices, Cortana seamlessly integrates with the operating system, enabling users to perform tasks using voice commands, typed text, or even gestures.

5. IBM Watson (IBM Watson, 2023), a pioneering example of popular multimodal interaction solutions, stands at the forefront of cutting-edge artificial intelligence and cognitive computing. As an advanced AI platform developed by IBM, Watson seamlessly integrates multiple modes of interaction, such as natural language processing, machine learning, and deep learning, to facilitate intuitive and comprehensive human-computer communication.

5. Multimodal interaction solutions in education

The use of multimodal interaction solutions in the educational setting has become increasingly popular with the advancement of technology and the rise of ubiquitous computing, multimodal interaction solutions have become a way to bridge the gap between physical and virtual instruction (Li et al. 2019).

The use of multimodal interaction solutions in educational settings is becoming increasingly popular as technology advances. Multimodal interaction solutions (Sugumaran et al., 2022) are defined as the integration of multiple input and output modalities to allow for more natural and intuitive interactions between humans and computing devices. This can include a combination of speech, touch, gestures, facial expressions, and several types of sensors (Chen et al., 2018). Multimodal interaction solutions allow for a more natural and intuitive interaction between the user and the computer, which can make learning more engaging and efficient.

One example of a multimodal interaction solution in education is the use of augmented reality (AR) and virtual reality (VR) technologies. These technologies allow users to interact with digital content in a more natural way, allowing for more immersive learning experiences. For example, AR and VR technologies can be used to create virtual classrooms where students can interact with digital objects and collaborate with each other in a virtual setting (Nesenbergs et al., 2021). AR and VR technologies can also be used to create interactive simulations and game-based learning activities that can help to engage and motivate students (Xi et al., 2022).

Another example of a multimodal interaction solution in education is the use of machine learning (ML) and natural language processing (NLP) (Shaik et al., 2022). ML and NLP technologies can be used to analyse large datasets and find patterns in the data that can be used to create personalized learning experiences. For example, ML and NLP technologies can be used to detect student's emotions and provide learning experiences tailored to their individual needs.

The use of robots and drones (Palaigeorgiou, Malandrakis & Tsolopani, 2017) is another example of a multimodal interaction solution in education. Robots and drones can be used to provide physical feedback to students, allowing them to interact with digital content in a more tangible way. For example, they can provide virtual tours of historical sites, allowing students to explore and learn in a more immersive environment. These are some examples of those interactions:

1. Voice Interaction (Insider Intelligence, n.d.): this multimodal interaction solution allows users to interact with a system using voice commands. Also, for educational purposes allows the creation of interactive learning experiences, such as virtual tutoring or voice-controlled quizzes (Munteanu et al., 2017).
2. Gesture Interaction (Li et al., 2019): Gesture interaction allows users to interact with a system using hand gestures. Gesture interaction can be used in education to create interactive learning experiences, such as virtual labs or interactive 3D models of scientific concepts (Negi, Pawar & Lal, 2020).
3. Touch Interaction: Touch interaction allows users to interact with a system using touch-based input (Ibharim, Borhan & Yatim, 2013). Touch interaction can be used in education to create interactive learning experiences, such as virtual whiteboards or interactive 3D models of scientific concepts.
6. Smart Eye and Affective: Smart Eye is a computer vision technology that can measure and analyse human behaviours in real-time. It uses cameras, sensors, and algorithms to detect facial expressions, body language, and gaze direction (Bishay et al., 2023).

Natural user interfaces are a novel form of human-computer interaction that uses nature as its basis. This technology is made up of speech recognition, gesture recognition, touch screens, touch capability, eye tracking, and brain-computer interfaces. Such interfaces are great for education, as they decrease the cognitive

load, raise the level of engagement, and offer easy access to learning feedback (Yang et al., 2020).

6. Examples of multimodal interaction platforms for education

These solutions can be broadly categorized as "multimodal interaction technologies" or "multimodal interaction platforms." Multimodal interaction refers to the integration of multiple modes of communication, such as voice, text, gestures, touch, and visuals, to facilitate a more natural and effective user experience. There are some examples:

1. BrainWare Safari (BrainWare SAFARI, n.d.): This software utilizes a combination of audio, video, graphics, and text to help students learn and understand complex concepts. It also provides detailed feedback on student progress and performance.
2. SmartClassroom (Adobe, n.d.): This interactive platform combines audio, video, and 3D graphics to create an engaging learning environment. It allows teachers to create interactive lessons, quizzes, and games.
3. Kineo (Kineo, n.d.): This platform uses artificial intelligence, machine learning, and natural language processing to create personalized learning experiences. It also provides teachers with analytics to track student progress and performance.
4. Adobe Spark Video (Adobe, n.d.): it is a free online software that allows users to create engaging video presentations, with the ability to add text, video clips, music, and images. It is a great tool for creating educational videos for teachers and students alike.
5. Pear Deck (Pear Deck, n.d.): it is an online platform that allows teachers to create interactive and engaging lessons. Students can respond to questions and polls in real-time, which helps teachers gauge student understanding and track their progress.

Intelligent tutoring systems (Wu et al., 2022) (ITSs) are another type of multimodal interaction solutions that can be used in educational settings. ITSs use artificial intelligence (AI) to analyse a student's performance and provide personalized instruction and feedback. ITSs can enable teachers to monitor student progress and provide personalized instruction and can also enable students to practice and improve their skills in a safe and controlled environment. There are several commercial ITS solutions available, one of them is IBM's Watson (IBM, n.d.).

7. Advantages and disadvantages of using multimodal interaction solutions

Like any technology, these solutions also come with their own set of disadvantages. It is essential to weigh both the benefits and drawbacks to make informed decisions about their implementation. We select some advantages and

disadvantages of using multimodal interaction solutions, shedding light on their potential to enhance user experiences while acknowledging the challenges they may present.

Table 1. Advantages and disadvantages of using multimodal interaction solutions, particularly in education

Advantages	Disadvantages
Increased Interactivity: Users can use touch, voice, and gesture inputs, allowing them to interact with the system in a more intuitive and natural way.	Increased Complexity: The system needs to be able to understand and process various input modalities, and the user needs to be aware of how to use the different modalities of interaction
Improved Usability: Allowing users to interact with the system in multiple ways, they can find the most effective means of input and output, making the system more user-friendly.	High Cost: Multimodal interaction solutions can be expensive to develop and maintain, especially when compared to single input/output solutions.
Enhanced Flexibility: Adapted to the user's needs, allowing them to use the system in the most efficient way. This can be especially beneficial when dealing with complex tasks, as the user can use different input and output modes to tackle the task at hand.	Reduced Accuracy: Multimodal interaction solutions can be less accurate than traditional single input/output solutions. For example, a system that is designed to understand voice commands may not be able to accurately interpret a gesture input.
Increased Accessibility: A user with limited mobility can use voice or gesture inputs to interact with the system, allowing him/her to access the same services as those without impairments.	Limited Usability: Multimodal interaction solutions may not be suitable for all users. For example, a user with a disability may not be able to use the solution due to physical limitations.

8. What challenges can we identify?

The challenges associated with implementing multimodal interaction solutions in education include cost, technical complexity, and privacy concerns. Implementing multimodal interaction solutions can be expensive, as they require specialized hardware and software. Besides, multimodal interaction solutions can be technically complex, as they require the integration of multiple technologies. Furthermore, privacy concerns can arise when using multimodal interaction solutions, as they can collect and store sensitive data about students.

The future of multimodal interaction solutions in education is bright. As technology continues to evolve, they will become more accessible and more affordable. The more research is conducted on the effectiveness of multimodal

interaction solutions, the more educational institutions will begin to adopt them. As more educational institutions adopt multimodal interaction solutions, more research will be conducted on how to best use them to create more engaging and interactive learning experiences.

The conception with which multimodal interaction solutions must be changed, they cannot be “a way”, they must be “the way”. It must be implemented in all educational software productions, so it would no longer have to talk about resources for blind or deaf people, it would be talk of resources for people in general because multimodal interaction solutions open access to all regardless of their physical and motor qualities. Implementing them in our developments will bring us closer to a more inclusive future and propitiate a better educational exchange.

9. Conclusions

Multimodal interaction solutions offer a range of potential benefits for educational settings, including increased engagement, improved understanding, and better learning outcomes. However, there are also some challenges associated with the implementation of these solutions, such as cost, complexity, and the need for specialized training. Nevertheless, the potential of these solutions is significant, and there is a great deal of potential for further research and development in this area. This is just a view about what we already have, we must improve the classroom performance to prepare students to face challenges and change the future.

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Exploring ethical considerations in Metaverse from the education perspective

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Abstract: *Originally seen as a specialized aspect of Web 3.0, the Metaverse has experienced a significant transformation, now emerging as a multi-trillion-dollar industry. The educational sector holds a crucial role within this industry, utilizing the Metaverse as an inventive tool for both educators and students. Interactions within the Metaverse are anticipated to heavily rely on an extensive flow of user-derived data. This encompasses the potential to track personally identifiable biometric information using wearable devices or advanced technologies. These advancements raise ethical and legal concerns related to privacy and accessibility. Given these concerns, it is appropriate to initiate meditation on the ethical aspects and establish guidelines and frameworks regarding user interactions. The purpose of this paper is to initiate a dialogue about the ethical consequences of Metaverse-centered education, providing a nuanced comprehension of the ethical facets of this emerging field. Our objective is to highlight a broader perspective on a potential solution. In this sense, we suggest a set of Metaverse Ethical Principles that can enrich the understanding of this poorly explored territory. These principles aim to ensure the responsible, fair, and comprehensive implementation of the Metaverse in the field of education.*

Keywords: ethical code, Metaverse, digital education, immersive experience.

1. Introduction

As the lines between the physical and digital worlds become increasingly blurred, we stand at the threshold of an exciting new era in education. The 'Metaverse', a multidimensional, interconnected virtual space (Zhang et al., 2022), has the potential to transform education in ways previously unimaginable. It promises to offer immersive, personalized, and inclusive educational experiences (Fernandez & Hui, 2022), redefining pedagogical strategies and learning outcomes. But as we embrace the possibilities of this digital frontier, we must be mindful of the ethical implications (Canorea, 2022) associated with this paradigm shift.

The objective of this paper is to introduce ethical principles that can benefit both creators and users during the process of designing and developing content and applications for the Metaverse, particularly focusing on its educational aspects.

As the virtual environment becomes more complex and potentially invasive, we must also consider several ethical issues such as data privacy and security, digital identity, access and equity, ownership, and control of the impact on intellectual property of immersive technologies. From the perspective of the educational process, these issues take on a specific dimension. In a Metaverse-driven educational environment (Hirsh-Pasek et al., 2022), where learning activities can be highly personalized and closely tracked, the subsequent inquiries may arise: what protections are needed to ensure the privacy of learners and the security of their data? How can the digital identities of learners be ethically managed, ensuring respect for personal boundaries and cultural diversity? How do we ensure equitable access to such advanced technologies, avoiding a potential 'Metaverse divide'? What rules should govern the use and ownership of educational content in the Metaverse? These questions require a robust ethical code that not only addresses current challenges but also anticipates future shifts in this rapidly evolving landscape. It is vital to ensure that the application of Metaverse technologies in education remains human-centred, prioritizing the well-being and rights of learners and trainers. This paper aims to play a role in shaping this code, promoting knowledgeable, accountable, and future-oriented approaches in Metaverse-based education.

Based on the existing extensive analyses regarding the ethical risks and challenges in the Metaverse, this paper provides a nuanced understanding of the ethical landscape of the Metaverse from an educational perspective. Our objective is to illustrate the path toward an ethical digital evolution in education, offering guidance to different stakeholders. By pursuing this objective, our motivation is to facilitate the deliberate and thoughtful expansion of the educational domain within the Metaverse.

The article is structured as follows. Section 2 considers related work about ethical issues in Metaverse. Section 3 presents risks and challenges from the Metaverse with an emphasis on the educational aspect. Section 4 proposes a code of ethical principles for Metaverse. The paper ends with a chapter of conclusions and references.

2. Related work

The issue of ethics in Metaverse is addressed in specialized literature through the prism of several aspects starting from the security of use to copyright and fake news. Based on a semantic and etymological approach, the study developed by Zallio & Clarkson (2023) analyses the evolution of the term ethics in different fields, as well as the term Metaverse and investigates how ethical questions, principles, and approaches can influence the design and development of a new Metaverse. At the same time, the research proposes a new concept and field of expertise - Metavehtics - approaching the scientific and the broader, technology-oriented communities with new questions and inspiring opportunities for the

creation of digital, virtual environments that are framed within the context of acknowledging positive ethical implications for human beings.

Fernandez & Hui (2022) focus on three factors to guide the development of the Metaverse: privacy, governance, and ethical design. They also propose a preliminary modular-based framework for an ethical design of the Metaverse. The ethical implications are analyzed from the perspective of creative actions and social aspects in Metaverse, the study emphasizing modular ethical design motivated the "Ethical Hierarchy of Needs" where each module is interchangeable. According to Kaddoura & Al Hussein (2023) a range of key challenges, ethical issues, and potential threats are outlined in relation to the utilization of the Metaverse in education. This delimitation offers a road map for future research, in order to improve learning and teaching experiences. In this study, the main addressed ethical issues are: integrity issues, including printing and spreading false information and fraud and violations of intellectual property rights. Benjamins et al., (2022) emphasize both the social and societal impact of the Metaverse, arguing that companies that are implementing the responsible use of AI are well prepared for the social and ethical risks of the Metaverse. Among the ethical issues mentioned in this study there are challenges associated with artificial intelligence, human intervention and appropriate system autonomy, privacy, security and safety, copyright and fake news, and deep fakes.

Cukurbasi et al. (2022) analyse several implications, including of an ethical nature regarding the use of the Metaverse in educational environments. According to this study, it is necessary to investigate the activity patterns of the learners, their level of involvement in the Metaverse, and the positive and negative effects of the learners on their learning activities. Cai & Song (2022) present two perspectives through which students can properly develop the ethical values to be considered when using the Metaverse for didactic purposes. The first is the privacy perspective, which was about how to protect individual private data and how to reasonably collect and store student data in the world of the capital-manipulated Metaverse. The second is the values perspective, which establishes correct values and worldviews in the context of a decentralized Metaverse, where students are exposed to different cultural outcomes and fake news. At the same time, the strong risk of "addiction" due to the immersive experiences and interactivity afforded by educational applications in the Metaverse should be considered.

3. Risks and ethical challenges in Metaverse from the educational perspective

For the adoption on the largest possible scale of an inclusive and responsible Metaverse, potential risks and challenges generated by the evolution of emerging technologies, innovation, and the appearance of new applications can be prevented. According to (Benjamins et al., 2023) risks in the Metaverse are determined by intentionally malicious actions or unintentional actions. Many of the risks are associated with the use of AI algorithms in Metaverse.

In the educational field, (Fernandez & Hui, 2022) refer to two types of risks: physical risks (such as distraction, and hitting) and psychological risks (such as addictive behavior or isolation) (Smith, 2022). In his paper, (Dwivedi et al., 2022) identified three categories of risks in the Metaverse, namely mental health issues, addiction to simulated reality, and privacy of data used or obtained in the Metaverse. (Identity Management Institute, 2023), (Certified Metaverse Security Consultant, 2023), (Kaddoura & Husseiny, 2023) and (Think Tank, European Parliament, 2022) present the category of security risks in Metaverse that may appear in areas of interest of users, such as remote work, training, health, education. Here there are cyberbullying, identity theft, unauthorized data collection, ransomware attacks, deep fake video recordings, social engineering attacks, shared spaces that bring people together, and new applications.

The challenges identified in the educational domains and applications already explored and used in Metaverse can be addressed from the perspective of data, users, content, and devices. (Benjamins et al., 2023) talks about two types of challenges: direct challenges found in companies, such as privacy and security, harm, ensuring equitable access of communities to Internet connectivity and affordable Virtual Reality (VR) devices (Tripathi, 2023), (Smith et. al, 2023) virtual property rights and, indirect challenges, which address issues that are noticed after a period of time, such as developing appropriate content that balances real world and digital skills in safely virtual learning environments or dependence on technology.

Therefore, the Metaverse offers multiple educational possibilities, which can be followed by risks and ethical challenges. Privacy concerns, data security, equitable access, maintaining a safe online environment, ensuring the right balance between engagement and over-dependence on virtual platforms, and providing accurate unbiased content are some of these key issues.

4. Ethical code for education

Due to the rapid expansion of Metaverse, both governments and companies give a significant focus on formulating strategies that aim not only to facilitate the creation of complex virtual worlds but also to address disruptive innovations and emerging technologies (Petre et al., 2023).

For instance, the United Arab Emirates (UAE) and Dubai have devised a Metaverse strategy aimed at enhancing the digital economy of the region, with intentions to generate approximately 30,000 Metaverse-related employment opportunities. Similarly, South Korea has introduced various funding initiatives to support creators within this industry while the Philippines and China are emphasizing the involvement of universities in driving industry development (CoinGeek, 2022). Congruently, prominent tech giants like Meta, Microsoft, Google, Apple, Nvidia, Epic Games, and others are making substantial investments in the advancement of VR platforms and expanding the Metaverse, envisioning a

future where it becomes an integral part of our daily lives encompassing fields such as commerce, education, medical services, and beyond (Mobile, 2023).

Despite all these substantial financial efforts, the exact extent and influence of the Metaverse on society and the economy remains uncertain (Nasdaq, 2023). However, it is not premature to initiate meditation on ethical concerns and establish guidelines and frameworks for ethical principles. Interactions in the Metaverse are poised to rely primarily on an extensive stream of data obtained from users. This includes the potential to monitor biometric data through wearable devices or through technological innovations such as neurotechnology and Brain-Computer Interfaces (BCIs). These advances raise ethical and legal considerations related to privacy as well as accessibility to these technologies (Park et al., 2021).

Tackling ethical risks and challenges in the Metaverse requires a multifaceted approach that involves various stakeholders, including technology developers, policymakers, researchers, and users (Anshari et al., 2022). In this sense, Responsible Metaverse Alliance, (2023) proposes a series of eleven Metaverse Ethical Principles that represent a subset of a Responsible Metaverse Strategy. These ethical principles embody the primary guidelines to adhere to when building immersive worlds, specifically: a) promoting the welfare of humans, society, and the environment, b) adopting human, safety & environment-centered design, c) assuring non-discrimination for individuals and their virtual representations, d) enabling access and inclusiveness for all people, e) offering safety and reliability in operation, f) assuring security and confidentiality, g) aligning with relevant regulations, laws, requirements, and societal norms, h) enabling contestability process, i) transparency and responsible disclosure, j) capacity to be explainable to other parties and k) identification and accountability for all parties.

The Ministry of Science and ICT (MSIT) in South Korea has established its Metaverse development strategy based on eight ethical principles: Authenticity, Autonomy, Reciprocity, Privacy Respect, Fairness, Personal Data Security, Inclusivity, and Responsibility for the Future. This framework aims to create a secure virtual environment where users can authentically express their identities within a safe, sustainable, and inclusive system (Soyeon, 2022).

In his analysis of the Metaverse, Don Heider (2022) discusses the concept of "safety" within virtual worlds, drawing a comparison between the risks existing in our physical reality and those within the virtual world. Heider asserts that complete safety is unattainable, highlighting how the technologies underpinning the Metaverse construction perpetuate similar hostilities, harassment, and aggressions observed in other societal and cultural domains. As a result, safeguarding marginalized individuals and vulnerable communities, as well as upholding the security of virtual spaces, necessitates the establishment of an ethical framework grounded in fundamental values acknowledged by all stakeholders. Such a code of ethics is pivotal not only in guiding the decision-making, design, and maintenance

of the Metaverse but also in fostering consistent standards and best practices for its users. Heider proposes a foundational blueprint for this code of ethics, comprising seven key principles: Show Respect, Tell the Truth, Do no Harm, Show Concern, Work for Good, Demonstrate Tolerance, and Respect Privacy.

To conclude, our perspective for constructing a code of Metaverse ethical principles from an educational perspective is anchored in four pillars: validated identity, safe experience, confidentiality, and cultural representation. Based on these values, we propose in Table 1 a set of fundamental principles intended to guide both developers and users in decision-making, design, and participation in the Metaverse educational process.

Table 1. Categories of ethical principles

Categories	Description
Privacy and Data Security	Companies and platforms operating in the Metaverse should be transparent about data collection, use, and storage practices. Users engaged in virtual learning environments should have control over their personal information and be informed about how their data is used.
Digital Ownership and Property Rights	Users (students and educators) should have clear ownership of their virtual assets, creations, and intellectual property, and mechanisms should be in place to prevent theft, unauthorized copying, and infringement of these rights.
Inclusivity and Accessibility	The Metaverse should be accessible to users with different abilities and should not discriminate against any group based on identity or background.
Security and Safety	Metaverse must implement measures capable of preventing harassment, abuse, fraud, and other harmful activities.
Content Moderation and Educational Quality	Metaverse must implement mechanisms to prevent the spread of harmful or inappropriate content, hate speech, harassment, and other forms of misconduct. Ensuring high-quality educational content aligned with established pedagogical standards.

Transparency and Fairness	The operation of algorithms, virtual economies, and governance systems should be transparent and fair. Users should be informed about how decisions that affect them are made.
Identity and Authenticity	Ensuring the authenticity of users' identities and preventing identity fraud or misrepresentation. Online interactions must align with real-world values.
Digital Equity	Ensuring that socioeconomic factors won't limit education opportunities and avoid disadvantaging marginalized groups.
Loss of Physical Interaction	Ensuring face-to-face interactions, with attention to emotional development, and social skills.
Digital Addiction	Metaverse must create a balance between virtual and physical experiences, to avoid social isolation, addiction, mental health concerns.
Depersonalization of Education	Metaverse must take care of diminishing the role of teachers in favor of automated systems.
Regulation and Governance	Establishing appropriate regulations and governance structures for educational activities. Assuring a balance between fostering innovation and protecting user rights.
Environmental Impact	The ecological footprint of data centers and computing resources supporting Metaverse should be considered and mitigated.

These ethical principles should guide the development and operation of the Metaverse to ensure that it becomes a responsible, inclusive, and sustainable virtual space that benefits all its participants.

5. Conclusions

In line with the educational landscape's integration with the Metaverse, several notable risks and challenges come to the forefront. First and foremost is the concern about data privacy and security. As educational interactions become more immersive and interconnected within the Metaverse, there is an increased potential for sensitive student data to be compromised or misused. Striking a balance between providing personalized learning experiences and safeguarding students' personal information remains a formidable challenge.

Additionally, issues related to digital equity and accessibility emerge prominently. The Metaverse has the potential to offer groundbreaking learning opportunities, but it also has the capacity to exacerbate existing disparities in access to technology and digital resources.

Furthermore, the addictive nature of immersive digital environments poses concerns about students' engagement and well-being. Balancing productive educational engagement with potential negative consequences, such as excessive screen time or detachment from real-world experiences, requires careful consideration.

Finally, the evolving nature of the technology underpinning the Metaverse introduces a challenge in keeping curricula and practices up to date. Rapid advancements in virtual reality, augmented reality, and other related technologies mean that educational institutions must continually revise their strategies and content to remain relevant.

These are just some of the main challenges specific to the Metaverse, especially from an educational perspective. The consideration of associated risks and challenges is essential to ensure that its implementation leads to positive educational experiences for all learners.

As future work directions, the suggested ethical code will be enhanced by incorporating a range of new ethical and societal elements. These future upgrades are based on a series of practical trials conducted in laboratory settings, involving various educational applications designed for the Metaverse, and by analysing user interactions in-depth.

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Section 2

Changing Education Because of Technology Disruption

Empowering education: learning from crises to achieve resilient education in Romania

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Abstract: *Online learning is regarded as a solution that mitigates the risks posed by unexpected events and enhances the education system's resilience to diverse types of crises. Existing studies examining online education systems tend to focus either solely on the educational process or solely on technology. A gap exists for studies that adopt the service system approach, concentrating on both human and technological aspects, and aligning with the value co-creation process. In this paper, we employ the Service-Dominant logic approach to perceive the education system as a comprehensive service system encompassing humans, technology, and the value co-creation process. As such, we posit that a thorough understanding of the service context and the impact of unexpected events such as wars or pandemics on the value-creation process stands as the cornerstone for a resilient education service. While this study centres on the context of the pandemic within Romania, it significantly enhances our comprehension of the subject matter. Future empirical research endeavors may broaden the scope of the study to encompass diverse contexts.*

Keywords: Distance learning, value-creation, Service-Dominant logic approach, Education service resilience.

1. Introduction

During the COVID-19 pandemic, the need for online or distance education became evident. Many educational institutions were caught by surprise. While online education initiatives had already been initiated prior to the pandemic, few educational institutions were adequately prepared. The exceptions were open universities and other open educational institutions. The transition from traditional education to online education necessitated several elements: technical preparedness encompassing equipment and technological proficiency, development of digital content, pedagogical refinement, familial social support, and crucially, the capability to monitor and assess the educational process (Education Sector UNESCO, 2020). A comprehensive vision or strategy to steer this transformation was notably absent (Ciupercă et al., 2022). The repercussions of school closures will continue to influence the educational process even after schools resume operations (Powers et al., 2020).

It is crucial to extract valuable lessons from the crisis that impacted the education system throughout the COVID-19 pandemic. Accordingly, this paper introduces a framework for examining the education system's dynamics during the pandemic, employing the lens of Service-Dominant Logic (SD-Logic) (Vargo & Lusch., 2004; Vargo & Lusch, 2016) and the Service System approach (Maglio et al., 2009). SD-Logic facilitates an understanding of value creation processes, while the service-system approach aids in comprehending the broader context, pinpointing strengths and weaknesses, and fostering the formulation of a visionary pathway for future enhancements. This paper introduces a novel perspective on education, conceptualizing it as a collaborative value-generating service achieved through the integration of resources. Within this context, we outline our viewpoint, setting the stage for empirical validation in forthcoming research.

Therefore, the paper is organized as the following: the next section presents an overview of SD-Logic and the Service system approach. Then a view of the online education service during the COVID-19 pandemic in Romania is presented. In the fourth section we have presented the analysis of online education using the lens of SD-Logic and SSA. Finally, in section five we conclude our findings.

2. Service Dominant Logic (SD-Logic) and the service-system approach (SSA)

This paper investigates the value co-creation process within online education, utilizing the framework of Service-Dominant Logic and the Service System as its theoretical foundation. In the following sections, we provide a comprehensive overview of both approaches and highlight their interrelation:

2.1 Service Dominant Logic (SD-Logic):

Service-Dominant Logic (SD-Logic) was initially introduced in 2004 (Vargo & Lusch, 2004). Since then, it has revolutionized our comprehension of how value is created. SD-Logic perceives the service as the foundational bedrock of exchanges, applicable to both tangible and intangible commodities. Within this perspective, the knowledge and competencies invested in the development and construction of a product are what matter in value creation, surpassing the value of physical products.

Bringing this viewpoint to the context of this paper, let's consider the instance of participating in an online course as an example of a value co-creation process. In this scenario, the accessibility and availability of knowledge and skills hold greater significance than the mere presence of digital infrastructure. Possessing the necessary knowledge and skills enables the exploration of alternative solutions while possessing an impeccable digital platform without the requisite skill set to operate it renders the intended value unrealized.

SD-Logic expands upon the traditional perspective of exchange, surpassing the traditional business-to-consumer or tutor-to-learner relationship. Within SD-

Logic, all involved parties contribute resources to the process of resource integration. Consequently, all transactions within SD-Logic are characterized as Actor-to-Actor (A2A) exchanges (Vargo & Lusch, 2011). Therefore, SD-Logic perceives value as a collaborative creation involving multiple actors, with the beneficiary consistently being part of the equation. In this context, value is not pre-generated and delivered to the beneficiary (Vargo & Lusch, 2016).

For instance, learning is not solely fashioned by the curriculum and digital materials; rather, it is an interactive process that engenders knowledge (Badawi, Carrubbo et al., 2021; Badawi, Drăgoicea et al., 2021) through the dynamic interaction among educators, students, and other entities that contribute to the educational process, such as families and society.

Furthermore, value is consistently distinctive and phenomenological in nature (Vargo & Lusch, 2016). As the combination of resources is inherently unique, the resulting value stemming from their integration is also unique, depending on the integration's contextual circumstances, and established by the beneficiary. This underscores the significance of service assessment. The evaluation of services should be geared toward their beneficiaries and designed with metrics that effectively encapsulate the value generated within the given context. SD-Logic places a strong emphasis on the role of institutions and institutional frameworks in orchestrating the process of co-creating value.

In SD-Logic, institutions are perceived as the norms, rules, and guidelines that facilitate and regulate service exchanges (Vargo & Lusch, 2016). These institutions provide access rights to shared information and establish intentions and limitations. Additionally, institutions establish the contextual definition of value, influenced by the norms of the beneficiaries. What holds value for specific individuals within a particular context might hold less value for a different actor or within an alternative context. In conclusion, both competencies and institutions stand as pivotal elements in ensuring the efficacy of the value co-creation process (Akaka et al., 2019).

2.2 The Service System Approach (SSA)

Within the realm of Service Science, the service system is defined as "a configuration for co-creating value, encompassing people, technology, value propositions that link internal and external service systems, as well as shared information" (Maglio & Spohrer, 2008; Maglio et al., 2009). The service system approach aligns with SD-Logic in its comprehension of value co-creation. However, the distinct value of applying a Service System approach lies in the clear illustration of the value creation elements, coupled with a clarification of the interconnections and governance mechanisms that bind the various service systems together.

According to the Service System Approach, the service system is constructed from the following components: 1) Resources: Resources are categorized as either tangible or intangible, as well as operant or operand.

2) Actors: Actors represent the entities and stakeholders within the service system. 3) Networks: Networks denote the collaborative partnerships formed among the entities within the service system. 4) Interaction: This encompasses the process of value co-creation. 5) Service outcomes: The resultant outcomes of the service process. 6) Evaluation: This facet furnishes metrics to assess the quality, productivity, compliance, innovation, and sustainability of the service system. 7) Institutions: Institutions establish the means by which resources are accessed and governed. 8) Ecology: This represents the service system's capacity to collaborate with other service systems, ensuring its own survival and contributing to the survival of the entire service ecosystem (Badawi et al., 2020; Badawi, Carrubbo et al., 2021).

Both SD-Logic and the Service system approach help develop a distinct theoretical framework. SD-Logic explains the process of value creation within the service system, while the Service system approach outlines the components for accomplishing a fruitful value co-creation process. In the subsequent section, we provide a comprehensive overview of online education in Romania throughout the COVID-19 pandemic.

3. Case Study: Online education in Romania during the COVID-19 pandemic

Due to the COVID-19 pandemic, on March 11, 2020, the Romanian government suspended all in-person educational activities and encouraged and facilitated the continuation of education through online means. In response to the shift to online learning, the Romanian Ministry of Education and Research took several measures, including the establishment of a digital repository for educational materials and textbooks, provision of teacher training on educational platforms and curriculum through the CRED project, development of free learning platforms, and broadcasting of courses on national TV (Holotescu et al., 2020). Although these initiatives positioned Romania fairly well for online education, a study conducted at the University of Petroșani revealed that the country was not adequately prepared for online learning during the COVID-19 pandemic due to insufficient online learning tools and a lack of technical support (Edelhauser & Lupu-Dima, 2021).

During the transition to online learning, students were faced with a deficit in self-confidence, closely tied to their limited technological skills (Edu et al., 2022). Additionally, an analysis of the online education system during the COVID-19 pandemic in Romania underscores the collaborative function of teachers, students, and families in the value-creation process (Ionescu et al., 2020). Parents assume the role of monitoring the educational process, furnishing technological support, and aiding in mitigating the potential repercussions of social isolation (Ionescu et al., 2020). Although the involvement of education managers was pivotal in guiding the shift to online education in many instances, their performance fell short of expectations (Edelhauser & Lupu-Dima, 2021).

The attitudes of both students and teachers toward online learning represent crucial factors in influencing the acceptance and utilization of online learning tools, ultimately fostering productive and efficient collaboration. A study examining students' attitudes toward online learning in Romania highlights that students' perspectives on online education are shaped by their technical proficiency, their capacity to access online courses, and the teachers' aptitude for conducting online classes (Butnaru et al., 2021). Conversely, the digital divide between rural and urban areas emerges as a determinant impacting teachers' motivation to embrace online learning (Petrila et al., 2022).

A study investigating the efficacy of online learning during the COVID-19 pandemic at the School of Economics in Romania discovered that inadequate internet connectivity, distractions arising from family matters, and inadequate study environments are more likely to adversely affect online education (Roman & Ploeanu, 2021). Drawing from (Boca, 2021; Zamfiroiu et al., 2022), it can be inferred that online learning is preferable in scenarios where effective teaching methods, high-quality online courses, and robust digital infrastructure are present. Additionally, ensuring equitable access to infrastructure and digital competencies for both students and teachers constitutes key elements within a prospective education strategy (Nicolau et al., 2020).

4. Discussion

Service-Dominant Logic is founded on the fundamental principle that value is collaboratively co-created within a process (service), involving all contributing parties, including the beneficiary (Vargo & Lusch., 2004; Vargo & Lusch, 2016). To apply this perspective to the online education context, the value derived from online learning is co-created through a process encompassing, though not limited to, educators, technology suppliers, internet providers, families, and most significantly, the students themselves. Technology and internet suppliers function as service facilitators or providers (Polese et al., 2021), playing a crucial role in the educational process. Their absence can significantly impact the potential of the service to generate value. This situation was particularly evident in certain rural areas in Romania during the COVID-19 pandemic, where conducting online lectures posed challenges due to limited internet accessibility (Petrila et al., 2022).

Education aligns seamlessly with the service perspective in SD-Logic. Within SD-Logic, service is conceptualized as an exchange of competencies (comprising knowledge and skills) that are exchanged to provoke value creation (Lusch & Spohrer, 2012). The presence of knowledge and skills stands as the key determinant of learning success, consequently shaping the resulting value (Caridà et al., 2019).

In SD-Logic, much like in education, the concept of value is perceived as co-created, rather than predefined or predetermined. In the context of learning, the creation of value involves the exchange of knowledge and the application of skills.

Within this perspective, the emphasis lies primarily on the process itself, with resource availability at the right time, or resource density (Akaka et al., 2012), serving as a vital component. Resource density acts as the driving force propelling both the learning process and the co-creation of value (Akaka & Vargo, 2014).

As mentioned earlier, the value co-creation process is inherently collaborative, with families playing a significant role in the learning journey. The availability of families equipped with digital skills posed a challenge for online learning during the COVID-19 pandemic. According to 2019 Eurostat statistics, only 34% of households with children under 16 possessed basic or higher-level digital skills in Romania (EUROSTAT, 2020). This challenge subsequently impacted the ability to deliver equitable and satisfactory education to all students.

To comprehend learning as a service, it becomes essential to adopt a broader perspective and understand the service system that underpins the exchange of resources. This service system is perceived as an arrangement involving people, resources, and technology, which interconnects with other service systems to collaboratively generate mutual value (Maglio et al., 2009). This conceptual view inherently complicates the task of demarcating definitive boundaries for the service system. The focal point of the service system is rooted in the value creation process. Every instance of value co-creation initiates with a value proposition (representing the promised value from interaction). Upon the acceptance of the value proposition, the resource exchange commences, transforming the involved entities into integral components of the larger service ecosystem (Quero & Ventura, 2019; Vargo & Akaka, 2012).

While it could be argued that defining boundaries is not strictly necessary, such demarcations do aid in the allocation of responsibilities. However, it's worth noting that these boundaries can inadvertently limit our perspective, potentially causing us to lose sight of the broader context and our responsibilities in supporting others to fulfill their roles (responsibilities).

In scenarios where conventional educational services face disruption due to unforeseen circumstances such as COVID-19, the significance of assessing the resilience of the service system becomes paramount. Resilience within a service system is defined as its capacity to react and adjust in the face of disruptive events while upholding the continuity of services (Polese et al., 2021). This resilience is exemplified by the service system's ability to restructure its existing resources (both tangible and intangible) or to incorporate new resources promptly, in order to sustain service delivery and mitigate the impact of ongoing stress factors.

Moreover, comprehending the context exerts a significant influence on attaining service resilience (Badawi, Carrubbo et al., 2021). There is no universal solution that can be uniformly applied across all contexts. Each educational service system operates within its unique context, which encompasses varying levels of skilled participants, availability of resources, and degrees of technological advancement. Throughout the COVID-19 pandemic in Romania, the sole

contextual aspect that garnered attention was the infection level. During that period, this focus was rational given the primary aim of safeguarding public health. However, as the pandemic subsides, a broader perspective must be adopted when formulating a strategy for enhancing service resilience. This perspective should encompass tailored strategies that cater to the specific parameters of each context, ensuring equitable opportunities for a comprehensive education.

5. Conclusion

Amidst the COVID-19 pandemic, the majority of countries suspended in-person education and transitioned to online learning. However, this shift encountered challenges shaped by the readiness of each country. This investigation recognized a disparity in the planning and execution of this transformation, arising from an inadequate grasp of the intricacies of the educational process. This study introduces a theoretical framework grounded in SD-Logic and The Service System Approach, designed to analyze the educational system both prior to and amidst unforeseen crises. Comprehending the service context empowers policymakers to formulate strategies for seamless adaptation in the face of similar future events, thereby ensuring service resilience.

The findings underscore that perceiving the education service as a value co-creation process highlights the critical significance of resource availability, particularly competencies (knowledge and skills). A notable challenge hindering effective transition to online education is resource density. While this study's scope was confined to the context of online education in Romania during the COVID-19 pandemic, and relied on available empirical data, it significantly enhanced our comprehension of the phenomenon. To validate the framework and assess its applicability in various contexts, further empirical research is imperative.

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Digital Curriculum: a bibliometric analysis

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Abstract: *The paper represents a bibliometric analysis of the studies indexed in the Web of Science database, utilising the "Digital Curriculum" keyword in order to generate explanatory graphical models through the use of the VosViewer software. The purpose of the analysis is to determine the keywords having the highest frequency of use in studies regarding the topic of "Digital Curriculum", while also individuating the countries having the biggest impact and the largest number of publications in the mentioned domain of interest. The study reveals the quantitative relevance of "curriculum", "design", "education" and "students" keywords, highlighting the influential nature of digital curricula on the performative results of students during the educational process, due to the possibility of redesigning pedagogical materials, exercises and problems to be solved interactively. A relevant result may be observed in the relatively high total link strength for the "mathematics" keyword, suggesting the intricate connection between the two domains of study and the suitability of mathematics to be taught through digital means.*

Keywords: Digital Curriculum, Bibliometric Analysis, Mathematics, Education.

1. Introduction

The implementation of digital curricula in the psycho-pedagogical process of educational institutions represents admittedly one of the frontlines' subjects in the development of teaching practices.

Utilising technological means adequately designed for facilitating the learning experience could not only increase efficiency and offer teachers, tutors and professors' innovative ways of displaying and structuring their courses, but also improve students' academic performance.

Although its presence may have a positive impact, using digital curricula implies the necessity of having trained teachers with a high level of technical and pedagogical readiness (Al-Awidi et al., 2017) that, once properly trained, may benefit from a large variety of facilities, such as monitoring the number of attempts

made by students while solving interactive exercises, or adjusting to the students' individual learning paces (Pepin et al., 2017).

Offering students the possibility of choosing their own customizable learning paths when possible (Edson, 2017) and accessing various online programs available on the internet (Darragh, 2021) highlights the utilitarian value of the implementation of digital curricula in the pedagogical experience.

A particular study-case in the literature is represented by the advantages digital curricula bring to mathematics teachers' design of exercises and problems to be solved, as broadly discussed in (Araujo et al., 2017; Choppin, 2016; Pepin, Gueudet & Trouche, 2017; Pepin et al., 2017; Pepin & Gueudet, 2020; Pepin, 2021), due to the compatibility of the mathematical domain with digital pedagogical tools' capabilities.

The rest of this paper is structured as follows: Section 2 will present the methodology we used in our research, while Section 3 is offering the findings. Section 4 is devoted to discussions based on our findings and in the end we present the conclusions of our study.

2. Method

The aim of our research is to understand which are the most relevant papers addressing the topic of digital curriculum, based on several criteria. The purpose of this analysis is to determine the most frequently used keywords in the studies on "Digital Curriculum" and which countries the distributions of the publications belong to.

Therefore, our approach was to address the keyword "Digital Curriculum" in the Web of Science database, by selecting "all fields" in the search criteria. Certain limitations were made while analyzing the studies. The relevant limitation is to Citation of authors, Co-occurrence-all keywords, Bibliographic coupling of documents, Bibliographic coupling of sources, Bibliographic coupling of countries.

Once the results are obtained from Web of Science, we used this information as an input to VosViewer (VosViewer Tool, 2023) in order to analyze the data obtained in the previously described step. The study took place on July 12, 2023. As a result, 90 studies were found and the data were analyzed with VosViewer.

3. Findings

3.1 Citation of authors

The criteria selected in VosViewer when analyzing the citation of authors required the number of published documents of an author to be at least 2, while the minimum number of citations of an author could also be 0. Out of 130 authors, 4 meet the imposed thresholds. In Figure 1, it can be observed the graph obtained in

VosViewer in relation to the citation of authors, while Table 1 highlights the most important authors from this domain and their citations.

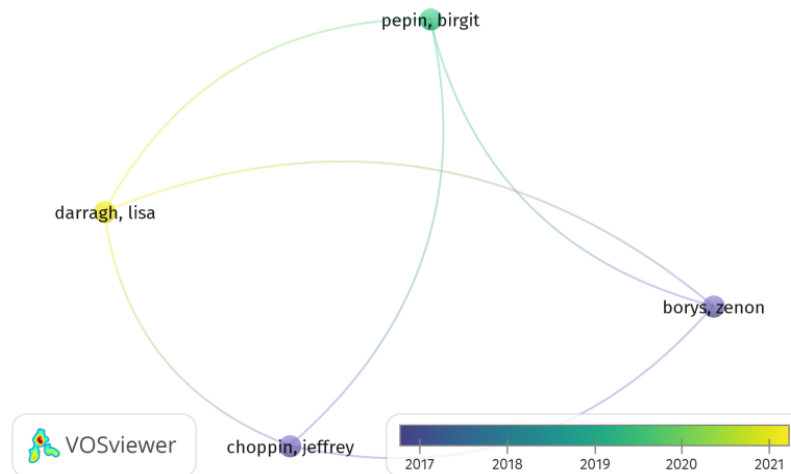


Figure 1. Graph generated with VosViewer for citation of authors

Table 1. Table of citations of authors

Author	Documents	Citations	Total link strength
borys, zenon	2	13	3
choppin, jeffrey	4	64	7
darragh, lisa	2	6	6
pepin, birgit	3	50	6

3.2 Co-occurrence-all keywords

The criteria selected in VosViewer when analyzing the "Co-occurrence-all" connections between different keywords imposed the minimum number of occurrences of a keyword to be 5, resulting in the shrinking of the initial data pool of 223 keywords to 8. The graph generated in VosViewer for co-occurrence-all keywords is presented in Figure 2, while the associated Table 2 presents the number of occurrences for the keywords.

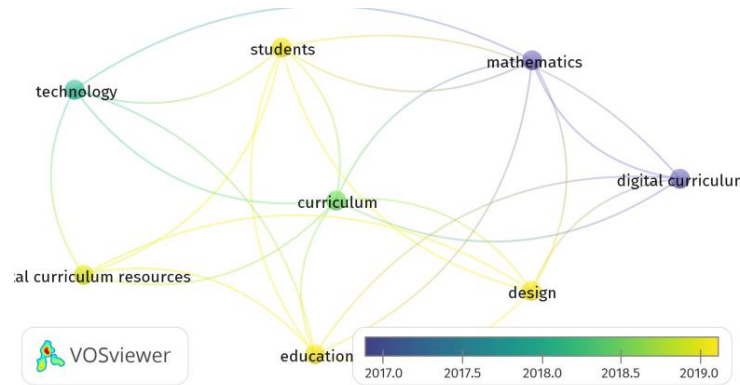


Figure 2. Graph generated with VosViewer for co-occurrence-all keywords

Table 2. Table for co-occurrence-all keywords

Keyword	Occurrences	Total link strength
curriculum	9	15
design	6	14
digital curriculum	12	9
digital curriculum resources	8	10
education	7	16
mathematics	5	13
students	5	16
technology	5	7

3.3 Bibliographic coupling of documents

The selected criteria for the bibliographic coupling of documents imposed the minimum number of citations of a document to be 5, filtering out 15 of the 50 initial documents. In Figure 3 and Table 3 it can be noted the name of the authors and the number of citations regarding bibliographic coupling of documents.

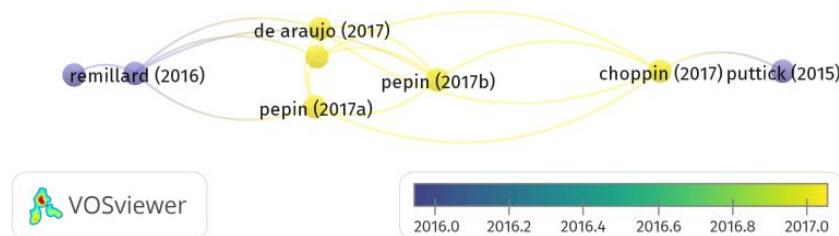


Figure 3. Graph generated with VosViewer for bibliographic coupling of documents

Table 3. Table for bibliographic coupling of documents

Document	Citations	Total link strength
al-awidi (2017)	15	0
puttick (2015)	8	1
pepin (2017a)	45	16
pepin (2017b)	47	37
choppin (2017)	13	22
de araujo (2017)	11	11
remillard (2016)	18	11
leary (2016)	17	1
rangel (2015)	13	0
ciccone (2019)	5	0
edson (2017)	7	17
abell (2005)	11	0
norman (2014)	5	0
wijngaards-de meij (2018)	32	0
memon (2019)	5	0

3.4 Bibliographic coupling of sources

The criteria selected in VosViewer when analyzing the bibliographic coupling of sources included the minimum number of documents of a source to be 2 and the minimum number of citations of a source to be 0. Out of the 41 sources, 3 meet the thresholds, as it can be noted in Figure 4. In Table 4 are presented the most important sources addressing the research topic and the number of documents for each source.

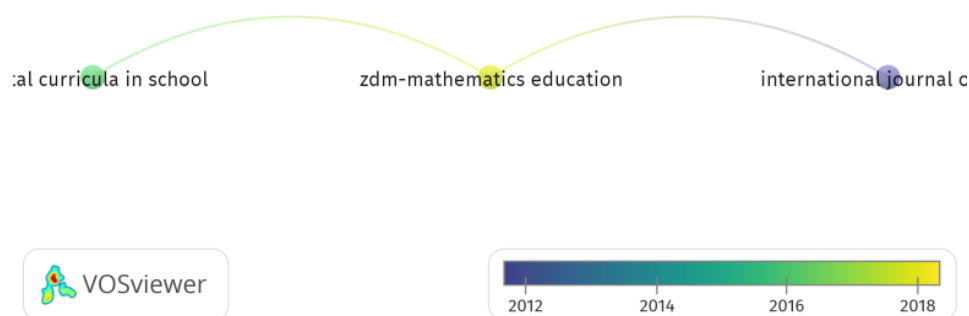
**Figure 4.** Graph generated with VosViewer for bibliographic coupling of sources

Table 4. Table for bibliographic coupling of sources

Source	Documents	Citations	Total link strength
digital curricula in school mathematics	3	25	41
international journal of emerging technologies in learning	2	8	1
zdm-mathematics education	7	124	42

3.5 Bibliographic coupling of countries

The criteria selected in VosViewer when analyzing the bibliographic coupling of countries imposed the minimum number of published documents in a country to be 2, while asking for the minimum number of citations of a country to be at least 1. 10 countries out of 20 meet the thresholds and are presented graphically in Figure 5 and detailed in Table 5.

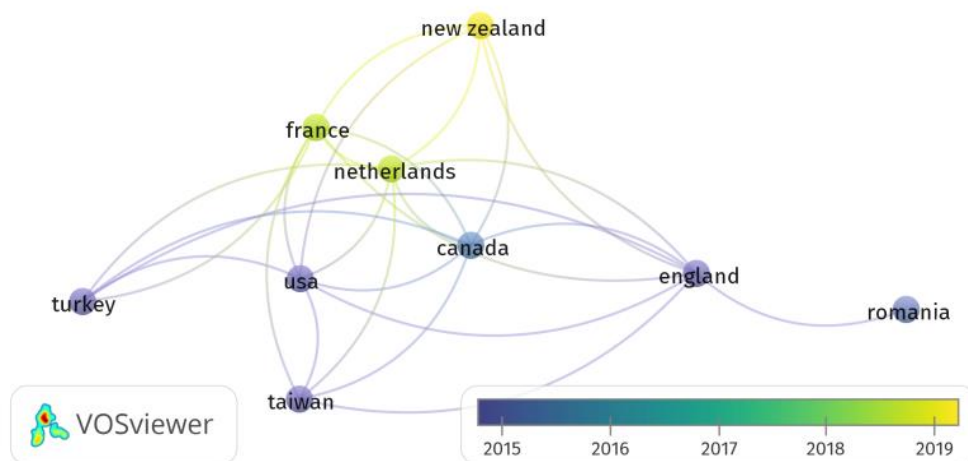
**Figure 5.** Graph generated with VosViewer for bibliographic coupling of countries

Table 5. Table for bibliographic coupling of countries

Country	Documents	Citations	Total link strength
Canada	2	52	334
England	2	51	336
France	2	47	188
Netherlands	6	127	514
New zealand	2	6	20
Peoples r china	6	2	0
Romania	4	3	1
Taiwan	2	1	10
Turkey	2	11	52
USA	16	132	513

4. Discussion

The paper represents a bibliometric analysis of the studies indexed in the Web of Science database, utilising the "Digital Curriculum" keyword in order to generate explanatory graphical models through the use of the VosViewer software.

When the graphs obtained with VosViewer are examined, a particular intensity in collaborations can be observed for Professor of Mathematics Education at University of Rochester Jeffrey Choppin, Lecturer at Faculty of Education at University of Auckland Lisa Darragh and Professor of Mathematics/STEM Education at Eindhoven University of Technology Birgit Pepin; the total link strengths for "choppin, jeffrey", "darragh, lisa" and "pepin, birgit" being 7, 6 and 6 respectively. From a quantitative analysis regarding the most individually cited authors in the literature, the present study highlights the scientific relevance in the "Digital Curriculum" domain of Professors Jeffrey Choppin and Birgit Pepin.

The analysis made on the "curriculum", "design", "education" and "students" keywords, reveals the influential nature of digital curricula on the performative results of students during the educational process, due to the possibility of redesigning pedagogical materials, exercises and problems to be solved interactively (Pepin, Gueudet, Trouche, 2017). The "mathematics" keyword resulted as one of the most utilised one, suggesting the intricate connection between the two domains of study and the suitability of mathematics to be taught through digital means (Reinhold, 2021).

The common source of citations' analysis highlights the importance of Professor of Mathematics/STEM Education at Eindhoven University of Technology Birgit Pepin, indicating also a close relationship between the study of

the utility of digital curricula and the domain of mathematics, as presented in the works: (Pepin, Gueudet, Trouche, 2017; Pepin, Choppin, Ruthven, Sinclair, 2017; Pepin, Gueudet, 2020; Pepin, 2021).

Another important detail resulted from the study would be the relevance of the “ZDM-Mathematics Education” journal, cited 124 times and having a constant and influential presence specifically through papers discussing the applicability of a digital curriculum in mathematics.

Examining the documentation of the studied domain, two countries come to the fore: the Netherlands, having 127 citations and a total link strength of 514, respectively the USA being cited 132 times and scoring a total link strength of 514. Canada, England and France have also scored relatively high total link strengths.

5. Conclusions

The paper represents a bibliometric analysis of the studies indexed in the Web of Science database, utilising the "Digital Curriculum" keyword in order to generate explanatory graphical models through the use of the VosViewer software. Our aim was to understand which are the most visible authors, the research with highest impact, as well as different collaborations that occur between researchers.

As a result of the analysis, noticeable impactful contributions have been brought in the specified literature by the works of Professor of Mathematics Education at University of Rochester, Jeffrey Choppin; Lecturer at Faculty of Education at University of Auckland, Lisa Darragh and Professor of Mathematics/STEM Education at Eindhoven University of Technology, Birgit Pepin; while the most cited countries in the field of study are the Netherlands and the United States of America.

In addition, the study shows that the “ZDM-Mathematics Education” journal is a fundamental scientific resource for pedagogical research, being cited 124 times in the studied Digital Curriculum domain.

Finally, the analysis shows the intertwining relevance of the “curriculum”, “design”, “education” and “students” keywords, revealing the influential nature of digital curricula on the performative results of students during the educational process, due to the possibility of redesigning pedagogical materials, exercises and problems to be solved interactively. A relevant result may be observed in the relatively high total link strength for the “mathematics” keyword, suggesting the intricate connection between the two domains of study and the suitability of mathematics to be taught through digital means.

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Shaping the educational landscape: the rise and potential of Verifiable Credentials in higher education

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Abstract: *In an era defined by rapid technological advancement, virtually every facet of society has undergone transformative changes. One of the most profound transformations has occurred within the realm of education, where technological innovations have revolutionized the learning landscape. This paper seeks to depict the immense potential held by Verifiable Credentials within the educational system and to unravel their multifaceted applications, positioning them as the vanguard of modern education. Additionally, the paper aims to examine the impact, challenges, and benefits arising from the infusion of this technology into the educational domain and to envision the forthcoming perspectives of this 'partnership' between technology and education.*

Keywords: New technology, Verifiable Credentials, Higher Education, International initiatives, Future Developments.

1. Introduction

Over the last decade, technology has brought about substantial advancements in various sectors, including education. The COVID-19 pandemic further accelerated the adoption of technology in education, leading to a transformation in learning paradigms. This shift has led to the exploration and implementation of new tools and methods aimed at enhancing the efficiency, interactivity, and security of educational processes. In the table below, we can observe the most important technology advancements in education, as well as the essential changes in the educational paradigm due to the pandemic period:

Table 1. Advancements and changes in the learning paradigm and education technologies [own source]

Advancement in Educational Technology	Changing paradigms due to the pandemic
Online Learning Platforms: Learning Management Systems (LMS) such as Moodle, Canvas, and Blackboard have	Remote Learning: Lockdowns and safety concerns led to the rapid adoption of remote learning, prom-

become integral to higher education. These platforms offer a centralized space for course materials, assignments, communication, and assessments.	pting educators to adapt their teaching methods for online environments.
Virtual Classrooms: Video conferencing tools like Zoom and Microsoft Teams have enabled real-time virtual classrooms, facilitating synchronous interactions between instructors and students	Hybrid Models: Many institutions adopted hybrid models, blending in-person and online instruction to accommodate diverse learning preferences.
E-Learning Resources: Open educational resources (OER), digital textbooks, interactive simulations, and multimedia content have diversified the learning experience.	Assessment Techniques: Traditional in-person exams shifted towards online assessments, necessitating the development of secure, proctored online testing solutions.
Adaptive Learning: Personalized learning algorithms analyze student performance to provide tailored content and interventions.	Digital Collaboration Tools: Students and educators started using collaborative platforms for group projects, discussions, and knowledge sharing.
Gamification: Incorporating game elements into education engages learners and enhances motivation.	

As educational institutions embrace innovative learning tools and strive to enhance the digitalization of their educational frameworks, they are also confronted with significant security challenges. So, technologies as blockchain or verifiable credentials were integrating in order to assure strong and efficient systems that facilitates the interaction between students, educational institutions and other organizations that are requesting educational information.

This paper aims to examine the potential of integrating verifiable credentials into the educational system and environment. It will highlight various instances where this technology has been successfully employed, alongside initiatives that align with its principles. Furthermore, an in-depth exploration of the impact, challenges, and benefits associated with the adoption and integration of this concept will be addressed.

2. Understanding the main concepts

For a better understanding of the advantages of verifiable credentials and a clear view on the utility of them, the main concepts will be presented.

A digital identity is defined as a compilation of attributes that encompass pertinent information, facilitating the recognition and entry of an individual,

organization, or device within a specific context. Managed by designated identity providers, this digital identity paradigm introduces certain challenges related to data sharing and security. Identity owners often employ these identities to secure access or permissions to systems that might not align with established privacy and data sharing standards on the Internet, resulting in an inadvertent excess of information divulgence. This situation underscores the pressing need for a redefined digital identity framework, one that empowers users with comprehensive control over their identity and the intricacies of information sharing (Shuaib et al., 2022).

The concept of self-sovereign identity (SSI) was introduced to empower users with exclusive control over the management of their digital identities. SSI encapsulates three essential elements: individual control, security, and complete mobility. This paradigm deconstructs external controls, entrusting users with the ownership and administration of their data, eliminating the requirement for a centralized external entity to consolidate identities across diverse entities (Vasile & Dinu, 2021).

Christopher Allen, a luminary in security and cryptography, delineated ten cardinal principles underpinning the architecture of SSI (Allen, 2016):

- **Existence:** The user's societal existence constitutes the foundation of digital identity, anchored in official identifiers such as identity cards or birth certificates. It furnishes the requisite particulars for distinct situations.
- **Control:** The user retains absolute authority over their digital identity, possessing comprehensive rights to manipulate it, encompassing deletion and updates. This is sustained by algorithms and mathematical methodologies validating data authenticity.
- **Access:** Users are vested with access to their personal identity information and retain decision-making powers regarding identity-related actions.
- **Transparency:** The algorithms and systems undergirding the digital identity ecosystem must be transparent, validated, and accessible to the public.
- **Persistence:** An identity's validity endures for an extended duration, either until the data becomes obsolete or the user opts to relinquish the identity. The rapid evolution of the digital realm necessitates provisions for identity format updates.
- **Portability:** Identity data and associated services must be portable and accessible, empowering users to perpetually govern their own identity.
- **Interoperability:** Digital identity systems necessitate global operability and recognition across diverse digital identity types.

- Consent: User consent serves as a prerequisite for sharing or accessing digital identity information. Regulatory safeguards for user safety and privacy must be rigorously observed.
- Minimization: User digital identities must encompass solely the requisite data essential for identification within a specific context. For instance, an event organizer might seek first and last names, obviating the need for disclosing extraneous identity data.
- Protection: In cases of conflict between a user's digital identity and the network managing identities, the user's rights hold paramount significance. Authentication, conducted independently through network infrastructure-independent algorithms, upholds data integrity, authenticity, and persistence.

The main instrument for implementing SSI in the field of digital identity and decentralized identity management is by Verifiable Credentials (VCs). They are a way to digitally represent and prove various pieces of information about an individual, organization, or entity, while maintaining privacy, security, and user control over their data.

To assure the integrity, authenticity, and continuity of data, the implementation of self-sovereign identity management systems is grounded in blockchain technology. The core principle of self-sovereign identity revolves around the management and storage of verifiable credentials residing in off-ledger domains. The credibility of these signed data entities is upheld through the inclusion of a hash on a blockchain. When individuals submit verifiable credentials to a relying party, a comparison of the credential's hash with the accessible blockchain record, authenticated through an integrated signature mechanism, promptly and accurately substantiates the credential's validity. This process expedites the relying party's ability to affirm the credential's legitimacy. In the context of data integrity, a blockchain mechanism facilitates both the revocation of consent-related actions and the maintenance of auditable consent records, thus bolstering the security of data entities (Shuaib et al., 2022).

The concepts presented herein introduce a promising avenue for research and development, delineating a novel sphere in which applications and systems can be conceived to streamline administrative procedures and enhance traditional frameworks, with a specific emphasis on the domain of education.

This emerging field beckons the exploration of pioneering solutions that possess the potential to reshape administrative dynamics and amplify the efficacy of conventional paradigms. Notably, within the educational context, the assimilation of these concepts can herald an era marked by heightened efficiency, interactive engagement, and fortified security.

3. The integration of Verifiable Credentials in higher education

The domain of education is presently undergoing a gradual exploration of the capacities inherent in Self-Sovereign Identity (SSI) and Verifiable Credentials. These innovative technologies have been methodically introduced into various scenarios within the educational framework, with the explicit purpose of scrutinizing and deducing the advantages associated with their incorporation. This purposeful assimilation marks a significant juncture where educators and institutions are meticulously probing the potential of SSI and Verifiable Credentials. Their objective is to uncover new prospects and draw well-informed conclusions regarding the feasibility of integrating these technologies. In the subsequent sections, a range of approaches will be elucidated, shedding light on the multifaceted pathways through which the benefits of Verifiable Credentials are being unearthed and comprehensively comprehended.

Belgium and Italy have jointly leveraged their resources and expertise to conduct action research within a cross-border diploma use case, operating under the auspices of the European Blockchain Services Infrastructure (EBSI) and the European Blockchain Partnership (EBP). The EBSI Diploma Use Case comprises a blockchain-based system that provides a platform for students, educational institutions, and third parties to validate and authenticate educational documents, such as diplomas and certificates, without necessitating a centralized administrative procedure. This validation is achieved solely through the generation of educational credentials. The implementation of this cross-border system for verifying educational credentials was meticulously designed with due consideration for compliance with the General Data Protection Regulation (GDPR) and adherence to the principles outlined by the European Self Sovereign Identity Framework (ESSIF). The overarching objective was to establish the verification of student identification information and transcripts between two prominent universities, namely the University of Bologna and KU Leuven. The primary focus centered on facilitating the seamless exchange of students between these academic institutions. Consequently, two distinct types of credentials were generated and made verifiable: firstly, a comprehensive student ID credential containing all pertinent information, and secondly, a verifiable transcript of records detailing the academic achievements of the students. The outcomes of this endeavor have been demonstrative of noteworthy enhancements in the authentication and verification processes pertaining to students engaged in exchange programs between the aforementioned universities. (Tan et al., 2023).

Digital Credentials for Europe (DC4EU) stands as another pioneering initiative that harnesses the collaborative efforts of Member States to integrate verifiable credentials across several critical domains, including education. The electronic IDentification, Authentication and trust Services (eIDAS) trust framework, a cornerstone within the European Union, provides a foundational basis for establishing identity and trust within the digital landscape. The recent

expansion of this framework broadens its scope beyond identity, encompassing the electronic attestation of attributes (EAA). The formulation of technical measures, procedures, and protocols to establish trust frameworks within specific sectors assumes a pivotal role in fostering a digitally empowered Europe. In light of this, DC4EU is dedicated to identifying and applying these principles within the field of Education. This endeavor will primarily concentrate on the issuance of educational credentials and professional qualifications. Additionally, DC4EU's scope extends into the domain of Social Security, as it actively participates in executing the portable document A1 (PDA1) and the European Health Insurance Card (EHIC). The project's objectives will be realized through meticulous procedures that facilitate thorough testing of wallets. This comprehensive testing will involve the use of Qualified Electronic Attestations of Attributes (QEAA), Electronic Attestations of Attributes (EAA), and credentials. These evaluations will encompass both the national and cross-border functionalities of these elements within a controlled pre-production environment, aligning closely with corresponding use cases (UCs). DC4EU assumes a pivotal role in sculpting a fresh paradigm for citizens in the spheres of education and social security. This role seamlessly aligns with the guidelines articulated by the European Council concerning identity and data. Furthermore, the project steadfastly upholds the principles outlined in the European Declaration on Digital Rights and Principles. Through its partnership network, Romania emerges as an active participant in the fulfillment of the project's objectives. (DC4EU, n.d.).

In their recent work (Koukoularis, Markopoulos & Voutsinas, 2023), the authors introduced a novel model for the exchange of educational credentials. The primary objective was to enhance the process of sharing digital credentials, thereby streamlining diploma verification for purposes such as job applications or post-graduate studies. The model outlines the fundamental principles underpinning the digital diploma platform employed by Greek Higher Education Institutions (HEIs), known as eDiplomas.

The research underscores the significance of a unified Trust Framework as a pivotal factor in achieving interoperability and mitigating the risk of vendor lock-in. The authors conclude by highlighting the imperative for Universities and HEIs to embrace robust and cutting-edge infrastructure, built upon established secure protocols and state-of-the-art privacy-enhancing technologies. This proactive stance is emphasized as critical for sustained success in navigating the evolving landscape of digital innovation.

In the scholarly work conducted by (Strack et al., 2022), an insightful portrayal is provided of the Federal Ministry of Education and Research (BMBF) of Germany's innovative venture. This initiative revolves around the investment in a prototype platform recognized as the National Education Platform, abbreviated as "Nationale Bildungsplattform" (NBP). This endeavor is positioned as a pivotal element within a distributed educational digital service infrastructure. The authors approach this exploration with a dual perspective, emphasizing its centrality from

the vantage point of both the learning user and the decentralized educational service providers (namely, Educational Institutions, Higher Education Institutions, and Private Educational Institutions). The study endeavors to delve into the realm of possibilities and harnesses the potential of various technologies to realize the successful implementation of this platform. By scrutinizing both the user-centric approach and the broader perspective of educational service providers, the authors provide a comprehensive understanding of the endeavor's ambitions and implications.

Examining the limited number of initiatives outlined earlier, it becomes evident that a substantial interest exists in the adoption of educational credentials and the subsequent implementation of blockchain-based systems. These systems are tailored to facilitate the requisite procedures and actions within the educational framework. The momentum behind these endeavors underscores a collective recognition of the potential benefits derived from these advancements in the realm of education.

4. Integration of VCs in romanian education landscape

At the national level, we can admit that there is an interest in developing blockchain capabilities and exploring the concept of verifiable credentials. Between April 2021 and March 2023, UEFISCDI and Politehnica University of Timisoara conducted the European project titled 'EBSI4RO: Connecting Romania through Blockchain.' The project aimed to create an environment that provides knowledge, training, and awareness for adopting distributed technology. Moreover, the project supported the participation of Romania in EBSI, by developing an application based on digital credentials and microcredentials for the diploma use case, integrated with (Single) National Student Enrolment Registry (EBSI4RO, n.d.).

In 2021, ICI Bucharest announced a partnership with Selfd.id, developers of the first decentralized platform for digital identity in Romania. The aim of this partnership is to accelerate the digitalization of the public administration systems and alliging with the European initiatives in terms of adopting secure identity technologies (ICI Bucharest, 2021).

Furthermore, the article (Vasile & Dinu, 2021) introduced an informatics system that uses verifiable credentials to authenticate diplomas in correlation with users' identities. This system can pave the way for further opportunities in implementing digital student ID cards, examination credentials, and student qualifications.

5. Impact, challenges and benefits

The impact of verifiable credentials in the education sector has been transformative, ushering in a new era of efficiency, security, and transparency. Verifiable credentials, which are digital representations of educational

achievements and qualifications, have revolutionized the way educational information is stored, shared, and verified.

One of the primary advantages of verifiable credentials is their ability to enhance the portability and accessibility of educational records. Traditionally, paper-based transcripts and certificates were susceptible to loss, damage, or fraud. Verifiable credentials, being digital and cryptographically secured, mitigate these risks by providing a tamper-proof and easily shareable format. This has been especially beneficial for students who are pursuing higher education across borders or applying for jobs internationally, as their credentials can be instantly and securely verified by relevant institutions or employers.

Moreover, the implementation of verifiable credentials has streamlined administrative processes within educational institutions. The manual verification of academic records can be time-consuming and prone to errors. With verifiable credentials, the verification process becomes automated and instantaneous, reducing administrative burdens and allowing educational institutions to focus on more value-added tasks (Kishore et al., 2021).

Additionally, verifiable credentials contribute to the broader concept of lifelong learning. As individuals engage in continuous education and upskilling throughout their careers, these credentials enable a seamless way to showcase their new qualifications and competencies. This, in turn, supports a more dynamic and adaptable workforce.

However, challenges such as standardization, interoperability, and data privacy need to be addressed as the adoption of verifiable credentials grows. Collaborative efforts between educational institutions, technology providers, and policymakers are crucial to ensure that the benefits of verifiable credentials are realized while maintaining data security and ethical considerations.

The impact of verifiable credentials in the education sector has been substantial, ushering in efficiency, security, and adaptability. By modernizing the way educational achievements are stored and shared, verifiable credentials contribute to a more connected and agile learning ecosystem.

6. Conclusions

In conclusion, the integration of verifiable credentials within the education sector signifies a significant stride towards progress. This transition underscores the adaptability of education to the evolving technological landscape, while also exemplifying a pivotal step towards establishing a more secure, efficient, and globally accessible educational system.

Verifiable credentials bring forth three key attributes that warrant attention. Firstly, the utilization of blockchain-based mechanisms for heightened security ensures the preservation of the tamper-proof nature of educational records. This

fortified protection against fraudulent activities safeguards the integrity of academic accomplishments and enhances the credibility of the presented credentials.

Secondly, the streamlining of verification processes carries substantial importance. The agility with which institutions, employers, and evaluators can authenticate credentials accelerates decision-making processes, thereby benefiting both students and professionals. This swiftness holds particular significance in competitive domains such as job applications and academic admissions.

Moreover, the potential of verifiable credentials extends beyond local borders. The ease with which digital credentials can be shared enables individuals to transcend geographical confines, embracing opportunities on a global scale. This capability not only supports cross-border educational endeavors but also nurtures collaborations that bridge geographical and cultural gaps.

However, the effective integration of verifiable credentials hinges on collaboration, standardization, and ethical considerations. The harmonious interaction among educational institutions, regulatory bodies, and technology providers is pivotal to establishing uniform protocols that facilitate seamless data exchange. This standardization fosters an ecosystem where the benefits of verifiable credentials can be fully harnessed.

Ethical contemplations also play a substantial role, particularly concerning data privacy and consent. Striking a balance between the transparency enabled by verifiable credentials and the safeguarding of individuals' personal information requires careful thought and adherence to evolving regulations.

In essence, education's trajectory is veering towards a future illuminated by the potential of verifiable credentials. The commitments to heightened security, expedited verifications, and broadened global horizons hold immense promise. However, navigating this transformative journey necessitates the collaborative efforts of stakeholders to address challenges, align with standards, and uphold ethical principles. Through this collective endeavor, the education sector stands poised to harness the full potential of verifiable credentials, ushering in a new era of recognition and validation for educational accomplishments.

Acknowledgment

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Models for quality assurance in higher education area

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Abstract: *This paper examines some problems in quality assurance in higher education. The need to use specialized software systems to fully automate procedures and business processes for conducting assessment and accreditation procedures is motivated. Two quality assurance models are proposed, based on the idea of an automated transfer of information between higher schools and accrediting bodies - with stronger and weaker integration. The loosely centralized model provides greater opportunity for integration of the university's QA system with other internal systems of the institution and own control over business data. The highly centralized model minimizes the need for administrative support on the part of the higher school, but the possibilities for integration with available university systems are limited. A generalized net model of data processing for self-assessment procedures in higher education institution is also proposed in the paper.*

Keywords: Accreditation, Higher Education, Quality Assessment, Generalized Net Model.

1. Introduction

Quality assurance in higher education (HE) is an ongoing process that requires a lot of effort on the part of educational institutions and accreditation organizations. There are two main forms – ***internal and external quality assurance***. Higher education institutions (HEIs) build ***internal quality assurance systems*** and are free to establish their own rules and criteria for assessing various objects and subjects of the educational process. They are also subject to ***external assessment – accreditation performed by licensed national and international agencies***. They assess them on the basis of established and standardized criteria systems for quality assessment. In the general case, in external assessment the accrediting institutions require self-assessment reports from the HEIs, proving the implementation of the approved criteria system, and accompanied by a lot of evidence and documents. To receive higher assessment grades, ***HEIs build their internal quality systems in accordance with the criteria systems of the accrediting institution***. This undoubtedly motivates the main university units to meet the set criteria but also reveals ***prospects for formalization and centralization of the***

accreditation procedures. The possibility to create a centralized repository and a system for management and monitoring of accreditation procedures leads to greater transparency, objectivity and saves time, human and material resources.

Two models for quality assurance are proposed in this paper – one with stronger and another with weaker centralization, based on the idea of automated information exchange between higher education institutions and accreditation bodies. The presented models are based on the experience of the authors in building an automated system for quality assurance and accreditation COMPASS (Hadzhikoleva et al., 2016a), used in the University of Plovdiv “Paisii Hilendarski”. They extend the strictly institutional constraints of COMPASS by providing a framework for building a national automated system for quality evaluation and accreditation.

2. Accreditation of higher education in Bulgaria

The need for commensurability of the quality of higher education in the European Union motivates the definition of uniform quality standards. European Higher Education Area (EHEA) is characterized by a wide variety of higher education systems, educational institutions, bodies for external evaluation and accreditation, socio-cultural differences and educational traditions. This makes it impossible to establish a uniform quality assurance system. It was therefore necessary to develop standards that are so general that they can be adapted to the specificities of education at a national level, while at the same time be so specific as to give a common concept and vision of quality of higher education in the European Union. In 2005, a significant step was taken in this direction. European Standards and Guidelines for Quality Assurance (ESG) in the EHEA were developed. They were accepted by the ministers responsible for higher education in the countries of the European Union. The document was last updated in 2015 (Standards and guidelines, 2015). It contains many standards and guidelines for their implementation and is used by many quality agencies in the EU. ESG does not define specific methodologies and procedures for quality assurance. Educational and accreditation institutions develop their own methodologies and criteria systems for assessment, in accordance with ESG standards.

Bulgaria is one of the countries that apply the ESG standard. Ensuring the quality of higher education in Bulgaria is carried out by the National Evaluation and Accreditation Agency (NEAA). It is the only specialized state body for assessment, accreditation and quality control of higher education in Bulgaria. It is authorized through the Higher Education Act (Higher Education Act, 1995) to approve criteria and procedures for assessment and accreditation and related documentation.

By 2023, 8 types of accreditation procedures have been approved, incl. institutional accreditation; program accreditation of professional field, specialty and doctoral program; assessment of distance learning; assessment of projects for opening and transformation of units, professional fields, etc.

The quality assurance procedures follow a general scheme and include several main activities – self-assessment, visit of an expert group, evaluation and post-accreditation control. If we ignore the specific administrative activities carried out in HEIs and NEAA, related to discussion, voting and preparation of administrative reports and decisions, the stages of an assessment procedure can be defined as follows:

- ***Self-assessment.*** The assessed institution provides a basis for conducting external quality evaluation by conducting a preliminary self-assessment and preparing a self-assessment report. It should be developed in accordance with the requirements of the criteria system of the NEAA for the relevant procedure and contain a self-assessment and analysis of the achieved according to the basic standards, which are the subject of the verification and assessment.

- ***Visit of an expert group (EG) to the assessed institution.*** The EG makes an on-site visit to the institution being evaluated, checks the information provided and if necessary, requests additional information. The EG prepares a report on the performed inspection, containing an assessment and specific guidelines for future actions aimed at improving the quality of education.

- ***Evaluation.*** After discussions and votes, the NEAA makes a final decision on the evaluation and is motivated by relevant opinions and reports.

- ***Post-accreditation control.*** It includes procedures for follow-up control in the educational institution, aimed at monitoring the implementation of the instructions given.

Accreditation procedures are conducted in a similar way in many European countries. They require a lot of time, material and human resources, for many reasons:

- ***Universities collect, analyze and process a large volume of various types of data, incl. unstructured or semi-structured.*** The information is collected by various administrative and educational units. In some cases, there are no established standards and often the same type of information is structured differently by the different units. Some of the information is processed manually, whereby updating already processed information requires re-processing and summarizing. If the educational institution does not have a unified repository of administrative and educational documents, there is the risk of providing duplicate information, using outdated data and documents, etc.

- ***Members of the administrative and academic staff with different competencies*** participate in the evaluation procedures. They are from different units, have different rights and responsibilities, different access to information, different opinions and vision of the quality of education, teamwork skills, etc.

Accreditation procedures are conducted periodically, the periods ranging from 3 to 6 years depending on the type of accreditation procedure and/or the

previous assessment. This is related to *a few months' redirection of the efforts of a large part of the academic staff from the educational process to the accreditation procedure*. The university staff interrupt their main activities and make extraordinary efforts to prove compliance with the accreditation criteria and receive a high grade. Procedures for evaluation and accreditation in higher education must be a natural and integral part of the educational process. They should be held without much effort, unnoticed by students and academic staff. For this purpose, however, educational institutions must maintain repositories with up-to-date information about their activities, and accreditors must provide software tools for automated quality assessment. This is the only way to ensure an objective and indifferent assessment which would allow each higher education institution to identify its strengths and make an effort to improve its weaknesses.

3. Accreditation process by the university

Faculty and university quality commissions function to conduct the accreditation procedures at the higher education institutions. The staff of the faculty quality commissions (FQC) usually involves representatives of all primary units in a given faculty, including a representative of the student community. The FQC is responsible for conducting procedures for accreditation of professional fields and specialties of the regulated professions and doctoral programs. University quality commissions (UQC) are responsible for conducting institutional accreditation, project assessment and distance learning. It involves representatives of all faculties and branches, the student community, certified quality experts, etc. The FQC and the UQC have the responsibility to request, collect and process information related to the accreditation procedures and prepare the necessary reports and references. This is extremely complex in institutional accreditation because the main tasks are distributed within the UQC, assigned to the FQC, after which the information is collected by the academic staff, summarized at faculty first and then at university level. The careful enforcement of standards defining the way in which the main and primary units collect well-structured information from the academic staff is of great importance.

Many higher education institutions have built and maintain software systems for the publishing and research activities of the academic staff, but it is not always possible to extract all the information necessary for accreditation automatically. The important factor for this is the way this information is structured in the university system, and whether it complies with the requirements of the NEAA. In case the university does not have its own centralized software system, this information is collected by the academic staff by departments, summarized at the faculty level, and then at a university level. This creates the risk of making mistakes – e.g. re-reporting the same publications, especially if they are co-authored with lecturers from the same faculty. Various applications are usually used in practice which partially automate different quality assurance activities. Some types of them are presented in Figure 1.a. and Figure 1.b.

Many higher education institutions lack a system supporting the creation of a self-assessment report. In this case, the distribution of tasks for its preparation becomes hierarchical: the NEAA opens an accreditation procedure and notifies the university; the university accreditation commission allocates tasks for preparation of reports and preparation of texts for the individual standards to the corresponding units; the units collect information from various registers, university software systems with structured or non-structured data, as well as non-digitized information (Figure 1.a). Despite the data collected by individual employees, the creation of the final version of the self-assessment report is no less difficult due to the need to summarize the data that is provided in different formats and bring the texts into a document with a common literary style.

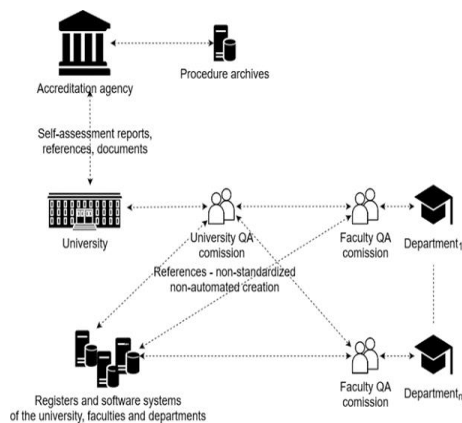


Figure 1.a. Model for preparing a self-assessment report without QA system

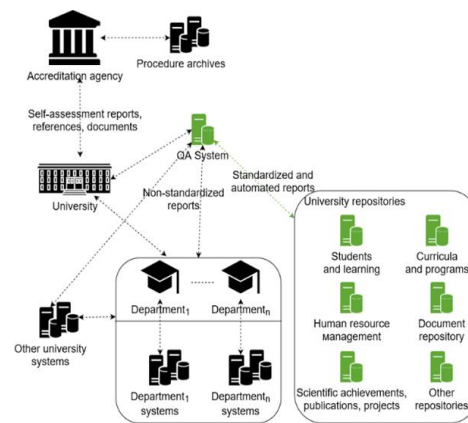


Figure 1.b. Model for preparing a self-assessment report with QA system

The availability of software tools supporting the creation of a self-assessment report provides opportunities for: ongoing control and monitoring of the activities for compiling a self-assessment report; automation of the access to standardized reports from internal and external registers; facilitated cooperation between the participants in the assessment procedures, etc. (fig. 1.b) (Hadzhikolev et al., 2016). There are no software solutions that fully automate the process of quality assessment or accreditation in higher education.

4. Weakly centralized model for accreditation

One possible approach for automation of the accreditation procedures is by building a centralized system of the accreditation agency and independent university systems for quality assurance (Figure. 2a). Each university QA system automatically retrieves the necessary accreditation data from the university repositories (students and learning, curricula and programs, human resource

management, document repository, scientific achievements, publications, projects, etc.). Another part of the information concerning justifications, explanations and conclusions is entered by university persons in charge and quality experts. At a certain point in time, the information from the university QA system is exported to the QA system of the accrediting institution.

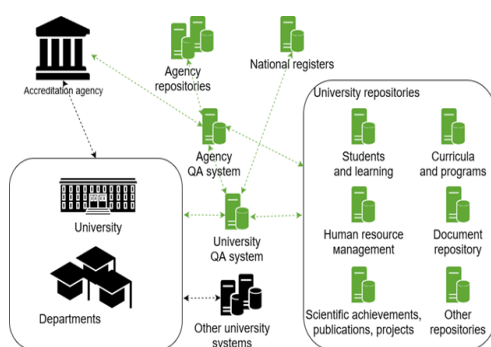


Figure 2.a. Process of accreditation of a HEI

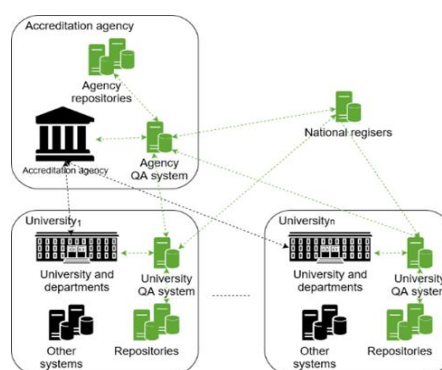


Figure 2.b. Process of accreditation in the system of HE

The advantages of this approach are the opportunity for each higher education institution to build its own QA system in accordance with its needs and its own information ecosystem, in accordance with the standards and protocols set by the accreditation agency. The provision of standardized QA systems receiving automated updates, easy to independently install, configure and use, would be a significant facilitation. Also, the existence of a centralized system of the agency means that universities would not create their own solutions but would only use the opportunities provided by the agency.

The advantages of this approach also determine its disadvantages. The creation of their own solution or the maintenance of a standardized application by the universities requires the presence of specialized IT specialists in each higher education institution. Creating a standardized University QA system is a laborious task that must take into account the availability of many different university repositories and other software systems. Of course, the universality of such a system is desirable but not mandatory.

5. Highly centralized model for accreditation

The creation of a national centralized software system for quality assurance would allow more effective software support, provide transparency and monitoring of the quality of education. The highly centralized model proposes the use of a centralized cloud-based accreditation system. The system supports a module for the

QA agency as well as configurable modules serving the accreditation processes for the individual higher education institutions (fig.3). The use of a unified system enables the establishment of conveniences for integration and communication between the individual modules, user-friendly software updates, opportunities for easy integration of future software extensions, creation of dynamic analyses and reports on the data provided by all institutions. In this way, HEIs can use Quality Assurance in Higher Education as a Service (Hadzhikoleva et al., 2016b).

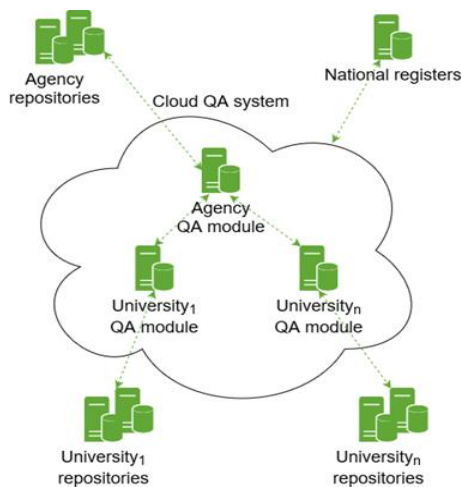


Figure 3. Centralized accreditation model

While in the weakly centralized model there are non-automated connections and processes, the highly centralized model not only removes many of the connections between various unstable components in the software environment, but also creates greater opportunities for automation of the quality assurance and accreditation processes.

The main functionalities in the modules of the agency and the higher education institutions in the highly centralized model are presented in Table 1. Many of them have been successfully experimented in the COMPASS system.

Table 1. Main functionalities and their management in a highly centralized model

Functionality	Description	Accr. Agency	HEI
Meta-meta-model of assessment methodology	Modeling the main types of assessment components of the assessment methodology and possible connections between them.	✓	✗
Meta-model of assessment methodology	Creating a data model for each type of assessment component and the possible actions (functionalities) on it.	✓	✗
Model of assessment methodology	Creating a hierarchical model of assessment methodology.	✓	✗
Model of procedure for	Indication of the methodology used for a specific type of assessment. Determining basic	✓	✗

self-assessment / assessment based on methodology	parameters on an assessment procedure: setting start and end dates, roles, access rights to the activities, etc. Specific procedures based on methodology can be for: self-assessment by the HEI, assessment by an expert group, accreditation, etc.		
Starting a procedure	Determining values of parameters necessary for starting the procedure by the NEAA: users with administrative rights under the relevant procedures, deadlines, etc.	✓	✗
Procedure administration	Configuration of users and additional parameters by administrators of: <ul style="list-style-type: none"> • The HEI (in the case of self-assessment); • Expert group (in case of assessment by an expert group); • Accreditation agency (in case of accreditation). 	✓	✓
Execution of a procedure	Entering data for a specific assessment procedure by authorized users.	✓	✓
Completion of a procedure	Hierarchical, step-by-step completion of the procedure.	✓	✓
Modeling of automated assessments, analyzes, reports, etc.	Creating standardized reports to help participants in assessment procedures. Creation of functions for automated assessment of assessment elements, methodologies or their sub-components, based on mathematical methods and functions. Creating functions for analysis and comparison between all or selected higher education institutions, using statistical methods and AI methods.	✓	✗

6. GN model of data processing of self-assessment in the higher education institution

The Generalized Net (GN) apparatus is a powerful tool for modeling time-parallel processes, applied in various fields and fields of application (Atanassov, 1991; Atanassov, 2007). We used GN notation successfully to formalize different QA processes and systems (Hadzhikoleva et al., 2019; Hadzhikoleva et al., 2020).

The GN, describing data processing of self-assessment procedure in the higher education institution contains the following set of transitions:

$A = \{Z_1, Z_2, Z_3, Z_4\}$, where:

Z_1 – Data collection from various data sources;

Z_2 – Data integration;

Z_3 – Data processing on the requirements, related to the criteria system;

Z_4 – Preparation of self-assessment report and relevant applications.

The following tokens are used to describe the processes:

- α -token – data on the activity of the higher education institution;
- β -token – members of the administrative and academic staff, members of the quality committee and the self-assessment report preparation group;
- μ -token – criteria system of the accrediting institution;
- η -token – Data repository with up-to-date information on the activities of the higher education institution, necessary for the preparation of a self-assessment report;
- γ -token – Data processing tool;
- σ -token – Data request from an user/application.

The Generalized Net model is presented in figure 4.

Transition 1: Data-collection from various data sources.

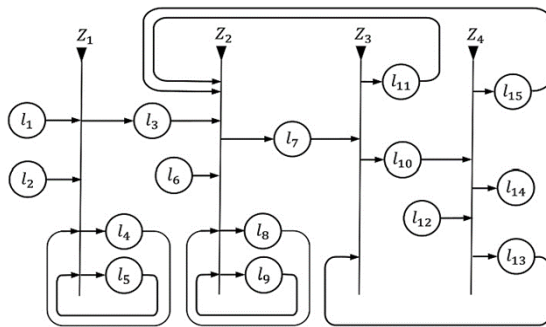


Figure 4. GN model of data processing of self-assessment procedure in HEI

The information is collected by various administrative and educational units. In some cases, there are no established standards and often the same type of information is structured differently by the different units. Some of the information is processed manually, whereby updating already processed information requires re-processing and summarizing.

If the educational institution does not have a unified repository of administrative and educational documents, there is the risk of providing duplicate information, using outdated data and documents, etc.

The process is started when α -token enters the generalized net from position l_1 , with initial characteristic: “*ID data (set of data), value*”.

Through position l_2 , new members of the administrative and academic staff can come through β -tokens, with initial characteristic: “*ID, user name*”. In position l_4 stands α -token with characteristic: “*higher education institution environment data store*”.

In position l_5 stands β -token with feature: “*users - members of the administrative and academic staff*”.

The users - members of the administrative and academic staff are with different competencies participate in the evaluation procedures. They are from different units, have different rights and responsibilities, different access to information, different opinions and vision of the quality of education, teamwork skills, etc.

During the activation of transition Z_1 , the α -token of position l_5 is split into two tokens. One remains in position l_5 and the other token merges with α -token from position l_1 and enters position l_3 gaining a characteristic:

“*ID data, ID user, value*”.

$Z_1 = \langle \{ l_1, l_2, l_4, l_5 \}, \{ l_3, l_4, l_5 \}, r_1 \rangle$,

$r_1 =$	l_3	l_4	l_5
l_1	$W_{1,3}$	true	false
l_2	false	false	$W_{2,5}$
l_4	$W_{4,3}$	true	false
l_5	false	false	true

$W_{1,3}$ = “new data (a set of data) has arrived from the environment”;

$W_{2,5}$ = “a new user (member of the administrative/academic staff) has arrived”;

$W_{4,3}$ = “a new data (set of data) proceeds to Data repository”.

Transition 2: Data integration in Data repository.

During the activation of the Z_2 transition, a μ -token enters through position l_6 with characteristic: “*criteria system of the accrediting institution*”.

The α -token from position l_3 merges with μ -token from position l_6 and enters position l_7 receiving a characteristic: “*ID data, ID user, type of processing*”.

In position l_8 cycles η -token with characteristic:

“*Data repository with up-to-date information on the activities of the higher education institution, necessary for the preparation of a self-assessment report*”.

A data repository can have a different structure and type of data stored.

Various applications are usually used in practice which partially automate different quality assurance activities. They automatically retrieve the necessary accreditation data from the university repositories (students and learning, curricula and programs, human resource management, document repository, scientific achievements, publications, projects, etc.).

This tool can perform pre-processing of the received data, as well as the necessary format transformations, and subsequently, these data are integrated into Data repository. For this purpose, in position l_9 cycles γ -token with characteristic:

“Data processing tools”.

$$Z_2 = \langle \{ l_3, l_6, l_8, l_9, l_{11}, l_{15} \}, \{ l_7, l_8, l_9 \}, r_2 \rangle,$$

$r_2 =$	l_7	l_8	l_9
l_3	false	$W_{3,8}$	$W_{3,9}$
l_6	true	false	true
l_8	$W_{8,7}$	true	false
l_9	$W_{9,7}$	false	true
l_{11}	false	$W_{11,8}$	$W_{11,9}$
l_{15}	false	$W_{11,8}$	$W_{15,9}$

$W_{3,8}$ = “data has arrived in the repository”;

$W_{3,9}$ = “data processing was performed by a tool”;

$W_{8,7}$ = “a data (group of data) has been retrieved from the repository”;

$W_{9,7} = W_{3,9}$;

$W_{11,8}$ = “new data has arrived as a result of Data analytical processing”;

$W_{15,8}$ = “a request has been received for data from the repository”;

$W_{11,9}$ = “a data processing tool is implemented”;

$W_{15,9} = W_{11,9}$.

Transition 3: Data processing, on the requirements related to the criteria system. For the preparation of the main document – the self-assessment report, it is necessary to collect a large amount of diverse information and documents, and to prepare a variety of reports. This includes, for example, reports on the structure of the academic staff, participation in scientific and educational forums, number of international scientific contracts, information on successful PhD students, number of publications and citations of the academic staff, publications abroad and of international forums, publications in peer-reviewed scientific journals, etc.

During activation of transition Z_3 a-token enters position l_{10} or position l_{11} receiving a characteristic: “ID data (set of data), applied analysis tool”.

$$Z_3 = \langle \{ l_7, l_{13} \}, \{ l_{10}, l_{11} \}, r_{13} \rangle,$$

$$r_3 = \begin{array}{c|cc} & l_{10} & l_{11} \\ \hline l_7 & W_{7,10} & W_{7,11} \\ l_{13} & false & W_{13,11} \end{array}$$

$W_{7,10}$ = “the data analytics process has not completed”;

$W_{7,11}$ = “the process for analytical processing of the data is completed”;

$W_{13,11} = W_{7,11}$.

Transition 4: Preparation of a self-assessment report and the relevant applications, based on the data from the repository.

During the activation of the transition Z_4 , a σ -token enters through the access l_{12} with a characteristic: “data request from user/application”,

An α -token from position l_{10} merges with a σ -token from position l_{12} and enters position l_{13} , l_{14} or l_{15} receiving a characteristic respectively:

“ID user, request for analytical processing”;

“ID user, data (set of data), included in the self-assessment report”;

“ID user, request data from the repository”.

$Z_4 = \langle \{ l_{10}, l_{12} \}, \{ l_{13}, l_{14}, l_{15} \}, r_4 \rangle$,

$$r_4 = \begin{array}{c|ccc} & l_{13} & l_{14} & l_{15} \\ \hline l_{10} & W_{10,13} & W_{10,14} & W_{10,15} \\ l_{12} & true & true & false \end{array}$$

$W_{10,13}$ = “execution of an analytical processing request is required”;

$W_{10,14}$ = “requested data has been included in the assessment report”;

$W_{10,15}$ = “a request for data from the repository is required”.

A formal model is proposed here, describing data processing of self-assessment in the higher education institution. Many refinements can be made by using a hierarchical operator (H3 of the GN theory) that replaces a given transition or position with a sub net that has the same but described more detailed behavior of the elements. Based on the created GN model and the collected data from real processes, behavioral patterns and performance analysis of various system components can be detected.

7. Conclusions

A major challenge for accreditation institutions is to provide an opportunity for commensurability of the evaluation of the quality of educational services offered by higher education institutions. This paper proposes two models for quality assurance in the higher education area – highly and weakly centralized, and a formal model of data processing for self-assessment procedures in HEIs.

The main goal of the first two models is to propose a platform that facilitates the work of all participants in the evaluation and accreditation procedures both on the educators' side and on the accrediting institutions' side. They provide an opportunity to automate the processes related to the various stages of the accreditation procedures. The use of software systems based on the proposed models has many advantages – centralization of the assessment processes, which facilitates their administration and monitoring; providing a common platform for asynchronous team work of users with different rights and responsibilities; ability to work at any time and from any place, facilitated communication and transparency; automated generation of documentation; optimization of time and material resources; reducing the likelihood of making mistakes, etc. The weakly centralized model provides a greater opportunity for integration of the university QA system with other internal systems of the institution and its own control over business data. The main disadvantages are the need for additional IT specialists to maintain and upgrade the QA system, as well as duplication of a large amount of information in the centralized module of the agency. The highly centralized model is easier to use by the higher education institutions, it minimizes the need for administrative support by the HEI, eliminates the need for duplication of information but complicates the possibilities for its integration with existing university systems.

The proposed GN model aims to formalize the main steps and activities in the collection, storage, processing, and distribution of the data from various sources, necessary for self-assessment in the higher education institution. The proposed model can be used as a basic framework and can be expanded on, by further developments and improvements.

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Educational metasystemology perspective in management of Artificial Intelligence paradigm within teacher training

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Abstract: *This study, focused on understanding how to manage the artificial intelligence paradigms and diversity of pedagogical design frameworks in education, aims to contribute to the study of whether and how nowadays teachers design feasible learning environments. The emergence of the new idea of artificial intelligence, its impact on the real-virtual ecosystem of learning and communication, and its advancement in open science are explained in detail. Particularly, this study intends to explore teachers' opinions regarding how to develop successful learning strategies in the minds of their students as the integrity of cognitive, affective, metacognitive, and social life-long learning strategies. The web-based questionnaire created in Google Forms was used as a reference case. Its results completed by pre-university teachers (N= 64) who attended a teaching training program are presented. The conclusion indicates that teachers do believe that artificial intelligence replaced linear approach and systematic instructional design in favor of metasystems learning design. However, the opinions of teachers regarding the impact of artificial intelligence in digital assessment are not in line with the finding of researchers concerned with the issue of pedagogical design in the diversity of learning environments.*

Keywords: Artificial Intelligence, Metacognition, Ecosystem of learning and communication, Pedagogical design, Learning Strategies, E-assessment.

1. Introduction

Artificial Intelligence (AI) is a common term used to define things or processes generated by ‘intelligent behavior with minimal human interventions’ (Hamet & Tremblay, 2017). Even if until now, AI has mostly remained conducted among stakeholders in higher education, we have also begun to observe that its practice has seeped into theory and practice of e-assessment. Nevertheless, we lack a global perspective of what has been done in pedagogical design and its results. In response, this study offers some insights from the perspective of educational metasystemology – a new line of research studying the context, content, and

methodology of education at the intersection of pedagogy and management, taking into account the rapid diversification of research and learning environments.

1.1 Lesson study

The origin of AI is connected to Ancient Greek, and Egyptian Myths, and other ideas related to the incredible power of a Mechanical man. In science, the term was coined in 1956 by John McCarthy (Andresen, 2002). Then, for a couple of decades, it was two competing paradigms, defined as *symbolism* and *connectionism*. Symbolism, dominated by the end of the 1980s, following the hypothesis of Newell and Simon et al. that intelligent human behavior is the arbitrary set of symbols and rules that manipulate the symbols, the manipulators are syntactic, and the syntax has a systematic semantic interpretation. Symbolism adopts an assumption that human thought consists of manipulating words according to rules of reasoning and rules of conjecture. In sum, symbolism, known also as a knowledge-driven paradigm, was based on a linear mode of thinking of the human mind, using predefined knowledge, algorithms, and computing power (Zhang, Zhu & Su, 2023).

Connectionism, dominated by 2015, was based on the idea that AI is a system of intelligent networks of artificial elements and the human mind. The perceptron, a prototype of an artificial neural network, developed by Rosenblatt in 1958, is the first model of connectionism, which unified biophysics and psychology in the form of learning curves and neurological variables (Rosenblatt, 1958). In education, connectionism was applied mostly in intelligent textbooks, which ‘are a new form of digital textbooks that provides students with intelligent learning services, such as automatic question answering, adaptive navigation support, automatic linking, and personalized recommendation’ (Jiang, Gu & Du, 2023).

One can observe the emergence of the third generation of AI. This generation is *generative* because of its proven capacity to generate text, sound, code, or other facilities of the human mind. However, in the opinion of Zhang, Zhu & Su (2023) for more intelligent AI we need robust and explainable AI theories versus safe, reliable, and extensible technology, which will integrate knowledge-driven and data-driven methods by ‘simultaneously using the four elements of knowledge, data, algorithms, and computing power’. Such epistemology should integrate the psychological and pedagogical aspects of learning and communication.

How to manage the emergent generation and other technologies of AI? How to identify the best practices of AI and implement them in pedagogical design? With these ideas in mind, it was developed the theoretical framework, developed questionnaire, and was conducted online survey in the Republic of Moldova, where the interest in using AI in education, especially in the programming and use of robots in elementary education is high. This article aims to renew the debate about the affordability of artificial intelligence design frameworks and challenges for education, including the dynamicity of AI solutions and their impact on learning

design approaches. Initially, we present a brief review of representative research concerning the role of AI in education and the increased number of articles related to this area and it is presented the results of an online survey.

The theoretical background that helped to identify the questions for the questionnaire is covered in the first section. We started by looking for research regarding AI in education, and SMART opportunities of AI for education. The second section focuses on the dynamic nature of research on linear, systems, and metasystem models of thinking. The last part of this investigation concerns the opinions of in-service teachers in supporting digital assessment in the pedagogical design of teacher-centered and/or learner-centered learning environments.

2. Theoretical background

Nature of the AI and its impact on education was investigated by Chassignol, et al. (2018). These authors find that the impact of AI in education needs to be investigated taking into account the norms and experience for the design of content, use of innovative methods for teaching, learning, and evaluation, norms for technology-enhanced assessment, and rules for learning and communication,

2.1 The expanding amount of research on AI in education

The application of AI in education was gaining increased interest in the last few decades. There are at least five lines of research that integrate the theory and technology of AI:

- *programmed instruction* (Berchin, 1981; Daniel & Murdoch, 1968; Fincher & Fillmer, 1965; Kulik, Cohen & Ebeling, 1980; Wood, 1964);
- *intelligent tutoring systems* (Nwana, 1990) and practical application in the form of educational software, intelligent digital textbooks, etc., including the design of innovative *learning environments* (Lawler & Yazdani, 1987);
- *agent-based learning environments* (Baylor, 2002; Harrer, 2001) including chatbot conversational systems (Jia, 2004);
- *interactive humanoid robot* (Ishiguro, 2001);
- *social artificial intelligence*, including but not limited to the Internet of Things, machine learning, neural networks, smart learning, deep learning, smart assistants (Ghosh, Chakraborty & Law, 2018; Hwang & Chien, 2022; Yang, 2022), and intelligent social interventions.

This idea can be proven using the Books Ngram Viewer. Figure 1 shows the growing number of studies concerned with the subject of ‘artificial intelligence in education’.

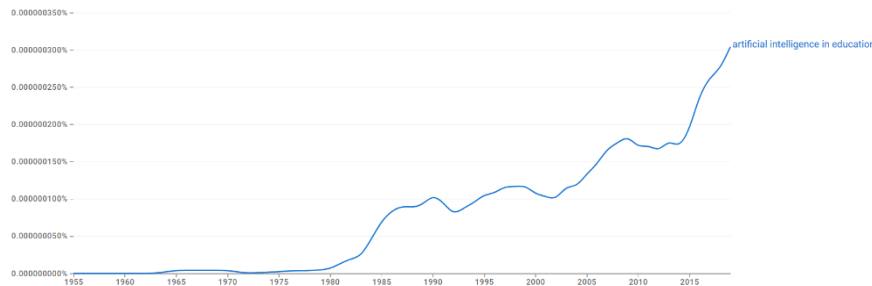


Figure 1. The increased number of research on AI in education

These five lines of research investigate the impact of AI in education through the newest educational technologies and environments. Nowadays, the most researched term is *AI literacy*, which refers to the competencies of life-long learners to enable understanding of the management of artificial intelligence programs, the scope of instructional design frameworks, and the essence of pedagogical design. According to Yang (2022), ‘AI literacy is an organic part of digital literacy for all citizens in an increasingly intelligent society’. But, how to achieve this?

Programmed instruction is related to the linear thinking paradigm. Students are introduced to new material in an artificially designed instructional environment through a graded progression of ‘intelligent’ supervised steps. This system offers rich feedback or individualized learning through ‘branching programs’ (Crowder, 1959) or ‘adaptive systems’ (Werbos, 1987) – a branch of ‘generative systems’ (Wexler, 1970) able to generate and solve problems in the limit of programmed instruction. The ‘intelligence’ of these programs is related to step-by-step instruction, intelligent analysis of student’s answers, and immediate feedback on what was previously programmed.

Intelligent tutoring systems (ITSs) use AI in two ways: (a) direct instruction (e.g., students gain knowledge from presented didactical material) and (b) indirect instruction (e.g., LOGO - students learn by programming). With the increased use of ITSs in business, the labor market, and education it was developed three main types of machine learning were: supervised, reinforcement, and unsupervised learning. However, the majority of ITSs models were based on system thinking as ‘an attempt to produce in a computer behavior which, if performed by a human, would be described as ‘good teaching’’ (Nwana, 1990). Such ‘intelligent’ tutors were integrated into Intelligent Computer Aided Instruction and Intelligent Assessment Technologies. Moreover, the alternative ways to teach students are learning environments – a space to exercise creativity through innovative ideas.

The development of agent-based learning environments was grown on the ‘agent metaphor’ used to identify the system mode of thinking. As was noted by Baylor (2002), the agent-based learning environments approach is a way to operationalize and simulate the ‘human’ aspect of instruction in a more ecological

way than other controlled computer-based methods. Agents use learning objects and, therefore, allow more flexible modes to generate the instructional content and analyze students' answers. However, with the emergence of chatbot conversational systems, the models of agent-based learning environments become more flexible. It was observed a big potential to use conversational interfaces to facilitate learning.

The interactive humanoid robot was designed to assist humans with 'tasks that are physically demanding, unsafe, unpleasant, or boring' (DiSalvo et al., 2002). Even the emergence of the interactive humanoid robot was guided by the idea to develop more efficient models of learning and communication, soon was observed that human-robot interaction is an important question for a learning and communication ecosystem. For instance, in '*Homo Deus: A Brief History of Tomorrow*', Yuval Noah Harari notes that people try to create an artificial life using famine, plague, and war as manageable challenges. After it was observed that more people pass away from eating too much 'safe and nutritious food' than from infectious diseases or from suicide or self-harm than from terrorists and criminals.

Nevertheless, the improved artificial models of interactivity and flexibility common in designing interactive humanoid robots opened a door for novel models of social artificial intelligence. On the one hand, social artificial intelligence arises the problem of how humans will control the humanoid robots, firstly because of the unexpected digital ecosystem and secondly, because control is the primary function of management, therefore, such a problem should be solved at the intersection of the educational and management sciences. On the other hand, AI uses advances in Virtual Reality or/and Augmented Reality to create more innovative products for educational purposes, mostly in digital media (Gong, 2021). Moreover, AI cannot compete with human intelligence that includes material, economic, emotional, spatial, and spiritual forms of intelligence among others.

One more thing is related to *generative artificial intelligence*. This term refers to technology that (a) can generate all kinds of data (e.g., images, 3D objects, texts), (b) perform all kinds of data transformation (e.g., domain transfer, style transfer), and (c) enrich datasets and improve machine learning. Baidoo-Anu and Owusu Ansah (2023) observed that GAI took the world by surprise that artificial intelligence can perform complex tasks in the field of education, including but not limited to (a) promotion of personalized and interactive learning environments, (b) providing ongoing feedback to inform teaching and learning and (c) generating prompts for formative assessment. In sum, the management of artificial intelligence paradigms and pedagogical design frameworks is a huge issue, identified at the intersection of education and managerial sciences.

2.2 SMART opportunities of /for AI in education

While this is still a lively debate in the frontier area of education and management regarding whether and to what extent AI is useful in design for more successful teaching, learning, and assessment activities, the research community

seems to agree on several features that should characterize an innovative pedagogical design framework with AI. To understand this, we will look at SMART opportunities of/for AI in education (Table 2).

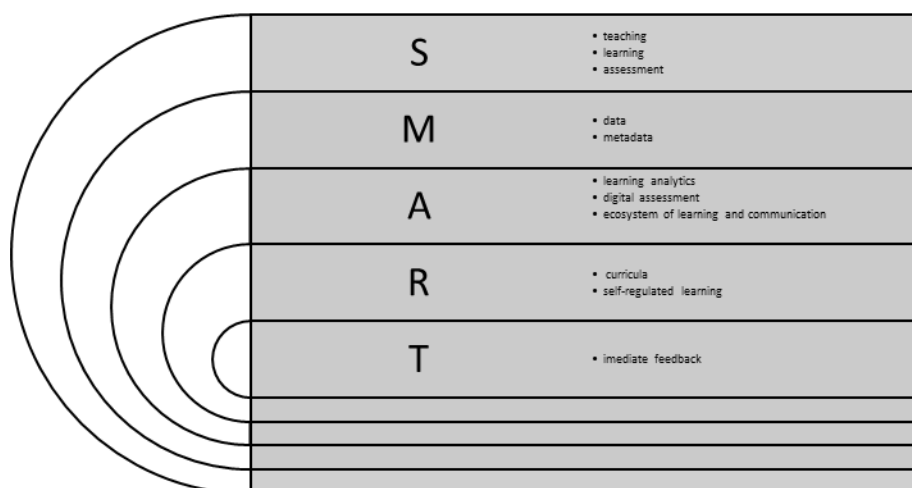


Figure 2. SMART opportunities of /for AI in education

‘Connection’ between AI in education and SMART opportunities allow us to understand the essence of AI. In the opinion of Ahmad et al. (2021) AI applications in education refer to Intelligent Tutoring Systems (ITS), social robots, and smart learning devices. ITS is an intelligent system tutoring students based on detailed input by presenting information in an interactive form and providing an interactive test of a student’s knowledge at the end. Social robots are intelligent machines following social behavior and are used in education for teaching and tutoring instead of human teachers. Smart learning devices and other personal means and tools used for learning are mobile technologies addressing students’ education-related issues (e.g., locations, and schedules).

The new generation of AI can help both teacher and student to generate the first draft of an essay, identify the most relevant literature, assist in composing a research methodology, edit and format the paper, and summarize the entered text to compose a suitable abstract or/and a conclusion, etc., and all these activities save the time of researcher because they are time-consuming. The potential application of AI for education is to summarize research data in affordable figures, tables, and other visual elements. However, nowadays more than ever it is important to critically analyze this paper and effectively manage the theory and technology of education. An important issue is ethical concerns (Salvagno, Taccone & Gerli, 2023).

The opportunities of AI for teaching, learning, and assessment were described. Bhbosale, Pujari & Multani (2020), for example, note that robots like Ozobot and Cubelets teach and help learners to learn. However, as was noted by Alam (2021) ‘AI is an area of research in which computers, robots, and other technologies are programmed to exhibit human-like intelligence, as characterized

by cognitive skills such as learning and adaptation, as well as decision-making capabilities '. Even, in theory, capabilities are associated with metacognition, in practice the impact of AI in education need to be related to creativity and 'human' forms of intelligence (e.g., material, emotional, and spiritual).

The disadvantages of AI are more related to patterns of thinking. Even if AI can increase the performance of teacher to monitor students' learning through learning analytics, diversification of learning environments create in students' minds a collapse of reality. AI in education is unable to compete with human soft skills like curiosity, critical thinking, problem-solving, and innovation based on insight. Intelligent people will always be able to communicate, experiment with new ideas, evaluate feedback critically, observe and solve problems 'outside the box,' and apply creative solutions to pressing issues.

3. Method

3.1 Data collection

In the endeavor to find answers to the above RQ, it was decided to use the qualitative method of questionnaire and collect the data through an online survey tool consisting of questions 'extracted' from the theoretical background of this paper and purposely built to investigate the above RQs. The questionnaire 'Teachers' and students' perceptions of the impact of AI on learning outcomes' was designed and developed by the author of this research and was implemented in the form of an online survey using Google Forms. It comprised a total of 16 questions designed for collecting qualitative data from teachers and students.

The opportunity to respond to an online survey was promoted in several training activities for in-service teachers organized in 2023. These had been established in response to the urgent need to provide in-service teachers with specific teacher training on approaches, strategies, and methods regarding how to deal with innovative technologies, specifically with AI technology in education (e.g., educational robots, and digital assessment). 64 participants responded to the call to complete the online survey. Most of the participants are students (68,2%) and teachers (15.6%). Regarding age, our sample population was composed as follows: 21-30 years = 50 (78,1%), under 20 = 12(18,1%), and 31-40 years = 2(3.1%). School level is presented, as follows: high school = 31(48,4%), university level = 20(31.3%), college = 8(12.5%), and other = 5(7.8%). In terms of learning activity, most of our respondents were from town = 61(95.3%).

3.2 Results

The majority of our respondents responded that the best learning strategies are (a) problem-solving in real school settings = 26 (40.6%), (b) interactive discussion with peers = 15 (23.4%), (c) teacher's lecture = 26 (40.6%), and (d) comprehensive reading = 6 (9.4%). However, to achieve this result is important to

develop soft skills. The term 'soft skills' refers to 'personality traits, goals, motivations, and preferences' (Heckman & Kautz, 2012). Therefore, the best learning strategies for a contemporary student are problem-solving.

In the opinion of our respondents, the most comprehensive category of methods refers to (a) methods of exploring reality (based on direct or indirect contact with reality) = 30 (40.9%), (b) methods of acquiring and transmitting knowledge = 19 (29.7%), (c) action-based methods (role play, project, etc.) = 10 (15.6%). This outcome supports the findings of our earlier research, which indicated that the majority of actual students consider themselves to be world travelers rather than individuals looking to influence the world in any way.

Our respondents state that the most important method for them is (a) practical work = 30 (46.9%), (b) description of what was observed and investigated = 13 (20.3%), (c) storytelling = 6 (9.4%). Regarding what digital resources are used to convey teaching message, participants respond, as follows, (a) video/audio files = 23 (35.9%), (b) simulations with educational software = 20 (31.3%), (c) photos/videos made personally = 10 (15.6%), (d) images from the Internet = 8 (12.5%). These findings suggest that students 'come' to university for practical skills out of curiosity and a desire to develop their curiosity, creativity, problem-solving, and decision-making skills to deal with ambiguous situations.

It was a surprise for us to observe that most of our respondents report that the students' activity is evaluated mostly by (a) oral communication = 28 (43.8%), (b) tests on paper photographed and transmitted online = 20 (31.3%), and (c) computer interactive tests = 13 (20.3%). Respondents selected the following statements for the actual situation, in which we are living: (a) assessment measures the quality of the teaching process = 28 (43.8%); (b) assessment measures learning outcomes / educational goals = 19 (29.7%), and (c) assessment is a unique opportunity to develop learning competence = 17 (26.6%). Moreover, in the opinion of our respondents, digital assessment is more (a) correct (i.e., sensitive to the psycho-pedagogical and cultural characteristics of groups of students) = 30 (46.9%); (b) accurate (i.e., the measurement error of competencies is minimized) = 18 (28.1%), and (c) reliable (i.e., obtains and provides the same results for all situations) = 16 (25 %) in comparison with traditional forms of assessment (e.g., paper-and-pencil). E-assessment tools are balanced if the pedagogical design is based on principles of coherence, comprehensiveness, and continuity – state 27 (42,2 %) of participants.

4. Conclusion

Nowadays, AI generates text, images, voices, movies, etc. Traditionally, pedagogy and learning theories have a special role in supporting the applicability of educational technologies in various learning settings. Less explored tasks are

psychological aspects of learning and assessment with AI. Learning occurs in a variety of learning environments, both physical and virtual.

This article presents the findings of a theoretical-practical investigation of AI in education. Overall, findings show that the term ‘AI’ is used to describe things or processes produced by intelligent behavior. In the context of digital education, AI takes the form of (a) supervised learning, where each data point has features and a corresponding label, (b) unsupervised learning, where a certain kind of algorithm learns patterns from untagged data, and (c) semi-supervised learning, where a combination of labeled and unlabeled data is used to train models. However, AI cannot compete with human skills such as curiosity, critical thinking, problem-solving, and insight-driven innovation even can generate text, music, and pictures. Thus, AI may increase the performance of lifelong students if is adequately applied.

5. Limitations of the study and future research

Nowadays, pedagogical resources and learning tools integrate a variety of AI solutions in the form of adaptive interactive environments and AI-generated guidance aims to support learning through hyperlinks, glossaries, multimodal communication, and various immediate feedback strategies. However, none of these solutions address the question of how to ‘learn more effectively with self-paced environments’ and instead focus on cognitive load and motivation (Koc-Januchta, Schonborn, Tibell, Chaudhri & Heller, 2020). For learning with digital tools, developing AI literacy is, therefore, essential.

Recent developments in learning and assessment with AI emphasize affective, social, and metacognitive strategies. However, effective strategies are more related to emotional AI (Ho, Mantello & Ho, 2023; Zainol, Keikhosrokiani, Asl & Anuar, 2023; Chen, Cheng, Zou, Zhong & Xie, 2023; Geetha et al., 2023) and not to the natural stimulation of students' emotions, feelings, attitudes, creativity, and motivation to learn in various kinds of learning environments, both physical and virtual. Regarding metacognition, AI methods focus on ‘real-time assessment of a learner's verbatim transcript’ (Wang & Lin, 2023), ‘meta-learning’ (Drigas, Mitsea & Skianis, 2023), meta-awareness, etc., which could include (meta)cognitive strategies of self-regulated learning.

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Agent-oriented tutoring systems - an alternative for education

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Abstract: *Agent-oriented tutoring systems have gained significant attention in the field of education due to their potential to enhance personalized learning experiences. This paper explores the concept of agent-oriented tutoring systems in the context of education. A proposed methodology for creating an agent-oriented tutoring system is presented, outlining the essential steps involved in the development process. Additionally, various methods for designing and implementing agent-oriented tutoring systems are explored, highlighting the use of AI, machine learning, and natural language processing techniques. This paper provides an overview of agent-oriented tutoring systems in education, offering insights into their development, benefits, and considerations. What do we already have? What do we have and do not use? What are the benefits and challenges of implementing an agent? Those are questions we are answering in this paper.*

Keywords: Tutoring systems, artificial intelligence, machine learning, education, frameworks, programming language.

1. Introduction

Throughout human history, technology has consistently evolved, starting from the wheel's creation. From the initial innovation of the steam engine to the contemporary growth of artificial intelligence (AI), technology has persistently led the way in terms of advancement and novelty. AI, the latest technological breakthrough, holds immense potential to transform human interactions with the world. It enables process automation, enhances decision-making, and even forecasts future results. Intelligent Agents (IA) (*Britannica*, 2023) are software programs that autonomously act on behalf of a user to accomplish tasks or goals. IA can be used to automate tedious and repetitive tasks, aid users, and analyze large and complex datasets. In the educational context, IA can be used to create agent-oriented tutoring systems which are an innovative approach to create individualized learning experiences, these systems are designed to increase student engagement and provide personalized instruction tailored to an individual's unique needs. By leveraging the power of AI, these systems provide an adaptive learning environment that can monitor student progress and adjust instruction accordingly.

Agent-oriented tutoring systems (Moga et al., 2014) are becoming increasingly popular as they provide an effective and engaging way for learners to acquire knowledge. This technology has been adopted by many educational institutions to provide personalized tutoring to students. These systems are designed to assess each student's individual learning abilities and preferences and then deliver tailored instruction based on those assessments. Additionally, agent-oriented tutoring systems can be used to monitor student progress and provide feedback to the student on their performance. This technology can also be used to provide students with personalized feedback and support. By using agent-oriented tutoring systems, educators can provide students with more meaningful and effective educational experiences. What do we already have? What do we have and do not use? What are the benefits of this agent-oriented tutoring systems? Those are questions we are answering in this paper and exploring the key principles of agent-oriented tutoring systems for Education, the applicability of machine learning (ML), natural language processing (NLP) and artificial intelligent (AI), the agent-oriented tutoring system's advantages and challenges, and the future of this technology.

2. Artificial intelligence (AI), machine learning (ML) and natural language processing (NLP)

AI has many definitions but always around the same ideas and propose:

Artificial Intelligence (AI) refers to the replication of human intelligence in machines, particularly computer systems, encompassing functions like learning, reasoning, and self-correction. Its applications involve creating computer systems that can imitate and enhance various cognitive abilities of humans, including problem-solving and decision-making. (*Artificial Intelligence*, n.d.).

Artificial Intelligence (AI) has gained significant attention and prominence in the field of education, offering a range of potential benefits and opportunities. Here's a description of AI in education:

AI in education involves incorporating artificial intelligence technologies and methods into educational practices and systems (Guan et al., 2020). It involves leveraging machine learning (Phatak et al., 2022), natural language processing, data analytics (Hussain et al., 2020), and other AI tools to enhance teaching and learning experiences, personalize education, and improve educational outcomes. One key area where AI is making an impact is in personalized learning. By analyzing student data, such as performance, learning styles, and preferences, AI algorithms can create personalized learning paths. These adaptive systems deliver tailored content, resources, and activities that cater to each student's individual requirements, resulting in more effective and engaging learning experiences. Intelligent tutoring systems (Graesser & Li, 2023) are another example of AI's application in education. These systems utilize AI techniques to provide students with personalized feedback and guidance by analyzing student responses, identifying areas of difficulty, and offering targeted explanations and support,

intelligent tutoring systems aim to improve learning outcomes and foster independent problem-solving skills. AI also plays a role in automating administrative tasks and improving efficiency in education. For instance, chatbots powered by natural language processing (Davis & Chiang, 2022) can assist students with common queries and provide timely support. Automated grading systems (Pathak et al., 2021) can analyze objective assessments, such as multiple-choice questions, saving educators time and enabling them to focus on more qualitative aspects of evaluation. Data analytics and predictive modeling are valuable AI tools in education (Abe, 2019). By analyzing large educational datasets, AI can identify patterns, trends, and insights that inform instructional design, curriculum development, and decision-making. Predictive analytics can help identify students at risk of dropping out or those who may benefit from additional support, enabling timely interventions to enhance student success and retention rates.

Machine learning (Satyanarayana et al., 2022) is increasingly being applied in various aspects of education, offering new opportunities to enhance teaching and learning experiences. Here are some notable areas where machine learning is being utilized in education nowadays:

- Personalized Learning
- Intelligent Tutoring Systems
- Automated Grading
- Recommender Systems
- Predictive Analytics
- Natural Language Processing
- Educational Data Mining

It's important to note that while machine learning has the potential to transform education, it is not meant to replace human educators, the human touch is extremely important, feelings, understanding each other, replicate a parent position, those are very important ways for teachers to interact with students than the machines cannot replicate. Rather, it serves as a tool to augment and enhance the teaching and learning process, supporting educators in their efforts to provide personalized and effective education.

According to (Hazzan & Mike, 2023), there are up to 6 types of **machine learning algorithms** starting with supervised (as decision trees, random forests, support vector machines, naïve Bayes classifiers, k-nearest neighbors, linear and logistic regression, and neural networks), unsupervised (as clustering, dimensionality reduction and association rule), reinforcement, semi-supervised deep and ensemble learning algorithms. But it is up to the developer to select the one that best suits what they want to achieve.

These are just some of the most common types of machine learning algorithms, and there are many variations and specialized algorithms within each

category. Choosing the right algorithm depends on the nature of the problem, the available data, and the desired outcome.

Natural Language Processing (NLP) (Davis & Chiang, 2022) is a branch of artificial intelligence that focuses on the interaction between computers and human language. In the context of education, NLP has the potential to revolutionize various aspects of teaching and learning. Here's an overview of the application of Natural Language Processing in education:

1. Language Learning and Tutoring
2. Automated Essay Grading (Pathak et al., 2021)
3. Text Mining and Information Extraction (Sun et al., 2018)
4. Intelligent Content Recommendations (Parikh & Shah, 2021)
5. Sentiment Analysis and Student Feedback (R et al., 2022)
6. Question Answering and Intelligent FAQ Systems
7. Language Generation and Content Creation

By leveraging NLP techniques, educational institutions can enhance language learning, automate certain grading tasks, extract valuable information from educational texts, provide personalized recommendations, analyze student feedback, facilitate question-answering systems, and generate educational content.

NLP has experienced a great advance in recent years thanks to the development of models based on deep neural networks, such as language transformer models (Jojoa et al., 2022), which have significantly improved the accuracy and performance of many natural language processing tasks.

Transformer language models (*Aprende Machine Learning*, n.d.) are a recurrent neural network architecture developed by Vaswani et al. in 2017 that has revolutionized the field of natural language processing. These models (Zhang et al., 2023) are based on the idea of multi-head attention and do not use recurrent layers, allowing them to capture long-range relationships in text sequences more efficiently. Here are some notable Transformer language models:

Table 1. Transformer models. NLP

GPT (Generative Pre-trained Transformer)
BERT (Bidirectional Encoder Representations from Transformers)
RoBERTa (Robustly Optimized BERT pretraining Approach)
GPT-2,3(<i>Transformers</i> , n.d.)

3. Methodology and methods to create an agent-oriented tutoring system. Advantages and challenges

According to the information mentioned above a **methodology** is proposed to create an Agent-oriented tutoring system.

1. Define the Goals and Objectives: In designing an agent-oriented tutoring system, it is important to establish the goals and objectives of the system. This will involve defining the learner population, the topics that the system should cover, the desired outcomes, and any other relevant criteria.

2. Create the Agent: The next step is to create the agent. This will involve defining the agent's design, capabilities, and interaction model with the user. The agent should be designed to interact with the user in a natural, conversational manner.

3. Develop the Knowledge Model: The knowledge model should be developed to represent the topics covered by the system. This should include the topics and associated facts, rules, and relationships.

4. Implement the System: Once the goals and objectives have been defined, the agent designed, and the knowledge model developed, the system needs to be implemented. This will involve creating the user interface, developing the agent's logic, and programming the system.

5. Evaluate the System: Once the system has been implemented, it should be evaluated to ensure that it meets the desired objectives. This can involve testing the system with users or running simulations to verify its accuracy.

This methodology provides a clear and logical sequence of steps for creating an Agent-oriented tutoring system. It emphasizes the importance of defining objectives, designing an effective agent, developing a knowledge model, implementing the system, and evaluating its performance.

It proposes some **methods** to create an Agent-oriented tutoring system according to the information mentioned above.

1. Use AI to create an intelligent tutor: AI-based tutoring systems can use natural language processing and machine learning algorithms to provide students with personalized guidance and feedback. (AI, ML)

2. Develop a conversational agent: Conversational agents can provide students with detailed instructions and explanations, as well as offer personalized advice and support. (AI, NLP)

3. Create an interactive virtual tutor: Virtual tutors can use interactive elements such as simulations, games, and quizzes to help students learn in a more engaging and effective way. (AI)

4. Incorporate multi-modal tutoring: Multi-modal tutoring systems can use both visual and verbal elements to teach students in a more comprehensive way. (AI)

5. Apply educational data mining: educational data mining can help tutoring systems to analyze student data and provide better learning recommendations. (AI, ML)

6. Leverage user models: User models can help agents to understand and anticipate student behavior, providing more tailored instruction. (AI, ML)

This list provides a clear and concise overview of the different methods that can be employed to create an Agent-oriented tutoring system.

It is not something rigid, it is just a proposal to create agents based on AI, ML and NLP, with more personalized and effective interaction, the agent is not a teacher, but it must be a close copy, enabled to answer questions, give feedback, support, recommendations, interacting with the most natural language. The closest to the real interaction it be, more useful it became for users.

An agent-oriented tutoring system which understand a human language will provide better solutions to the users' needs, and an interaction with a natural language will be more understanding by the users. The closer these systems can be to replicate human interaction will lead to better results. In education, this is a very important part, since although they do not replace teachers, at some point, they must act as teachers, because they will be enabled to interact in a natural way and provide feedback to any doubt students' have. Maybe the feeling side will be hard to replicate, understand what users need even they do not say or write, it is a challenge that researchers are trying to replicate with face recognition technologies, text analysis, voice vibrations amount others. The knowledge is in our hands, let's these systems be part of the day to day in our educational process, it depends on us.

Examples:

1. ETHOSCHOOL: An Artificial Moral Agent Model for Collaborative Learning (Córdova et al., 2023)
2. Exploring the Use of Augmented Reality in a Kinesthetic Learning Application Integrated with an Intelligent Virtual Embodied Agent (Iqbal et al., 2019)
3. Secondary effects converted to useful knowledge in e-Learning system (Cholakov, 2021)
4. Mathematics intelligent tutoring system for learning multiplication and division of fractions based on diagnostic teaching (Shih et al., 2023).
5. Studying Affective Tutoring Systems for Mathematical Concepts (Mastorodimos & Chatzichristofis, 2019)
6. Intelligent Augmented Reality for Learning Geometry (Uriarte-Portillo et al., 2023, p. intelli)

Along with its advantages, the creation of such a tutoring system also comes with its fair share of challenges. This paper delves into the advantages and potential hurdles involved in developing an agent-oriented tutoring system, shedding light on the transformative impact it can have on education while addressing the complexities that must be navigated for its successful implementation.

Table 2. Advantages and challenges of creating an agent-oriented tutoring system

Advantages	Challenges
Increased flexibility and control over the learning environment: Agent-oriented tutoring systems can adapt to individual student needs, allowing learners to progress at their own pace and explore different learning paths.	High initial cost of development and deployment: Requiring investment in software development, infrastructure, and ongoing maintenance. This initial cost can be a barrier, especially for smaller educational institutions or resource-constrained environments.
Automation of common tasks: These systems can automate tasks such as grading assignments, tracking student progress, and providing timely feedback. This automation saves time for educators and allows them to focus on higher-level instructional activities.	Difficulty in designing and implementing appropriate rules and instructions: Creating comprehensive and adaptive knowledge models that align with diverse learner needs requires careful planning and domain expertise.
More engaging and personalized learning experiences: Agent-oriented tutoring systems can provide interactive and personalized learning experiences through adaptive instruction, real-time feedback, and tailored recommendations.	Limited ability to replicate natural student-teacher interaction: they may lack the nuanced interaction and human touch of a face-to-face interaction between a student and teacher. Replicating the complexity of human conversation and empathy in an AI-driven system remains a challenge.
Improved scalability and availability of resources: With these systems, educational resources can be made available to many students simultaneously, regardless of geographical location. This scalability allows for broader access to quality education and overcomes physical constraints	Privacy and security concerns: Safeguarding student data, ensuring compliance with privacy regulations, and addressing ethical considerations associated with data collection and usage are important challenges that need to be addressed.

Overall, while agent-oriented tutoring systems offer significant advantages in terms of flexibility, automation, engagement, and scalability, they also present challenges that need to be carefully considered and addressed to ensure their successful implementation and use.

In conclusion, agent-oriented tutoring systems hold significant potential in transforming education by providing personalized and interactive learning experiences. By leveraging the available software tools, frameworks, and methodologies, educators and developers can harness the power of intelligent agents to enhance the educational journey for students. It is important to continue exploring and advancing these systems while addressing the challenges to ensure their effective and ethical integration into educational settings.

4. Conclusions

To conclude it could be said that agent-oriented tutoring systems have emerged as a promising approach to enhance education by leveraging intelligent agents and advanced technologies. This paper has provided an overview of agent-oriented tutoring systems in the context of education, discussing various aspects related to their development and implementation.

Furthermore, a proposed methodology for creating agent-oriented tutoring systems was presented, outlining the essential steps involved in the development process. This methodology provides a structured approach to guide practitioners in designing effective and efficient systems that align with the educational goals and objectives.

This paper also discussed different methods employed in creating agent-oriented tutoring systems, such as the use of AI, machine learning, and natural language processing. These methods enable systems to provide personalized guidance, engage students through interactive elements, and analyze educational data to offer valuable insights for improved learning experiences.

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Digitalization in education: navigating the future of learning

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Abstract: *The digital revolution of the 21st century has led to a profound transformation in nearly every aspect of human existence, and education stands as one of its most impacted domains. The integration of digital technology into education, often referred to as digitalization, has not only changed the way we teach and learn but has also opened up new frontiers of possibilities. This paper delves deeper into the multifaceted nature of digitalization in education, exploring its far-reaching effects, potential challenges, and the long-term implications for learners, educators, and the global society. As we embark on this exploration, it is imperative to understand the diverse manifestations of digitalization in education. From interactive e-learning platforms to immersive virtual classrooms, from gamified educational apps to data-driven personalized learning pathways, the possibilities seem boundless.*

Keywords: education, digitalization, e-learning, Metaverse, Blockchain, Artificial Intelligence, Virtual Reality, Augmented Reality.

1. Introduction

In an era characterized by rapid technological evolution and an unprecedented interconnectedness, the world of education is undergoing a profound metamorphosis. This transformative journey is driven by the pervasive force of digitalization, which is reshaping traditional educational paradigms and revolutionizing the way knowledge is acquired, disseminated, and applied (Whalley et al., 2021).

At its core, digitalization in education represents the convergence of education and technology, encompassing a spectrum of innovative tools, strategies, and methodologies that harness the capabilities of digital resources to enhance and modernize the learning experience. This phenomenon extends far beyond the mere incorporation of devices and software into classrooms; it heralds a shift towards a

new educational landscape, where the boundaries of time and space are redefined, and learners are empowered with unparalleled opportunities for engagement and exploration.

Central to this transformation is the concept of accessibility. Digitalization in education has the potential to break down the geographical and socioeconomic barriers that have historically hindered the pursuit of knowledge. Online courses, virtual classrooms, and open educational resources enable learners from diverse backgrounds to access high-quality education that was once out of reach. This democratization of learning fosters a global community of learners, fostering cross-cultural understanding and collaboration.

Moreover, digital tools facilitate personalized learning experiences that cater to individual strengths, weaknesses, and learning styles. Adaptive learning algorithms analyze data and adapt content, pacing, and assessment to suit the unique needs of each student, cultivating a more efficient and effective educational journey.

However, as with any transformative force, digitalization in education presents a multifaceted set of challenges. The digital divide remains a significant concern, with unequal access to technology and reliable internet hampering the inclusivity of this new era. Additionally, the role of educators is evolving, requiring them to navigate the integration of technology into pedagogical approaches and develop digital literacy skills alongside their students.

This paper aims to explore the complex nature of digitalization in education, especially focusing on the applications of Blockchain and Metaverse in this specific field. Potential challenges will be analysed, as well as the long-term implications for learners, educators, and the global society. Thus, the present article aims to contribute to ongoing debates regarding the benefits and limitations of digitalization in education which need to permanently be in touch with technological advancements and the new opportunities and risks they bring.

2. Enhanced accessibility and equity

Digitalization has bridged geographical gaps and shattered barriers to education. Online learning platforms, open educational resources (OER), and massive open online courses (MOOCs) have democratized learning, making high-quality educational content available to a diverse global audience. This increased accessibility is especially impactful for individuals in remote areas, those with disabilities, or those facing socio-economic constraints. As education becomes more inclusive, the potential for nurturing talent across all strata of society becomes a reality.

Learning management systems (LMS) employ data analytics and artificial intelligence to track individual student progress, tailoring content and assessments to meet each student's unique needs and pace of learning. This personalized approach enhances student engagement, motivation, and overall learning outcomes.

Digital tools have breathed new life into pedagogical practices. Interactive simulations, virtual labs, multimedia presentations, and gamified learning modules make abstract concepts tangible and complex subjects more approachable. This dynamic and engaging approach not only caters to varied learning styles but also instills a sense of curiosity and exploration, fostering lifelong learners (Hongsuchon et al., 2022).

Inequities arising from socio-economic disparities have long hindered access to quality education. Digitalization has been a powerful equalizer, mitigating these barriers by offering affordable or even free educational resources. Open educational resources (OER) provide cost-effective alternatives to traditional textbooks, reducing financial burdens on students. This democratization of learning materials ensures that economic constraints do not impede a student's ability to access educational content.

Digital tools have also revolutionized education for individuals with disabilities, ensuring that learning environments are more inclusive and accommodating. Screen readers, captioned videos, and text-to-speech applications enable students with visual or auditory impairments to engage with digital content. Furthermore, adaptive technologies and personalized learning platforms tailor content to suit varying learning styles, supporting neurodiverse students.

3. The effects of digitalization over the education systems

One of the most prominent effects of digitalization on education is the transformation of pedagogical approaches. Traditional teacher-centered methods have given way to student-centered and interactive pedagogies. Educators now have an array of digital tools at their disposal to create dynamic and engaging learning experiences. Concepts that were once abstract can now be made tangible through interactive simulations, virtual labs, and multimedia presentations, fostering deeper understanding and critical thinking among students.

Digitalization has ushered in a new era of student engagement. Interactive content, gamified elements, and multimedia resources have revolutionized how students interact with learning materials. This shift from passive consumption to active participation has resulted in heightened engagement and motivation. Moreover, the ability to access learning materials anytime and anywhere has empowered students to take ownership of their education, fostering a sense of responsibility and self-directed learning.

Individualized learning has become a hallmark of the digital age. Adaptive learning platforms leverage data analytics to provide personalized content and assessments tailored to individual student needs and learning styles. This personalized approach not only maximizes learning outcomes but also boosts self-confidence and motivation among students. As a result, the digital classroom caters to diverse learning preferences, ensuring that no student is left behind.

Global connectivity and collaboration are also prominent effects of digitalization. Virtual classrooms, online forums, and collaborative projects transcend geographical boundaries, bringing together students and educators from diverse backgrounds. This interconnectedness enriches the educational process with cross-cultural perspectives and enhances communication skills. Students are exposed to a global network of ideas and experiences, preparing them for an increasingly interconnected world.

Data-driven insights have become a cornerstone of digitalized education. Digital tools generate a wealth of data on student performance and engagement. Educators can harness data analytics to gain insights into learning patterns, identify areas of improvement, and adapt their teaching strategies accordingly. This data-driven approach allows for evidence-based decision-making and continuous improvement in pedagogical practices (Castro & Tumibay, 2021.)

However, the effects of digitalization are not limited to students and educators alone. The digital era demands a redefinition of the educator's role. Teachers must adapt to new roles, becoming facilitators of learning rather than mere conveyors of information. Professional development becomes crucial as educators learn to navigate digital tools, curate online resources, and effectively integrate technology into their teaching methodologies.

Digitalization has also empowered individuals through lifelong learning. Online courses and microlearning modules provide opportunities for professionals to engage in continuous skill development. This emphasis on ongoing learning equips individuals with the tools to remain adaptable and competitive in an ever-evolving job market.

The effects of digitalization in education show no signs of slowing down. Emerging technologies like virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) hold the promise of further revolutionizing the learning experience, creating immersive environments and personalized learning journeys.

While the effects of digitalization on education are overwhelmingly positive, challenges remain. The digital divide, characterized by unequal access to technology and the internet, threatens to exacerbate educational inequalities. Bridging this gap is imperative to ensure that all individuals, regardless of socio-economic background, can access the benefits of digitalized education.

4. Challenges of the digitalization in education

The digital revolution has permeated virtually every aspect of modern life, including education. The integration of digital technology into education, often referred to as digitalization, holds immense promise for transforming the way we teach and learn. However, this transformative journey is not without its share of challenges.

Perhaps one of the most pressing challenges of digitalization in education is the digital divide—the unequal access to technology and the internet. While digital tools have the potential to democratize education, they can also exacerbate existing inequities. Students from lower socio-economic backgrounds or remote areas may lack access to necessary devices or reliable internet connections, hindering their ability to fully participate in digitalized learning experiences. Bridging this divide requires concerted efforts to provide equal access and ensure that technology-driven education is truly inclusive.

The digitalization of education entails the collection and sharing of vast amounts of student data. While data analytics can offer valuable insights into learning patterns and pedagogical effectiveness, it also raises concerns about data privacy and security. Protecting sensitive student information from breaches and unauthorized access becomes paramount. Schools and educational institutions must implement robust data protection measures and adhere to stringent privacy regulations to safeguard both students' personal information and their learning experiences.

The abundance of online educational content can be both a blessing and a curse. While digital platforms offer a vast array of resources, not all content is created equal in terms of accuracy, credibility, and educational value. Educators must critically assess the quality of online materials to ensure that students are exposed to accurate and reliable information. Moreover, the sheer volume of content can make it challenging to curate and select resources that align with specific learning objectives.

As a side effect, digitalization can also lead to a reduction in face-to-face human interaction. Traditional classroom interactions, peer-to-peer learning, and teacher-student relationships are essential components of the educational experience. Overreliance on digital tools may diminish these interpersonal connections, potentially affecting students' social and emotional development.

Effective integration of digital technology into the classroom requires educators to possess a certain level of digital literacy. However, not all teachers may be adequately prepared to navigate the complexities of digital tools and online platforms. Providing comprehensive and ongoing training and professional development opportunities for educators is essential to ensure that they can harness the full potential of digitalization to enhance learning outcomes.

While digitalization holds the promise of revolutionizing education, it is not without its challenges. The digital divide, privacy concerns, content quality, human interaction, digital overload, teacher training, and the rapid pace of technological change are all complex issues that demand thoughtful consideration. Addressing these challenges requires collaborative efforts from educators, policymakers, parents, and technology developers. By proactively addressing these concerns, we can harness the benefits of digitalization while ensuring that the future of education remains equitable, effective, and responsive to the needs of all learners.

5. Synergistic technologies in transforming the education system

5.1 Blockchain technology in education

In an era of rapid technological advancement, the landscape of education is undergoing a profound shift, driven by the convergence of digitalization and innovative technologies. Among these transformative technologies, Blockchain has emerged as a game-changer with the potential to revolutionize how we approach education.

Blockchain is an open, distributed, single, shared, tamper-evident ledger for maintaining permanent records of transactional data. The records are called blocks and are linked using cryptography (Vevera et al, 2019). Blockchain, originally introduced as the technology underpinning cryptocurrencies like Bitcoin, has transcended its financial origins to find applications in diverse sectors. Education, with its intricate web of institutions, students, credentials, and data, stands to benefit immensely from the inherent attributes of Blockchain – decentralization, transparency, immutability, and security (Marin, I.,2022). Blockchain technology, originally developed as the underlying technology for cryptocurrencies, has found diverse applications across various industries. In the realm of education, Blockchain technology holds the promise of revolutionizing traditional systems by enhancing security, transparency, and efficiency. This subchapter explores the application, benefits, and challenges of utilizing Blockchain in the field of education.

Blockchain is reshaping education, transcending traditional boundaries and paving the way for an era of enhanced collaboration, accountability, and authenticity.

As traditional methods of managing educational records and credentials struggle to keep pace with the demands of the digital age, Blockchain offers a paradigm shift. No longer confined to the confines of physical documents susceptible to loss, damage, or tampering, academic achievements and certifications can be securely stored in a decentralized digital ledger. This technology not only empowers individuals with control over their own data but also establishes a new standard for trust and verification.

5.1.1 Benefits of using blockchain in education

Incorporating Blockchain technology into education has the potential to significantly enhance the quality, efficiency, and trustworthiness of educational systems, benefitting both learners and institutions alike. Blockchain allows students to maintain a lifelong, immutable record of their academic achievements. This record can include degrees, certifications, grades, and even extracurricular activities. Employers and institutions can verify these records quickly, streamlining admissions and hiring processes. Blockchain can provide a secure identity verification system for students, faculty, and staff. This reduces identity fraud and ensures that only authorized individuals gain access to sensitive educational

resources. One of the primary applications of Blockchain in education is the secure verification and authentication of academic credentials. Blockchain can serve as a tamper-proof ledger that stores educational records, ensuring their authenticity and reducing the prevalence of fraudulent degrees and certificates. Smart contracts, self-executing contracts with the terms of the agreement directly written into code, can be utilized for various administrative processes within educational institutions. These contracts can automate tasks such as student enrollment, fee payments, and course registrations, reducing administrative overhead.

The decentralized and immutable nature of Blockchain makes it highly resistant to data tampering and fraud. Academic records stored on a Blockchain are secure from unauthorized alterations, providing trust in the authenticity of credentials. Blockchain creates a transparent and auditable ledger of academic records and transactions, enhancing trust between educational institutions, students, and employers. This transparency can reduce disputes and streamline administrative processes. Automating administrative processes through smart contracts can significantly reduce administrative costs for educational institutions. This efficiency can lead to cost savings that can be redirected toward improving educational quality. Blockchain allows for the rapid and global verification of academic credentials, making it easier for students to apply to international institutions or seek employment abroad. This globalization can benefit both students and institutions seeking to attract diverse talent.

5.1.2 Challenges of Blockchain technology in education

Despite the benefits of using Blockchain in education, it also poses challenges. For example, adapting existing educational systems to incorporate Blockchain technology can be complex and costly. Institutions must invest in the necessary infrastructure, software, and training for successful implementation.

Storing sensitive student data on a Blockchain raises concerns about data privacy and compliance with regulations like GDPR. Striking the right balance between transparency and privacy is crucial. The lack of standardized protocols for educational Blockchain systems can hinder interoperability between institutions and employers. Developing industry standards is essential to maximize the technology's benefits.

Also, ensuring equal access to Blockchain-based systems for all students, including those without internet access or technical expertise, remains a challenge. Addressing this issue is crucial to prevent creating new inequalities in education.

Blockchain's potential to reshape education is vast, offering increased security, transparency, and efficiency. As institutions continue to embrace this technology, learners and educational stakeholders stand to benefit from a more streamlined and innovative educational experience. However, careful consideration of implementation challenges and a commitment to ongoing development will be key to realizing the full potential of Blockchain in education. Blockchain

technology has the potential to transform education by providing secure, transparent, and efficient solutions for credential verification, record-keeping, and administrative processes. However, implementing Blockchain in education comes with challenges, including integration complexities, data privacy concerns, and the need for standardization. Overcoming these challenges is essential for realizing the full potential of Blockchain in education, ultimately benefiting students, institutions, and employers alike. Further research and collaboration are needed to harness the power of Blockchain technology effectively in the education sector.

5.2 The Metaverse: transforming education in the digital age

The concept of the Metaverse has emerged as a transformative force in the realm of modern technologies, holding the potential to reshape various aspects of human interaction, communication, and engagement. As societies become increasingly interconnected and reliant on digital platforms, the Metaverse offers a novel perspective on the digitalization of education, creating new opportunities for immersive and collaborative learning experiences. (Giosanu, 2019) notes that „the rapid digitalization is changing the face of our social interactions and is also altering our manner to relate to reality”. This affirmation is especially true in the case of Metaverse, when applied in education but not only.

A concept that links Metaverse and education is educational technology. This notion refers to the use of tools, technologies, processes, procedures, resources and strategies to improve learning experiences in a variety of ways, such as formal learning, informal learning, non-formal learning, lifelong learning, on-demand learning or on-the-job learning (Ciupercă et al., 2021).

Rosa (Rosa, 2022) broadly defines Metaverse as „the next evolution of the Internet. There will be platforms within the Metaverse that offer content, experiences and the chance to live in different, virtual worlds. These platforms will, eventually, become interconnected. The vision is for us, as users, to be able to move seamlessly from one platform to the next. The Metaverse will also incorporate augmented reality (AR) content that will be overlaid onto the physical world”. This operative definition of the Metaverse offers us some important clues regarding the benefits of Metaverse in education. For example, it may facilitate access to (virtual) higher education in any part of the world, just by using a computer. Of course, this is only one aspect of the almost endless possibilities offered by this evolution of the Internet. Ball (Ball, 2022) notes that „virtual worlds can reproduce the real world”, which is often referred to as a “digital twin”. In this light, two major spheres of application and purposes of this virtual world are possible (Ball, 2022): 1. A “game-like,” purpose which is to say there is an objective such as winning, killing, scoring, defeating, or solving, or 2. a “nongame-like” purpose with objectives such as educational or vocational training, commerce, socializing, meditation, fitness, and more. Of course, education fits in the second identified category. In the following, let us look one by one at some of the benefits of Metaverse in the field of education.

5.2.1 Facilitating access to education

For many years, futurists have anticipated that distance learning and online education will partially replace traditional classroom instruction, especially in postsecondary education and vocational training. The price of conventional, in-person education has risen steadily (even though Romania would rather be a positive exception in this case compared to other countries such as US), while applications to universities and colleges are increasing, even though the overall impression is unchanged.

Ball (Ball, 2022) notes that none of the most prestigious schools in the world have even attempted to offer distance programmes that aspire to the quality or imprimatur of their face-to-face counterpart, partly because employers are unlikely to recognise them as such. And for millions of parents around the world, the COVID-19 pandemic was a lesson in the inadequacy of children learning from a 2D touchscreen alone. Many imagine that the improvements in 3D virtual worlds and simulations, as well as VR and AR headsets, and AR headsets, will fundamentally change our educational practices, and rightly so.

5.2.2 Augmented learning environments

In the context of education, the Metaverse poses a paradigm shift in how learners engage with content and interact with peers and educators. Augmented learning environments, facilitated by the Metaverse, transcend the limitations of traditional classroom settings. Learners are immersed in dynamic, multisensory experiences that enhance understanding and retention of complex concepts.

Educational institutions are exploring the integration of the Metaverse to provide interactive simulations, virtual laboratories, and historical re-enactments, enabling students to actively participate in learning scenarios that would be otherwise impossible to recreate in a physical classroom. For instance, medical students can practice surgical procedures in a risk-free VR environment, fostering hands-on learning in a controlled setting. This also leads to a refinement of specific abilities and a lower rate of fatal mistakes in real procedures.

5.2.3 Collaborative learning and global connectivity

The Metaverse's impact on education extends beyond content delivery to collaborative learning experiences. Geographical barriers are overcome, allowing students and educators from around the world to engage in real-time discussions, team projects, and cultural exchanges. Through avatars and digital personas, learners can communicate in virtual classrooms, breaking down language and cultural barriers while promoting diversity and inclusivity.

Furthermore, the Metaverse promotes co-creation and co-design of educational content. Learners can actively participate in shaping their learning materials, curating digital artefacts, and constructing virtual exhibits, fostering a sense of ownership and agency over their education.

5.2.4 Personalized learning

The Metaverse allows for personalized learning experiences. AI algorithms can analyze students' progress and preferences, adapting the content and pace of learning to individual needs, ensuring optimal learning outcomes. (Hwang & Wu, 2014) discusses how adaptive learning systems in virtual environments can provide tailored instruction based on individual progress, helping students learn at their own pace.

(Means et al., 2013) indicates that personalized learning algorithms, when applied in virtual environments such as the Metaverse, can lead to improved learning outcomes. These algorithms adapt content based on student mastery levels and learning preferences, enhancing engagement and understanding.

Another study (Kao et al., 2018) discusses how the Metaverse can offer scaffolded learning experiences. Virtual environments can provide real-time feedback, hints, and guidance tailored to individual student needs, promoting deeper understanding and problem-solving skills. Personalized learning experiences in the Metaverse can enhance student engagement and motivation. (Vlachopoulos & Makri, 2017) highlights that when learners have control over their learning paths and can interact with customized content, they are more motivated to learn and participate actively.

5.2.5 Resource-rich environment

The Metaverse can provide an extensive library of digital resources, from historical artefacts to cutting-edge research simulations. This wealth of resources can enrich learning experiences and support deeper exploration.

In the Metaverse, educators can build virtual libraries and archives filled with digital resources such as books, research papers, historical documents, and multimedia content. Students can access these resources from anywhere, promoting self-directed exploration and research.

The Metaverse can also host interactive simulations and models that allow students to visualize complex concepts. For instance, physics students can interact with virtual experiments, biology students can explore molecular structures, and history students can virtually visit historical events. Virtual museums and galleries within the Metaverse can showcase artefacts, artworks, and exhibits from various cultures and time periods. This provides students with a unique opportunity to explore and appreciate global heritage and history.

The Metaverse enables the creation of 3D learning objects that can be manipulated and examined from different angles. This is particularly useful for subjects like anatomy, architecture, and engineering, where a tangible understanding of spatial relationships is crucial. Virtual guest lectures and expert talks can be hosted in the Metaverse, allowing students to interact with professionals and researchers from around the world. This fosters exposure to

diverse perspectives and current advancements in various fields. The Metaverse can offer collaborative spaces where students can work together to create projects, presentations, and simulations. This encourages teamwork and creativity, enhancing the learning experience.

5.2.6 Challenges and risks

While the integration of the Metaverse into education offers numerous benefits, there are also risks and challenges that need to be considered. For example, the problematic of digital equity and access may arise. Not all students may have equal access to the technology required for immersive Metaverse experiences, leading to a digital divide. Students without access to the necessary devices or high-speed internet could be excluded from valuable learning opportunities.

Another key challenge is related to privacy and personal data security. Virtual environments in the Metaverse may collect significant amounts of personal data and interactions. Ensuring the privacy and security of this data is crucial, as breaches could have serious consequences for both students and educators. As it is well known, the cyber-space is not a space guaranteed against criminal attacks, even if different in nature from those happening in the physical world. This leads to another danger, that of cyberbullying and harassment. Cyberbullying involves the use of information and communication technology (ICT) technology (Campbell & Bauman, 2018). Usually, a cyberbully holds more social power than their victim, in terms of perceived status or online friends. They may also be more technologically skilled (Smith et al., 2013). As such, virtual spaces can also become breeding grounds for cyberbullying, harassment, and inappropriate behavior. Effective moderation and reporting mechanisms are necessary to create a safe and respectful learning environment.

Another, maybe more counter-intuitive type of challenge would be that of cognitive overload. Complex virtual environments and interactions can lead to cognitive overload, hindering learning instead of enhancing it. Striking the right balance between engagement and cognitive demand is essential. This risk is also associated with other two: digital depersonalization of learning and loss of physical interaction. The immersive nature of the Metaverse might lead to a depersonalized learning experience, particularly if human interaction and face-to-face engagement are minimized in favor of virtual interactions. Overreliance on virtual learning environments could also lead to reduced face-to-face interaction among students and between students and educators. Social skills and personal connections could be negatively affected, researchers warn (Simeon & Abugel, 2006).

6. Conclusions

The digitalization of education is a complex and multifaceted phenomenon that has the power to reshape the landscape of learning and teaching. This paper has explored various dimensions of digitalization in education, including enhanced

accessibility and equity, the effects of digitalization on education systems, challenges of digitalization, and the potential of synergistic technologies like Blockchain and the Metaverse to transform education. Through this exploration, it is evident that digitalization brings forth both opportunities and challenges, necessitating careful consideration and proactive measures to ensure its successful integration and maximization of benefits. Technologies like Blockchain and the Metaverse offer exciting possibilities for education. Blockchain's decentralized and secure nature can revolutionize credentialing and data management. The Metaverse's immersive experiences foster collaborative learning, global connectivity, personalized learning, and rich resource environments. However, ensuring equitable access, data privacy, and avoiding cognitive overload are important considerations.

In conclusion, digitalization is redefining education by enhancing accessibility, personalization, and collaboration. It holds the potential to address educational inequalities, create engaging learning environments, and prepare learners for a digital future. However, the challenges of equitable access, data security, and maintaining a balance between virtual and physical interactions must be diligently addressed. By embracing digitalization's opportunities and navigating its challenges, educators, policymakers, and stakeholders can shape a future of education that is responsive, inclusive, and transformative.

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Analysis of practical and test-based evaluations

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Abstract: *This paper explores the correlation between different teaching evaluation methods, specifically 3 practical assessment formats and quizzes, and related impact on students' academic performance. The study draws from educational theory, using four significant stages: teaching, learning, evaluation, and feedback. The feedback phase is a crucial aspect of education that is dependent on the evaluation process used. The paper investigates various evaluation methods, including written examinations, practical projects and labs, test/quizzes, collaborative assessments, and portfolio-based assessments. Statistical analysis is conducted on a dataset of students' evaluations to determine which assessment methods yielded optimal results. The study suggests that quizzes tend to produce narrower score intervals and lower variances compared to practical assessment approaches. Correlations between evaluation methods are analyzed, and a significant correlation is observed between practical assignments and quiz performance. The findings contribute to a deeper understanding of evaluation methods in education and provide insights into selecting appropriate assessment approaches to improve students' learning outcomes.*

Keywords: educational environment, learning, evaluation, quizzes, assessments, evaluation methods.

1. Introduction

Educational systems can be viewed as four significant stages (Tuychieva and Xudoyorov, 2022), (Valieva, 2022) which include (see Figure 1):

- **teaching** – by teachers;
- **learning**- by students;
- **evaluation** – by teachers for students;
- **feedback** – by teachers for students.

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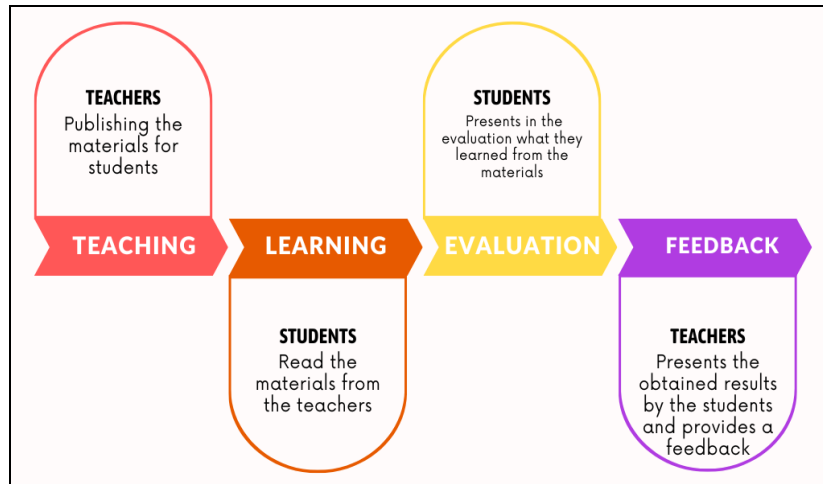


Figure 1. Linear Process of Learning

Each of these four phases is important to ensure a student moves through essential material, absorbs key elements, and demonstrates mastery. Teacher feedback reinforces learning and ensures any missing elements are communicated back to the learner. Within this process, evaluation of learning and feedback become key elements for an effective teacher. Depending on the evaluation method, various feedback approaches can be used for each student. For example, feedback may be provided for each question or in summary for related groups of questions. It may be oriented to individuals or to multiple students who work in a team. To facilitate learning, it becomes important to choose the correct method of evaluation for various learning objectives. This will impact the manner in which feedback will be provided by the teacher.

In this paper, we evaluate the third phase of this four-stage process: evaluation. Evaluation can utilize multiple approaches and methods. We examine 4 of these and then statistically analyze effectiveness to help teachers determine the appropriateness of each.

2. Background of evaluation methods

Student evaluation in a technological field can take place according to a variety of method. Several current approaches include the following (Baigi et al., 2022; Mohan, 2023). See Figure 2.

- **Written examinations or practical assessments.** Traditional assessment methods involve evaluating students' practical knowledge in areas such as programming, algorithms, data structures, or fundamental computer science concepts. For such assessments, the teacher must create requirements in a way that the student presents his acquired knowledge in a practical way (Paiva, et al., 2022). For this method of assessment the

teacher will assign deadlines and wait for the students to submit their work. The teachers review the submissions and provide feedback. The feedback will be provided to evaluate exactly what a student submits, and will be personalized.

- **Practical projects and labs.** Assessment through practical projects and labs allows students to apply knowledge and skills in real projects or practical scenarios. This may involve developing software, creating applications, configuring and administering systems, or solving practical IT problems (Bunse et al., 2022). Evaluation of practical projects assumes that the students are present physically or virtually. Feedback can be provided verbally or in recorded messages.
- **Quizzes.** Quizzes or tests can be used to assess students' theoretical knowledge and skills as well as practical knowledge by providing concrete examples and motivating the student to choose an optimal decision or approach. On platforms such as Moodle, quizzes are easy to create and can be used to evaluate students (Freitas et al., 2016; Lopez-Tocon, 2021). This method of the evaluation requires the teacher to prepare feedback before the evaluation phase. Generally, the teacher prepares feedback for each question and students see feedback depending on the answer they select. The advantage is that the teacher will prepare everything before the evaluation, and after the evaluation phase no additional work is required. The disadvantage is that feedback will be general and similar for all students.
- **Collaborative assessment.** Teamwork and collaboration are important aspects of technical fields. Therefore, collaborative assessment is relevant and often used as an approach for assessing learners' ability to work in a team, communicate, and collaborate with other team members (McConnell, 2002). The feedback for this type of evaluation is provided to the entire team. Students often are responsible for extracting relevant portions of feedback to better understand their strengths and weaknesses. Teachers see the high level result of deliverables so they collectively evaluate all work from team members.
- **Portfolio-based assessment.** Digital portfolios can be used to collect and assess projects, source code, documentation, and other work developed by students during courses or projects (Sanjaya et al., 2022). This method is important because the evaluation represents a collection of work developed by the students over a longer time period. Feedback is usually provided periodically and then culminates at the end of the semester. Sometimes, this means that students will not have a final opportunity to change their deliverables. In other situations, a project can be requested by the teachers in more phases, and feedback will be provided following each phase of the project before incorporation into a portfolio.

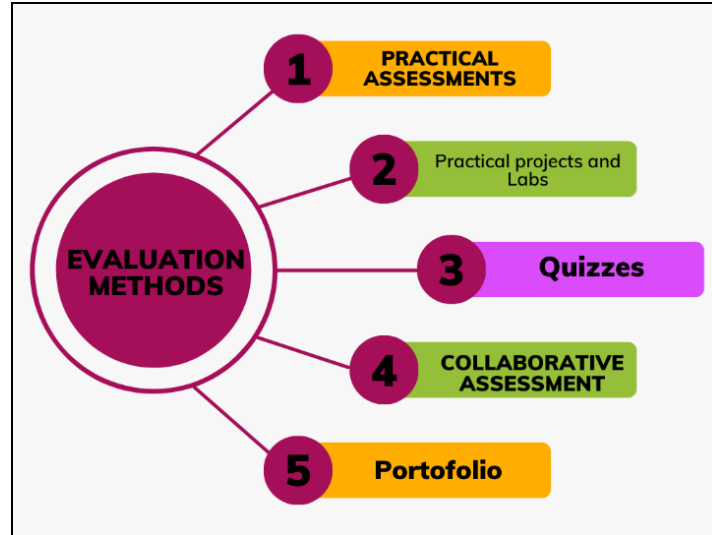


Figure 2. Evaluation Methods

3. Data sets and methodologies

Various evaluation methods are more effective under different circumstances. We analyze a sample of students to examine several methods of assessment. This is intended to allow us to observe which assessment method seems to encourage students to perform better.

3.1 Data and subjects

Subjects in this study were technology students enrolled in a programming class. An overall course grade was assessed according to the breakdown shown in Table 1.

Table 1. Weights for evaluation

Laboratory activity	10%
Practical assignment	20%
Project	10%
Exam - Quiz	60%

The first three elements are practical assessments which take place during the semester, and the final exam is assessed as a quiz. The purpose of this study is to observe the degree to which students score better on practical assessments or quizzes. This evaluation process is represented graphically in Figure 3.

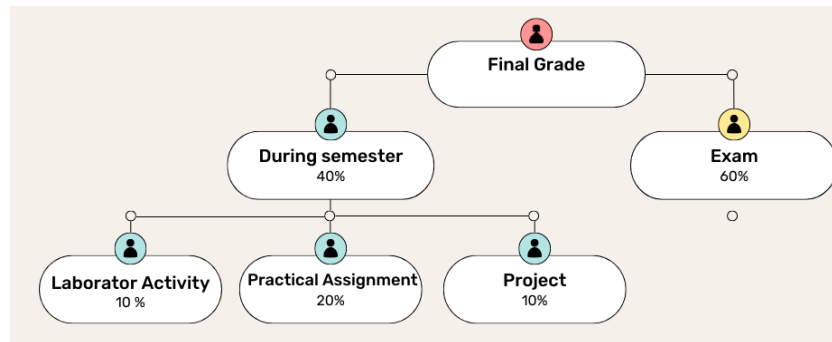


Figure 3. Evaluation process with weights

The study included 73 students divided into 5 groups. All 5 groups have the same content presented and the same evaluation approach. All students were in their 4th year and had a similar background in programming. The current course covered mobile device programming using the Java programming language.

The 4 types of evaluation used for this study can be considered as part of Self-Regulated Learning (Steinherr & Vay, 2023). This method applies because students develop their projects and learn by applying theoretical concepts to their project.

Evaluation through the quizzes was primarily a theoretical evaluation but some practical questions were included to ensure students were able to apply concepts in a practical way.

3.2 Applied analysis approach

The study examined 4 evaluation items. These included laboratory activities, practical assignments, projects and exam/quizzes. The portfolio and group approaches were not included. An average was calculated for each approach used and these were compared to determine the impact of each form of assessment. To observe the representativeness of the scores obtained by the students, standard deviation and variance were calculated for each respective evaluation approach.

Finally, we presented the correlation between the 4 types of student assessment. This allowed us to see the degree of student engagement correlated with the grades obtained in the other elements.

4. Results

Student grades are presented in Table 2. The first three assessment elements indicate the minimum student grade was 0 and the maximum was 10. This shows some students were very involved in the laboratory and practical work during the semester but other students did not get involved in this activity at all. This is normal for this course.

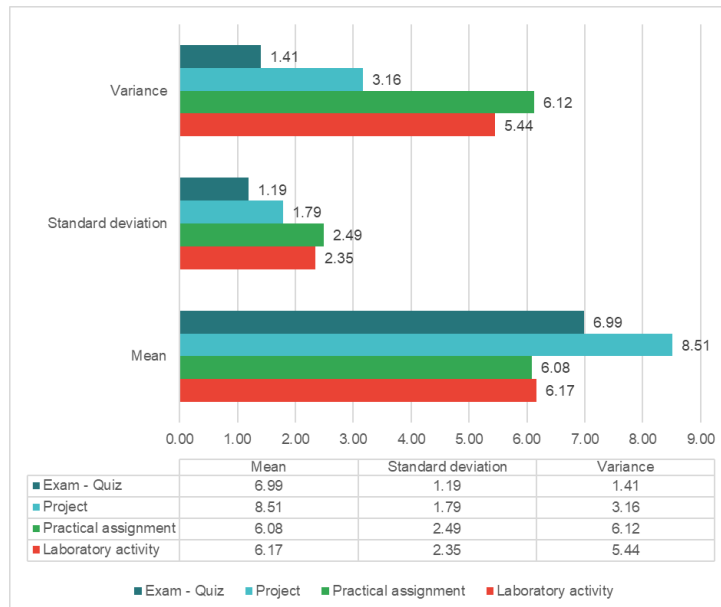
Table 2. Minimum and maximum grades for each method of evaluation

	Laboratory activity	Practical assignment	Project	Exam - Quiz
Minimum	0.00	0.00	0.00	4.50
Maximum	10.00	10.00	10.00	9.42

For the exam category, the minimum and maximum were 4.5 and 9.42. This shows that the evaluation through Quizzes reduced the interval for the obtained degree. To observe this conclusion in a statistical way we calculated the mean, standard deviation, and variance for all values in each evaluation method. The results are presented in Figure 3.

The mean was highest for the project evaluation at 8.51. The smallest means were obtained for the lab activity and practical assignment at 6.08 and 6.11. This indicates that when students have more time to resolve tasks, their outcomes are more likely to have been prepared more in detail.

We examined the standard deviation and variance. The interval of values was smaller for the exam category. That suggests that the quiz evaluation reduced the variance and standard deviation. It also helped increase the obtained mean. The largest variance was for the practical assignment at 6.12. This was determined to be due to lack of student preparation. Values are summarized in Figure 4.

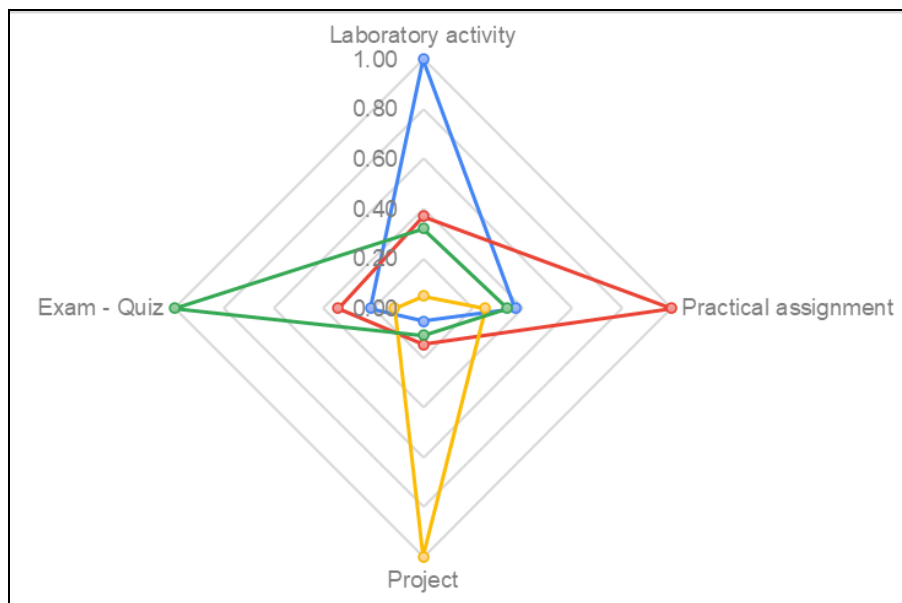
**Figure 4.** Mean, standard deviation, and variance

In the next phase of our research, we calculated correlations between grades obtained for each method of evaluation with other methods. For that, we created a matrix. See Table 3.

Table 3. Correlation for all students' degrees

Correlation	Laboratory activity	Practical assignment	Project	Exam - Quiz
Laboratory activity	1	0.37	0.05	0.21
Practical assignment		1	0.15	0.34
Project			1	0.11
Exam - Quiz				1

These correlations are presented graphically in Figure 5.

**Figure 5.** Correlations between evaluation methods

In Figure 5 we see the smallest correlation was between the project method evaluation and the other three methods because all three points are in the center of the graph. This shows that if the student has more time to resolve an assigned task he can improve the project. This means that results are different for those obtained in a practical assessment or in a quiz.

To further investigate the correlation between the practical assignment and the quiz form of the evaluation, we applied a t-Test and Z-Test. These outcomes of these analyses are presented in Table 4.

Table 4. t-Test and z-Test applied for Practical assignment and Quiz

	Practical assignment	Exam - Quiz
Mean	6.08	6.99
Variance	6.20	1.43
Observations	73.00	73.00
Pearson Correlation	0.34	
Hypothesized Mean Difference	0.00	
df	72.00	
t Stat	-3.27	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.67	
P(T<=t) two-tail	0.00	
t Critical two-tail	1.99	
Z	-2.80	
P(Z<=z) one-tail	0.00	
z Critical one-tail	1.64	
P(Z<=z) two-tail	0.01	
z Critical two-tail	1.96	

We can observe that p-value is 0.00. That means the obtained results on the practical assignment and the quiz (final exam) are statistically significant. So, even if the variance is different for these two sets, the values are correlated and significant.

5. Discussion and conclusions

A variety of evaluation methods can be used in teaching and those should determine the method of feedback provided to students. Several interesting outcomes were highlighted by our study. First, the analysis between practical assessments and quizzes, in the context of educational evaluation methods, suggested that quizzes tend to yield narrower score intervals and lower variances compared to practical assessments. Quizzes are typically more standardized and provide a consistent measure of students' knowledge and understanding. Reduced variability in quiz scores may be attributed to the controlled nature of quiz formats, where students are required to select predefined answers or make specific decisions based on given scenarios. In contrast, practical assessments involve subjective evaluations of students' performance, which can introduce greater variability in grading criteria and outcomes as well as greater variability in student approaches to solving a predefined problem. In quizzes, students generally have a fixed amount of time for completion while practical assignments are more open-ended and can vary based on student time commitments.

The analysis also revealed a significant correlation between students' performance on practical assignments and their quiz scores. This finding suggests that students who excel in practical assignments are likely to perform well in quizzes as well. One possible explanation is that practical assignments provide students with hands-on experience, allowing them to apply theoretical concepts in real-world scenarios. This practical application of knowledge may enhance their understanding and retention of the material, leading to improved quiz performance. Additionally, the correlation implies that teachers who emphasize practical assignments as part of the evaluation process may effectively assess and reinforce students' comprehension of the subject matter.

It is important to consider the strengths and limitations of each evaluation method. Practical assessments, such as projects and labs, provide opportunities for students to demonstrate their skills and problem-solving abilities in a realistic context. These assessments align with the demands of real-world situations and encourage critical thinking and creativity. On the other hand, quizzes, particularly when well-designed, can effectively assess students' theoretical knowledge and conceptual understanding. Quizzes also offer advantages in terms of ease of administration, automated grading processes, and timely feedback provision.

Teachers should consider the balance between practical assessments and quizzes based on learning objectives, subject matter, and desired learning outcomes. A combination of both evaluation methods can provide a comprehensive assessment of students' competencies, covering theoretical knowledge, practical application, and problem-solving abilities. By incorporating a variety of assessment approaches, teachers can gain a holistic understanding of students' strengths and areas for improvement, enabling personalized feedback and targeted instructional interventions.

Furthermore, the findings of this study contribute to the ongoing discussions on evaluation practices in education. Teachers must carefully select and design evaluation methods that align with the specific learning goals and the type of content being covered. Additionally, the study highlights the importance of providing personalized feedback to students. Feedback serves as a valuable tool for promoting student engagement, self-reflection, and continuous improvement.

The study had several limitations. For example, the analysis focused on a specific sample of students in a single university's Java programming course for mobile devices. The results may not be directly generalizable to other academic disciplines or locations. The study examined 4 evaluation methods, and other approaches, such as peer assessment, portfolio approaches, group assessments and oral examinations, were not included. Future research should explore additional evaluation methods and investigate the impact on students' learning outcomes in diverse educational contexts.

Acknowledgments

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Section 3

The Multidimensionality of Technological Education

Some contributions to the foundation of the e-Learning Pedagogy

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Abstract: *This article presents contributions to the introduction and use of the Internet and educational platforms at the Teacher Training Departments of Gh. Technical University Asachi and Al. I. Cuza University, Iasi, Romania. Collaboration with state universities from the Republic of Moldova, and with Menoufia University, Egypt, is also mentioned. Efforts to define the notions of e-Learning Pedagogy needed by teachers using online STEM education are reviewed.*

Keywords: e-learning Pedagogy, online educational platforms, Moodle, Significant publications.

1. Contributions to the foundation of the e-Learning Pedagogy

Highlighted below are the most important contributions to the Foundation of the e-Learning Pedagogy:

1. Ph.D. thesis (finished in December 2000, and sustained in January 2001) devoted to use of Learning Technology in Science, Technology, Engineering, Mathematics (STEM) education;

2. Online Electromagnetic Compatibility (EMC) course (in Romanian), completed in December 2000;

3. ”Computer Aided Training – e-Didactics” Manual (in Romanian), Iasi, Polirom Publishing House, 2007, using the ground-breaking research results for the doctoral thesis. Manual recommended by Professor Ioan Jinga in the Curriculum for Completion and Degree for Teachers of Technology and Economic Sciences. The Computer-Aided Instruction (CAI) manual, author Daniela Vlădoiu, from the Rural Education (PIR) Program, uses information and concepts from the doctoral thesis.

2. Ph.D. Thesis

The topic of the PhD Thesis ”Contributions to the improvement of the multimedia systems in the didactic process of knowledge transfer and assimilation in the subject domain of Fundamentals of Electrical Engineering (Electromagnetic

Compatibility)” (in Romanian) was recommended by EPF Lausanne (École polytechnique fédérale de Lausanne, Switzerland), by Professors Frédéric de Coulon and Michel Ianoz (Mircea Ianovici). The EPFL Laboratoire d'Enseignement Assisté par Ordinateur (LEAO) donated 12 computers for the realization of a Computer Aided Training Laboratory within the Faculty of Electrical Engineering in Iași (1994). Adrian A. Adăscăliței completed a training course at EPF Lausanne.

It is useful to mention words of appreciations by the doctoral supervisor, Professor Dan Gălea, and by Academician Mircea Stelian Petrescu, member of the Doctoral Committee.

2.1 General considerations

”The Ph.D. Thesis, having as author Adrian A. Adăscăliței, scientific researcher at the Institute of Theoretical Informatics, Romanian Academy, Iasi Branch, is devoted to a current, exciting topic, at the confluence of several fields, namely: a distinct chapter on Artificial Intelligence – Computer Assisted Education, Information and Communication Technology and Pedagogy of the Teaching of Engineering Sciences.

The emergence and development of the Internet communication network, as well as of the Web technologies, made possible the materialization of an idea that seemed utopian, until that moment, that of continuous and distance education. Complementary to the classical training solution, the open, continuous and distance education method widens the learning space from both the educator's and the student's point of view. Practically all the major universities, professional companies and commercial firms have reacted promptly to the challenge offered by the Internet technology. Numerous government strategies have been developed that support research programmes in this direction. The European Society for the Engineering Education (SEFI, Brussels, Belgium), the International Society of Engineering Pedagogy (IGIP, Klagenfurt, Austria), UNESCO CEPES (European Centre for Higher Education), IEEE (Institution of Electrical and Electronics Engineers), the UNESCO International Centre for Engineering Education (USICEE, Melbourne, Australia), IACEE (International Association for Continuing Engineering Education), the General Association of Engineers in Romania (AGIR) are just a few professional organizations which coordinate programs for the introduction of Information Technology in Education. The author of this thesis has kept permanent contact and exchanged information with specialists from the above-mentioned institutions. He launched his own ground-breaking research program developed through the Institute of Theoretical Informatics in Iasi of the Romanian Academy, having as initial partner the EPFL Laboratory of Computer-Aided Training (LEAO). Subsequently, in the framework of a Leonardo pilot program, carried out by the "Gh. Asachi" Technical University Iasi, information exchanges were conducted with other partner universities in the European Union,

to mention just a few: the Technical University of Lisbon, Portugal, the Technical University of Darmstadt, Germany, the University of Warwick, United Kingdom.

The result of the doctoral research is a combination of the oldest field of electrical engineering, electromagnetic field theory, engineering pedagogy and the newest information processing tool, web technology. The Ph.D. thesis retains attention by: its scale - 182 pages representing the actual work and 78 pages representing 3 annexes; a rigorous, clear and neat presentation; a large number of charts, graphs, organizational charts, figures, summary tables; a wide range of bibliographic references cited - 120, 20 of which are the author's papers published in the country and abroad."

2.2 On the content of the thesis

The doctoral thesis is structured into five chapters preceded by an introduction, three annexes containing the web locations of the virtual campus and of the EMC course, the list of citations of the Web course, as well as the list with the HTML code of some representative applications.

Chapter 1, "The current situation of the field (history, informatics pedagogy)", is an overview of the issues of the training process and of the fundamental theories regarding the planning of training. The study finally provides a classification of computer-assisted instruction programs (CAI). The author introduces the specific terms of the interdisciplinary field of research, that of learning technology (e-Pedagogy), analyses the stages of the training process, proposes the classical structure of the interactive lesson (tutorial) and of the practical exercise (to be performed by the learner). The author synthesizes each type of didactic activity used later in structuring online training.

Chapter 2, "Information system for training (hardware tools, network, multimedia)", presents the multimedia teaching tools used by the teacher. Compared to the classical method, the author proposes the structure of the computer-aided training model realized and implemented through Client-Server applications. The author also proposes the minimal hardware and software configuration necessary to carry out the training process with the involvement of multimedia tools. The structure of such a hypermedia system includes the components of a hypertext eBook and allows the circulation of Web documents, search, location and uploading of these documents, ensures compatibility with e-mail and allows connection to the server mailbox.

The author proposes that multimedia documents be considered discrete documents, if temporal relationships between components (text, graphics, static images) are not defined, and documents for which synchronization information is required (for which temporal relationships between components are essential). The author concludes that the structure of the multimedia documents requires more hardware resources of the system because, besides the logical structure of the data

representing the didactic material, a temporal component emerges, increasing the risk of the impossibility of covering these requirements with the available hardware resources.

In the author's opinion, for the network to be able to ensure the transfer of any type of document, it should comply with certain standards for format specification, content, the network's presentation, and sequencing. It follows that the networks currently used for classical e-mail cannot be used for multimedia document transfer.

Chapter 3, "Synthesis and Research," discusses the author's original vision of computer-based pedagogy of engineering teaching and learning (structuring a course) with the help of information technology. The main application areas of Learning Technology are presented, as well as the open research directions to be continued in the future. This chapter analyses all the necessary steps for the implementation of a computer-assisted education (CED) project are also analysed.

In conclusion, starting from the theoretical substantiation, offered by the communication sciences, of the human-computer interaction, the hierarchy of the distribution of the information presented in the form of HTML pages is proposed. Noteworthy is the facility offered by the system so that the selection in each situation of a sequence of documents accessible in the network can be carried out based on predefined structures of knowledge trees. Also, the user orientation in the training space can be done in parallel with the supervision by the system of the way in which each topic reacts to the interaction with the informative material.

In the 4th chapter, are exposed the two applications that are the subject of the thesis: the online EMC course, and the Informatics Structure called Virtual Campus (VIRTUiS, id est Virtual Campus of "Gh. Asachi" Technical University Iași).

The EMC course presents, by using of multimedia teaching tools discussed in chapter 2, and considering the structures presented in chapter 3, the coupling mechanisms through electromagnetic fields that cause undesirable phenomena of electromagnetic interference. Elements of equipment design and operation are described, so that the electrical equipment becomes immune to these interferences and the field dispersed by the equipment itself remains within the limits imposed by the standards. In this chapter, all the necessary steps for the realization of a computer-assisted education (CAE) project are analysed.

The basic notions specific to EMC, namely: the fundamentals of electromagnetic theory, the theory of antennas, filters, electrostatic discharges, and shielding are structured into several modules so that the traditional student-teacher communication can be replaced with a communication mediated by the information system.

The virtual campus integrates the network equipment and the software system based on the constructivist educational model, having as objective the notification of all the participants involved in the education and training activity. A

discipline holder can call on the online course designer by providing him with at least the following elements: structured information material including demonstrations and simulations, connection trees and how to test knowledge.

The closing chapter presents the author's conclusions regarding the obtained results and lays down possible directions of future research. The material presented in the annexes allows navigation in the VIRTUiS space, being able to follow in detail the functionality of the EMC online course.”

2.3 On the original contributions

”The author’s main contributions are the following:

1. Systematization of the problem of informatics pedagogy, the conclusions drawn allowing the proposal of original solutions for the design of student-computer interfaces.
2. Systematization of the information material of the EMC course and structuring of the educational components: the lesson, the dynamic exemplification of the phenomena, the simulation, the testing, the virtual laboratory work, the design elements, the interactive exercise.
3. Creation of a virtual library for the EMC course by highlighting the connections to bibliographic sources offered by various sites around the world.
4. Conceiving and designing the Virtual Campus as a distributed software system accessible to the Web, making it easier to perform operations corresponding to teaching activities.
5. Integration of the EMC course components into the structure of the Virtual Campus allowing for the implementation of the designed teaching process.
6. Optimization of the functioning of the distributed software structure mainly through: organization of video sequences in the form of optimal structures to obtain high performance in terms of high transfer rate and resolution; adaptation of the way documents are represented according to their complexity and; available network hardware resources necessary to achieve high transfer performance.”

2.4 Conclusions

”The theme approached by the author is ambitious and complex. In solving the formulated research problem, the author demonstrates that he masters the knowledge of modern pedagogical principles and their application in engineering education. The author is also an exceptionally good connoisseur of Web technology, which has allowed him to implement the structure of the educational model conceived through a VIRTUiS functional software product.

This software was installed on the server of the Faculty of Electrical

Engineering and has been tested by many users. The author considered the suggestions formulated by the students as well as by the partners within the research program. The EMC course, accessible on the Virtual Campus, VIRTUiS, is quoted by prestigious universities such as the University of Warwick, Great Britain, the Technical University of Darmstadt, Germany, the Technical University of Lisbon, Portugal, receiving words of appreciations. The research initiated by the author allows for the opening of a direction that may prove its usefulness in the modernization of the didactic process in Romania.”

3. Web-Supported Course Website

The online EMC course is an application and illustration of the concepts developed in the doctoral thesis.

3.1 Planning the Components of a Web-Supported Course Website

(Adăscăliței, 2006) There are two major uses to enhance a face-to-face course by using the Web: to make the course content available to students and to conduct online activities. As in all courses, the quality of the instructional planning maximizes the learning for all students. In the Web environment, the components of a course website, which enhance teaching and learning and save time by being posted for students’ online access, are especially valuable.

At the most basic level, instructors can post content and announcements to a course website. However, course planning usually begins with a course map – an outline of topics, weeks, objectives, activities, assignments, and assessments to show alignment of course components with each other in a weekly calendar format. Planning also includes the purposeful design of activities to create a student learning community – collaborative student groups in a course that develop with the students’ active access, pursuit, generation, and evaluation of information and learning in their discussion, chats, and e-mail communications.

3.2 Course website components

Course content (Figure 1) is aligned with curriculum standards, objectives, assignments, assessments.

- **Course Syllabus.** The course contains a syllabus and supporting documents. The course includes items such as: course title; correct course semester; course description; course contact and credit hours; course prerequisites; course objectives; course assignment; course test schedule; required course materials; grading criteria; testing information; library resources; any on-campus requirements; work ethics information.

- **Staff Information.** The course contains staff information: instructor name; appropriate picture (optional); e-mail address; telephone and fax numbers; office hours.

- Student Information. The course contains a student orientation and explains: how to get started; technical equipment requirements; technology competency requirements; browser recommendations; drop deadlines; format for assignments; requirements for chat room and/or e-mail; instructor response time; troubleshooting advice.

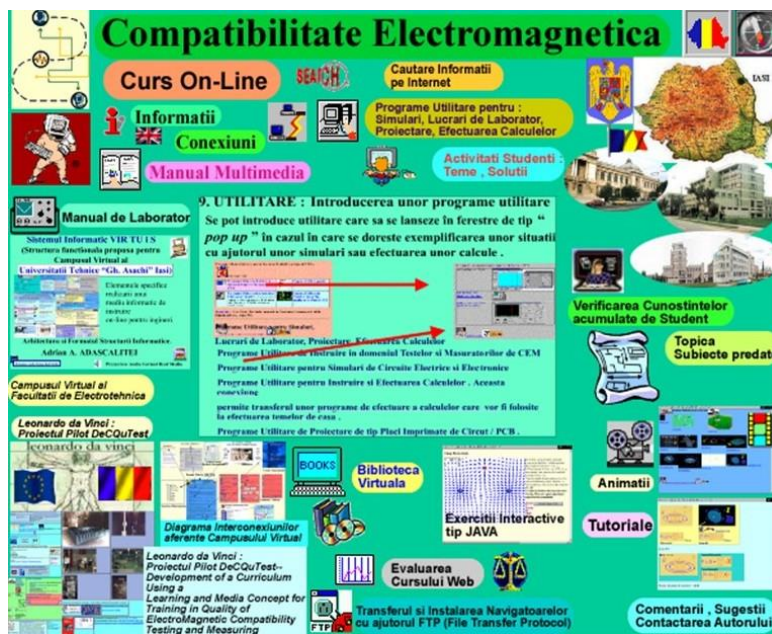


Figure 1. Electromagnetic Compatibility On-Line Course (in Romanian)

- Course Calendar – Scheduled dates for readings, activities, assignments, quizzes, and exams.
- Assignments and Activities, including directions and scheduled dates. Course assignments are designed: to be interactive, students being required to interact with each other and their instructor via e-mail, chat room, and/or discussion board; and to address a variety of learning styles through: written assignments; reading activities; discussions; simulations; case studies; and give students the opportunity to engage in critical and abstract thinking. Students are challenged to complete one or more of the following: solve problems; apply concepts in context; complete practical applications.
- Course Documents – Additional documents for reference or study or answers to frequently asked questions. Course document section includes a variety of learning media. Course content is delivered through media such as: PowerPoint presentations; Short lectures in audio or video format; links to resources on websites; CD-ROM materials.

- Lectures – Notes and audio to highlight key concepts of course content. A word of caution: for face-to-face classes with web-enhancement, faculty may wish to include required assignments, even if minor, for extra points to be turned in at the scheduled class times or other incentives to maintain class attendance.

- Communication Tools – Areas for sending and receiving e-mail, participating in group or class discussions about particular issues, keeping electronic journals, completing “dry or simulated lab” exercises to prepare for “wet or real lab” experiences, or engaging in chat sessions. Many students are able and willing to participate more fully online than in face-to-face classes, especially when discussion assignments require each student to post a comment or the results of a brief assignment and to reply to a comment or question from other students.

- Student Tools – Areas for using a digital drop box to send and receive completed papers, homepages, or personal profiles of students, and access to grades.

- Assessment Tools– Areas for quizzes, exams, and surveys; online grade books; and assessment statistics. Course assignments are designed to be interactive and require students to interact with: each other and their instructor via e-mail, chat room, and/or discussion board. The course structure includes adequate and appropriate methods and procedures to measure student mastery of course competencies. Assessments include a variety of the following: online or proctored testing; standardized tests; projects; demonstrations; presentations; case studies.

4. Computer Aided Training – e-Didactics Manual

(Adascalitei, 2007) Computer aided training. e-Learning Pedagogy, Polirom Publishing House, used for blended teaching and learning courses (Figure no. 2) is Manual developed within DPPD, UAIC and TUIasi for Computer Assisted Training (CAT) and associated disciplines. CAL Manual is a development of the doctoral thesis completed in December 2000 and defended in January 2001.

Computer assisted training (CAT) is a didactic method that capitalizes on the principles of modelling and cybernetic analysis of training activity in the context of new information and communication technologies. The synthesis between the pedagogical resources of the programmed training and the technological availability of the computer (information processing system) gives this educational method important qualities regarding: computerization of the teaching-learning-evaluation activity; improving training through management-documentation-interrogation actions and interactive automated simulation of knowledge and skills engaged in the educational process, according to official education planning documents.

Table of Contents (TOC): CAI, e-learning and instructional technology • Fundamental theories of training design • Classification of computer-aided training programs • Scenarios for conducting computer-aided training • Role and functions of the tutor in CAI • Development of study materials for CAI • Methodology for

designing and implementing computer-aided training programs • Interactions. Computer mediated communications • Model of an CAI education centre (online, e-learning) • Elements of design and standardization of resources for e-learning.

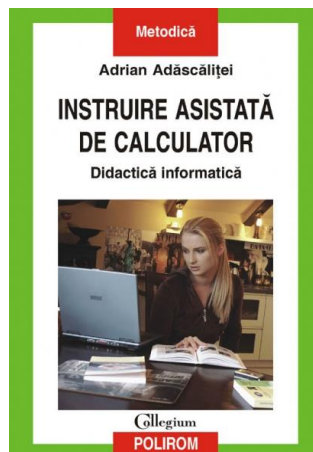


Figure 2. CAI Polirom manual cover

5. Activities and achievements that complement the use of learning technologies in STEM education

1. BTL (CAI) courses at DPPD from UAIC and TU Iași on moodle.ee.tuiasi.ro and elearning.utm.md/moodle/ platforms.

2. Active participation as trainer in the project "acquire skills in the field of interactive teaching and learning techniques and ICT", i.e. DIDATEC project. I produced an Online course located on moodle.ee.tuiasi.ro platform.

3. Participation in "the Création d'un Réseau d'Universités Numériques Thématiques en sciences appliquées et sciences économiques en Moldavie" (CRUNT) Program. I created an Online course on the network platform in the Moldova Technical University, Chișinău, Republic of Moldova. The papers published in collaboration with universities from the Republic of Moldova can be viewed and downloaded at Adrian A. Adăscăliței, National Bibliometric Instrument, https://ibn.idsi.md/ro/author_articles/47281.

4. Participation as member of Scientific Committee and reviewer in National and International Conferences devoted to Learning Technology in Education, such as: International Conference on Virtual Learning (ICVL); National Conference on Virtual Education (CNIV); International Scientific Conference on e-Learning and Software for Education (eLSE); |a.s.o.

In 2009 the CNIV and ICVL Conferences were organized in Iasi, by the Faculty of Electrical Engineering, Technical University "Gh. Asachi", with the support of AGIR Iasi Branch.

5. Collaboration with Menoufia University, Faculty of Engineering, Egypt. (Zein El-Din et. al., 2018; Adascalitei, et. al., 2019; Zein El-Din et al., 2019; Adascalitei, et al., 2020; Adăscăliței et al., 2021) in the BTL field also using virtual laboratory experiments and simulations, in online courses distributed on an LCMS platform (Moodle, for example).

6. Conclusions

In the attached selective bibliography, I have mentioned some of the significant works illustrating the content of the article.

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Effectiveness of ontology-based e-Learning in healthcare management: a case study from Romania

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Abstract: *Human resources management is an essential condition for increasing the performance of an organization in the public or private medical sector. The need to increase the quality of the medical act in contemporary Romanian society at the level of the standards on the international level implies the improvement of the quality of the healthcare management, which implies the increase of the level of professionalism of the managers. The paper proposes an e-Learning environment based on new semantic technologies, capable of leading the process of building personalized educational content, with the aim of training managers from a university hospital in Romania. The ontology-based e-Learning system is addressed to managers in a hospital but also to other people who want to access management positions in healthcare facilities in Romania. The system aims to offer a training course for professionals in the field of medical management, at a competitive level, according to the real requirements of the Romanian and European health system.*

Keywords: e-Learning, Healthcare, Management, Semantic Web, Ontology.

1. Introduction

Learning, an indispensable activity in today's knowledge-based society, is influenced by global changes, the increase in competition in all environments, the ICT (Information and Communication Technology) revolution, respectively by the importance of the network computer and the need to transfer information. The learning context and the requirements take new shapes, learning becoming more flexible, accessible and efficient through the use of the web (Tudor, Kyaw & Atun, 2018).

With the expansion and development of Web 2.0, e-Learning 2.0 enabled the transition from knowledge transfer to education as a creative activity, and e-Learning 3.0 offers intelligent solutions for web search, document management, and content organization, and the learning process will be more efficient through the use of collaboration techniques (Kozlova & Pikhart, 2021). Web 3.0, known as

the semantic web becomes an innovative technology that underlies the new e-Learning requirements (Yao & Sun, 2010). The enormous growth of learning resources available online through massive open online courses and learning management systems has necessitated personalized resource recommendations. Techniques such as ontology, artificial intelligence, among others, can provide personalized recommendations. Ontology is a way to model learners and learning resources, and offer great potential in environments such as online education, by providing, sharing, and reusing information between educational systems and providing support in their personalization (George & Lal, 2019).

Human resources management is an essential condition for increasing the performance of an organization in the public or private medical sector. Improving the management of human resources at the level of a medical unit requires the development of effective strategies. e-Learning allows transform health leadership and management education and addresses diverse training needs by facilitating information sharing, experiential learning, collaboration and just-in-time support through accessible, easily updated, scalable, and engaging training resources (Tudor, Kyaw & Atun, 2018). The management functions are analysed by many works in relation to digital transformation (Anghel, Pereteanu & Cîrnu, 2020). The core functions of management are interrelated and interdependent, and effective management requires a balanced approach to all (Banciu, Vevera & Popa, 2023).

The need to increase the quality of the medical act in contemporary Romanian society at the level of the standards on the international level implies the improvement of the quality of the management of the health unit, which implies the increase of the level of professionalism of the managers. This paper proposes an e-Learning environment based on new semantic technologies, capable of leading the process of building personalized educational content, with the aim of training managers from a university hospital in Romania. The e-Learning system is addressed to managers in a hospital but also to other people who want to access management positions in healthcare units in Romania.

This paper is organized as follows. Section 2 presents an overview about e-Learning healthcare systems and a selection of some applications that use ontologies in human resources management. Section 3 presents the ontology-based e-Learning platform for managers of healthcare system in Romania.

2. Overview

2.1 e-Learning healthcare systems

There are quite a number of e-Learning programmes for healthcare representatives that have been implemented, but evidence on their long-term outcomes is largely lacking, and direct comparisons between different delivery formats are very rare. At the international level there are a number of e-Learning platforms for healthcare domain, respectively knowledge in the field of Human

Resource Management (HRM). Also, there are organizations that provide support for medical e-Learning such as Medical Education Organizations Supporting E-Learning (Ruiz, Mintzer & Leipzig, 2006).

In paper (Reavley et al., 2021) 608 public servants completed either an e-Learning course and a blended course or a face-to-face course regarding provision of first aid to a person with depression or post-traumatic stress disorder. Both blended and eLearning courses led to significant longer-term improvements in knowledge, attitudes and intentions to help a person with a mental health problem. A self-study was applied to simultaneously research the development process and to integrate an evaluation of the resulting e-Learning program learning by the nurses who participated in pre and post-test questionnaires and focus group discussions is presented in (Mak & White, 2021). In USA, the University of Georgia Supplemental Nutrition Assistance Program Education includes a program that provides comprehensive eLearning nutrition education through a series of interactive lessons, learning games, educational and cooking videos, and online assessments to evaluate changes in participants' food- and nutrition- related behaviours (Stotz et al., 2019). Matete, Kimario & Behera (2023) have evaluated the use of three types of e-Learning, respectively text-driven, interactive, and simulation, in teacher education during COVID-19 in Africa. According with Everitt et al. (2022), in the areas of perinatal mental health and psychosocial, there were identified many innovative and diverse educational methods and strategies including face-to-face, online or blended learning that can be used to increase knowledge, skills and confidence of persons working in the nursing, midwifery and health disciplines.

Nowadays, in Romania, many universities use e-Learning platforms generally based on the Moodle-LMS platform or on the most popular collaborative educational platforms designed by Microsoft and Google. In the field of medical management, online learning programs are relatively new, appearing in postgraduate training programs and continuing professional education courses organized by software development companies. The National School of Public Health, Management and Professional Development, Bucharest (NSPHMPDB, 2023) conducts training courses to increase the effectiveness and efficiency of health services from the country, training courses in medical management, blended learning training techniques, by integrating online teaching tools into the specific activities of traditional education.

2.2 Ontologies in human resources management

Research on the use of ontologies in human resources management (HRM) has covered on different aspects. An ontological model that includes skills and occupations for e-recruitment systems needed to choose the right person for the job offered is presented in (Dorn, Naz & Pichlmair, 2007). The HRM ontology, which defines concepts such as competence, jobs and certain attributes of these concepts,

as well as the relationships between these concepts, can establish what competencies are required for a given job and what knowledge and experience are needed to reach a certain place, is described. A tool for representing knowledge in the corporate memory that guides the enterprise in the acquisition of capital is described in (Yelena & Probst, 2007).

Numerous studies and research attest to concerns in the realization of various IT systems based on ontologies in the healthcare field, such as the systems that provide access to interested parties to sources of medical data and knowledge belonging to an ontology (Ivanovic & Budimac, 2014); alert management system that helps managers integrate processes and handle events (Chiu et al., 2004); system that provides information exchange and communication in medical services using ontologies (Zeshan & Mohamad, 2012).

3. Study case: ontology-based e-Learning platform for managers of healthcare system in Romania

The e-Learning system is based on the ontologies models: the student model, the domain of interest model (HRM), and the learning process model, which play an important role in providing personalized training material. Modelling domain knowledge with ontologies is a key aspect of integrating information from different sources, supporting collaboration within virtual communities, as well as improving information retrieval. The prototype system offers learning techniques that ensure a structured organization of HRM knowledge, use, and retrieval of the necessary information, as well as new methods of data extraction from the web (Băjenaru, 2018; Băjenaru & Smeureanu, 2018).

3.1 The system ontology

In the ontology development process, respectively in the conceptualization phase, the information collected in the acquisition phase was organized and structured in a conceptual model that describes the identified solution. Concepts (terms) were identified, which define useful and potentially usable knowledge in the established field, as well as their meanings, which form the basis of a vocabulary of terms. Terms are represented by concepts, meanings, verbs, and properties; information about attributes or their values; information for the description of the concept itself; information related to the domain of knowledge, related attributes and constants. The Protégé-OWL environment was chosen for the development of the ontology (Horridge et al., 2011).

The classes identified are represented in the ontology developed using the Protégé environment as in Figure 1.

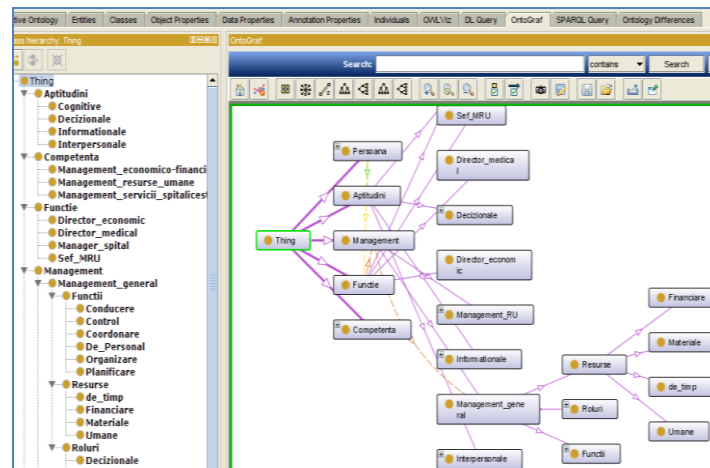


Figure 1. Graphical Representation of the Class Hierarchy of the System Ontology

In the left panel of the Protégé application, the concept hierarchy of the ontology is displayed in a tree, and in the right panel, the OntoGraf application provides a graphical representation of class and subclass hierarchies.

3.2 ONTO platform

To implement the e-Learning process in a real platform, an open-source web-based learning management system (LMS) was chosen. The e-Learning platform based on semantic web technology offers the necessary tools (e-Learning) to implement a new mechanism for obtaining relevant information from the Internet, offering the possibility of using the advantage offered by semantic web content and multimedia materials (materials in electronic format, links, images, animations, sound, movie, etc.). The e-Learning platform (ONTO) based on semantic web technology offers the necessary tools to implement a new mechanism for obtaining relevant information from the Internet, offering the possibility of using the advantage offered by semantic web content and multimedia materials sources (Băjenaru, 2018; Băjenaru & Smeureanu, 2018). Depending on the profile and function for which training is desired, the student will have access to the e-Learning platform, in order to obtain a personalized learning program based on a specific ontology, as well as to obtain bibliographies that meet their learning requirements.

In the following, the logical flow of actions offered by the prototype educational system for the acquisition of knowledge specific to a managerial function (position), by a student with higher medical education, who is training for the position of hospital manager, with the training level presented as advanced, visual/verbal learning style and other characteristics stored in his profile. According to the student profile and according to his training requirements, appropriate educational material is allocated, thus highlighting the personalization component of the prototype system. A training sequence, represented by specific

The student has logged into the platform based on a username and password received from the administrator and is accessing it for the first time. On the main page of the platform, a wizard-type sequence opens, which ultimately has the role of determining the optimal educational content, personalized for the student. After that, the student has access to the training section, after having authenticated and tested the learning style and to identify the initial level of knowledge for the position of hospital manager (Figures 2 and 3).

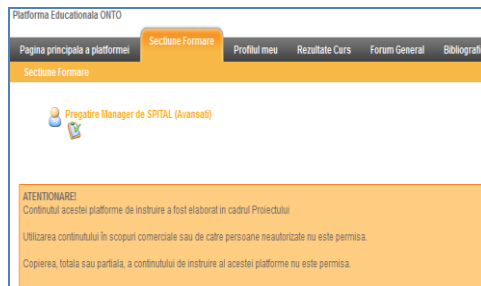


Figure 3. Training Section - Course Page

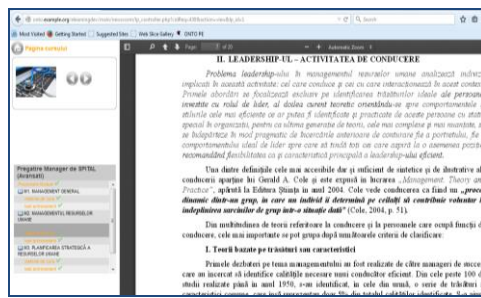


Figure 5. Lesson from a Course Module

4. Conclusion

The ontology-based e-Learning system aims to solve some limitations of e-Learning systems, related to the flexibility of the computer-assisted learning

process as well as to the promoted teaching methods, by offering new facilities for students, such as adaptive and personalized training process, the provision of educational material corresponding to the profile of each student. More flexible medical staff, having very good knowledge in various fields, with more skills and oriented towards teamwork, represent an essential component of a desired health system, which requires a new approach to the professional training of medical staff, respectively managers from the health field. The ONTO e-Learning system presented in this paper proposes an efficient method of improving the training system, by ensuring a learning process specific to each person, which corresponds to their profile and objectives, thus offering personalized educational content. The system contributes to increasing the performance, competence and evaluation capacity of medical management professionals.

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Use of Artificial Intelligence technologies in studying the phenomenon of electric current in physics education

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Abstract: *Utilizing software applications in Physics education to visualize and demonstrate various physical laws and phenomena is a crucial factor in achieving good learning results. The use of software tools with artificial intelligence further streamlines the learning process. This paper reviews suitable software applications for Physics instruction and shares practical experiences from teaching the topic of “Electric Current”. We used the Tinkercad application to model electric circuits and conduct experiments. Additionally, we present a practical strategy for employing the ChatGPT AI chatbot to assist students in self-training and coursework development.*

Keywords: Education, Electric current, Electrical circuit, Tinkercad, ChatGPT, Physics.

1. Introduction

Dynamically developing information technologies provide rich opportunities for the educational system, including the use of innovative technologies and software tools, through which learners can be more actively involved in the learning process. Adolescents are not only technologically literate; they are also deeply integrated with technology. This brings with it the need for the teacher to change the classic teaching approach and implement interactive methods and techniques that will attract the attention of students and help them study more easily (Raikova, 2016). The student must not only learn new knowledge but also be stimulated to engage in independent creative activities in which they can show their individual abilities (Milcheva, 2016). In order to stimulate the development of these skills and abilities, the teacher must be creative in teaching and engage learners through a variety of tasks and projects (Kirilova, 2023). They should aim to develop high-order thinking skills. As such, cognitive abilities are defined from the high levels of Bloom’s Taxonomy – analysis, synthesis, and evaluation (Bloom et al., 1956). They are important because they build qualities that help learners deal with complex life situations, analyse specific information, search for innovative solutions, generate ideas, etc.

With the advancement of information technology, teachers and students have more and more tools to visualize the studied objects, processes and phenomena – virtual laboratories, tools with built-in virtual reality, learning management systems, chatbots, software applications with artificial intelligence (AI), etc. The use of such tools in the learning process undoubtedly increases its quality.

2. Use of software applications in Physics education

There is a wide variety of software applications, including ones with AI, useful for organizing and conducting Physics lessons.

Smart Sparrow is a platform for adaptive and personalized learning (Smart Sparrow, 2023). It provides teachers with an intuitive authoring tool for creating learning resources and modeling adaptive pathways, where learning material can be adapted to the needs of each student. Teachers have real-time data analytics, accessible through the analytics dashboard, that reveal data about the learning process beyond the received grades. AI-driven algorithms monitor student progress and dynamically adapt learning materials to individual needs. The platform allows for integration with other educational software applications.

Squirrel AI Learning offers online extracurricular courses in subjects such as Math, English, Physics, and Chemistry (Squirrel AI, 2023). The project's goal is to provide each student with their own AI Super Teacher. The platform is powered by its proprietary AI-driven adaptive engine and custom-built courseware. It uses artificial intelligence algorithms to adapt the learning material to the needs of each student.

Another powerful tool for teaching Physics is Wolfram Alpha (Wolfram Alpha, 2023). With Wolfram Alpha, you can explore data on phenomena in the fields of Quantum Mechanics, Nuclear and Particle Physics, Thermodynamics, and Newtonian Mechanics. The application uses a variety of physical formulas and constants. It supports interactive calculators with which various physical phenomena can be studied easily and visually.

PhET provides interactive, research-based science and mathematics simulations (PhET, 2023). The simulations are designed to stimulate scientific skills by providing implicit guidance to students to conduct productive research. They visualize invisible phenomena, show visual mental models and different aspects of real-world processes through multiple representations, e.g. movement of objects, graphics, and numbers. At present, there are more than 100 simulations of physical experiments and phenomena. The simulations are open source and can be integrated into learning management systems with AI.

Teachers can use the Edpuzzle application for instructional purposes (Edpuzzle, 2023). It allows them to add interactive questions and remarks to video lessons on Physics. This motivates students to take an active part in the learning process, and stimulates their creativity and curiosity. Teachers receive real-time learning data analytics that helps them personalize their teaching and the assessment of students.

3. Interactive tasks in teaching Physics and Astronomy

The study subject "Physics and Astronomy" in Bulgaria is taught independently starting from the 7th grade. Until then, physical phenomena are studied within the combined subject "Man and Nature", which encompasses two natural sciences – Chemistry and Environmental Protection, as well as Biology and Health Education. The "Physics and Astronomy" curriculum aims for 7th graders to explore key aspects of "Electric Current", "Light and Sound", and "From the Atom to the Cosmos" within 54 class hours.

In the "Electric Current" section, knowledge about fundamental quantities and laws of electricity is acquired, which is further built upon during the high school stage. The effect of electric current on the human body and the measures for the safe use of electrical devices are examined. This educational material is more abstract and harder for students to perceive, so it's recommended to use visual aids to recreate specific learning situations. These aids enable students to develop their visual and auditory memory (Dimitrova, 2018). This, in turn, helps learners to successfully recall the information when encountering a situation similar to the one presented by the teacher.

Students can much more easily understand the situation with series and parallel connections of consumers in an electrical circuit when it is visually recreated through suitable software. Popular applications providing visual representation in physics and astronomy include Go-Lab (Go-Lab, 2023), PhET (PhET-2, 2023), Tinkercad (Tinkercad, 2023), and others. Go-Lab and PhET support a variety of different functionalities. They offer a laboratory environment not only related to electricity but also focused on light phenomena, the peculiarities of space, and so on. Unlike them, in Tinkercad, mainly the physical laws related to electricity can be demonstrated. Here, the teacher has a wider selection of elements for connecting in the electrical circuit, which is closer to real-life situations. This predisposes learners to be intrigued by this part of the curriculum and to learn things they can apply in their daily lives.

Tinkercad is a free application that provides multiple functionalities for modeling and experimenting with electrical phenomena and sample projects for educational purposes. Any teacher can create a virtual environment for students in a class to share educational resources, set assignments and track the progress of the students' work. In the learning process, students are given a variety of tasks related to the studied material. The aim is to develop learners' skills in applying their knowledge of electricity to new situations. The teacher demonstrates a solution to a specific task, then assigns a similar task for students to solve independently, allowing them the freedom to use different components.

Following the lessons on "Electric Current" and "Electric Voltage", students participate in two laboratory sessions. During these sessions, the teacher can intrigue the students by showing them through Tinkercad visually how to work

with electric circuits. Below are sample tasks used in the 7th-grade curriculum at the "Otets Paisiy" primary school. This school is located in the village of Topolovo, Bulgaria, and these tasks were utilized during the academic year 2022/2023.

Task 1. Make a model of an electrical circuit that contains a source of electrical energy with a voltage of 3V, a lamp as the consumer, and an ammeter.

1. How does the electric current in the circuit change when the applied voltage is doubled? Draw a conclusion about the relationship between voltage and electric current.
2. If the applied voltage is reduced by $\frac{1}{2}$ of the given value, by how much will the magnitude of the electric current be reduced?

The teacher presents the solution to the task as shown in Figure 1, then gives the students a similar task, but with the condition that they look for an alternative source of electrical energy. Examples of solutions include using a lemon or a potato, with students determining the appropriate electrical voltage for their solutions, as illustrated in Figure 2.

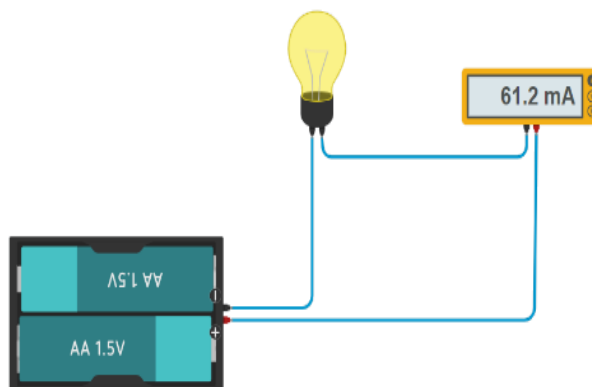


Figure 1. Electric circuit in Tinkercad with a power source, a lamp (consumer), and an ammeter

Task 2. Make a model of an electrical circuit that contains a source of electrical energy with a voltage of at least 3V, an electrical consumer, and a voltmeter.

Unlike the previous task where a voltmeter was not required, in this task, a voltmeter must be included in the circuit. Students should take into account that the two devices connect differently. They can experiment with various components in the circuit since the task specifies only the voltage value, which is also variable. The teacher can pose the following questions to the students:

1. How should the voltmeter be connected in the circuit to measure the correct voltage?
2. Determine if the voltage value will increase when you connect two equal-voltage electrical energy sources in series.

After studying the methods of connecting electrical sources and consumers, a more complex task can be introduced.

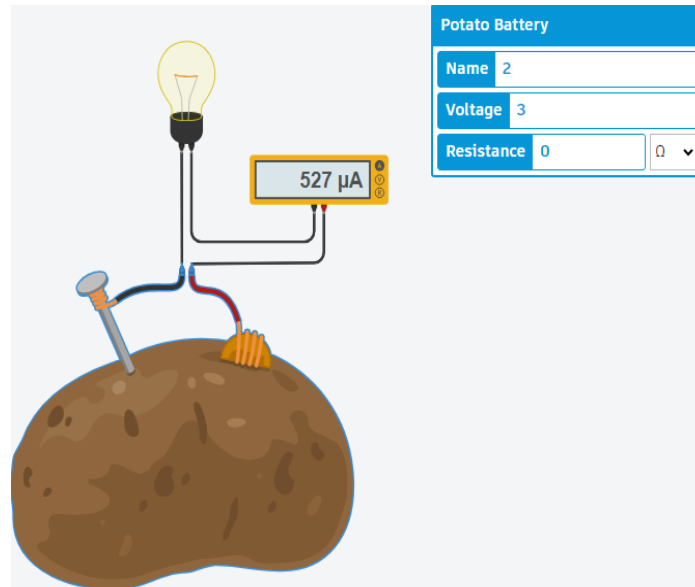


Figure 2. Exploring the potato's property as an electrical energy source in Tinkercad

Task 3. Make a model of an electric circuit with consumers connected in series. Prove the statement that when the electric circuit is interrupted, no electric current flows through either consumer.

1. What is the main difference between sequentially connected consumers and parallel connected ones?
2. Determine whether an electric current will flow if the circuit is broken between the two consumers.

In the third task, learners must apply their knowledge of electric circuit connections and visually demonstrate that when the current's path is interrupted, both consumers stop working.

Task 4. Make a model of an electric circuit with parallel connected consumers. Include at least three consumers.

In this task, students must consider the requirements for parallel connection and the number of consumers (Figure 3). It is appropriate to target them with the following questions:

1. Specify which type of connection of consumers is more suitable when building the electrical installation in a home?

2. Determine whether an electric current will flow if the circuit is broken between two of the consumers.

In their work, students may encounter difficulties of a different nature. They can use the ChatGPT artificial intelligence chatbot to resolve them on their own.

4. Using ChatGPT to support students

ChatGPT, developed by OpenAI, is an artificial intelligence chatbot (OpenAI, 2023). It not only can hold a conversation by successfully imitating a person but also perform more complex activities. These activities include generating ideas and explaining concepts (Lapuschin, 2023), composing works of art (Reich, 2022), writing code (Tung, 2023), and others.

ChatGPT can be used in training, but carefully, taking into account the fact that it is not always a reliable source of information. During Physics and Astronomy labs, students can use it to help them complete assignments.

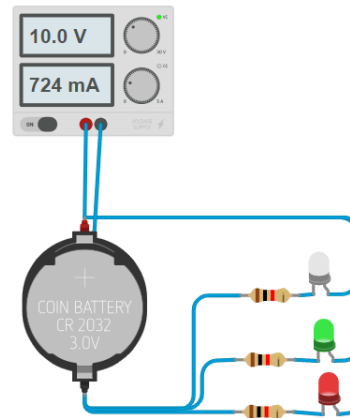


Figure 3. Electric circuit with 3 parallel connected consumers

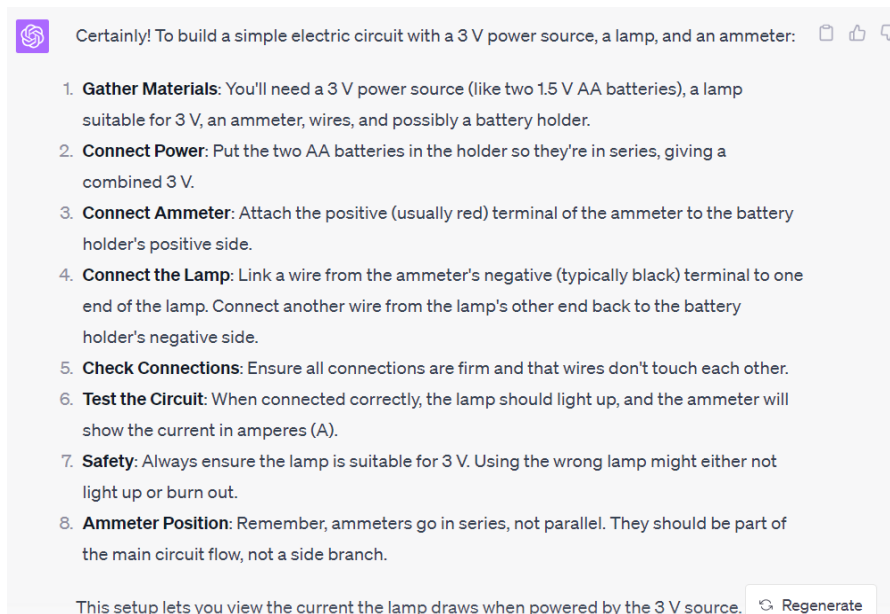


Figure 4. Question to ChatGPT and its answer, related to building a model of an electrical circuit

Students who are experiencing difficulties can use ChatGPT by asking appropriate questions related to completing tasks set by the teacher. For example, they can ask the following question on ChatGPT - "How to build a model of an electrical circuit that contains a 3V power source, a consumer (lamp), and an ammeter?". Part of ChatGPT's response is presented in Figure 4.

To find an answer to the questions posed or to test their knowledge, students can post a series of questions on ChatGPT, for example: "How will the value of the electric current in the circuit change if we increase the voltage twice?" (Figure 5), "Can I use fruits and vegetables as a source of electrical energy? Give me some examples of such fruits and vegetables." (Figure 6), etc. In general, ChatGPT gives very accurate and reasoned answers.

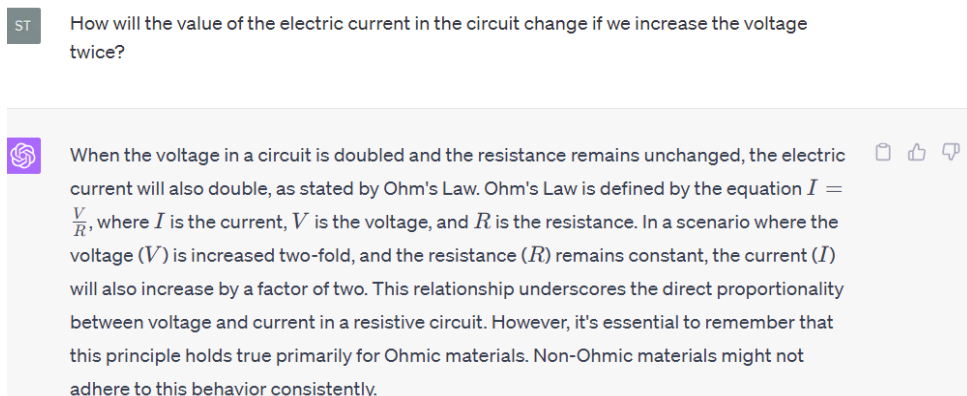


Figure 5. Question to ChatGPT – How will the value of the electric current in the circuit change if we increase the voltage twice?

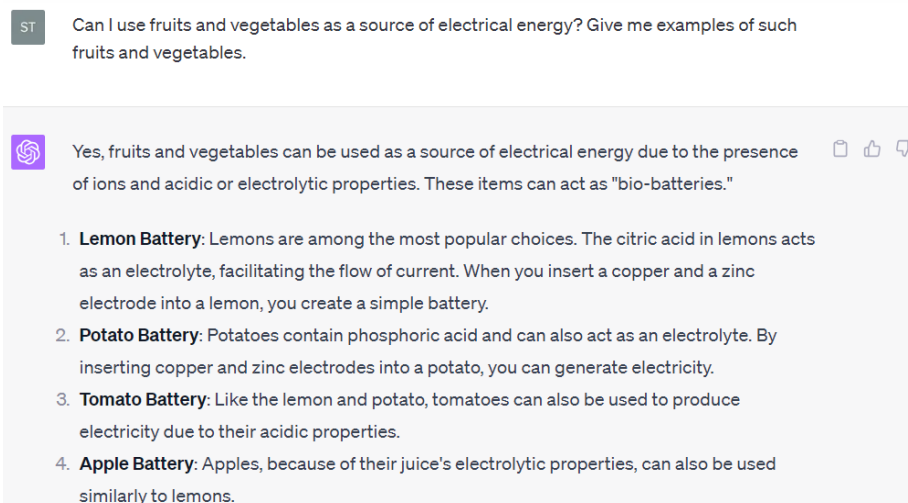


Figure 6. Question to ChatGPT about using alternative energy sources

5. ChatGPT – risks and limitations

The precision of the questions posed to ChatGPT is crucial for obtaining accurate answers. The model is sensitive to changes in question wording and may give different answers to slightly rephrased questions. For example, ChatGPT might not know the answer to a specific question but might respond correctly if the question is slightly altered. In cases where a user posts an ambiguous question, ChatGPT doesn't pose clarifying questions. Instead, it makes assumptions about the user's intent and provides a response accordingly (OpenAI, 2023).

ChatGPT often tends to be verbose and frequently uses certain phrases, emphasizing that it is a language model trained by OpenAI. In some cases, it might provide plausible-sounding but incorrect or nonsensical answers. Nevertheless, it has been successfully employed across various domains, such as learning foreign languages (Barrot, 2023), medical education (Currie, 2023), and rapid engineering (Short, 2023). To optimize the use of large language models in education, both educators and students should hone their competencies and literacies. This will enable them to better understand the technology, its limitations, and the unexpected vulnerabilities of such systems. Adopting a clear pedagogical approach, with an emphasis on critical thinking and fact-checking strategies, is essential (Kasneci, 2023).

For better or worse, AI chatbots are already visibly transforming modern education. Their benefits are undeniable – they assist teachers in creating learning content and act as online teachers by answering students' questions. The primary disadvantages include the potential for generating inaccurate or false data and the ability to bypass plagiarism detectors in situations where originality is paramount. To address the transformative effects of ChatGPT on the learning environment, educational institutions must take action (Gill, 2023). It's essential to educate both teachers and students about the opportunities and risks associated with using artificial intelligence. To ensure AI is employed responsibly and ethically in education, academic rules and regulations should be updated, specifying practices for its use and implementing stricter rules for intellectual property protection.

6. Conclusion

Education in Physics and Astronomy is important for the acquisition of fundamental knowledge about the evolution of our world and the universe. It enables students to develop observational and analytical thinking. The use of interactive methods motivates them to work actively and stimulates them to learn more easily. Such methods illustrate the practical applications of their knowledge, hone their ability to apply new insights in unfamiliar scenarios, and bolster their creativity and skills for conducting experiments.

The web-based application, Tinkercad, used for teaching 'Physics and Astronomy' subject in the 7th grade at 'Otets Paisiy' primary school in Topolovo village, has caused significant interest among the students. The experiments they

conducted, the questions they asked themselves, and the answers they found left them with lasting knowledge. This is evidenced by the good results of the conducted tests.

For more efficient work, students can also use ChatGPT artificial intelligence chatbot in their self-training. It can give ideas, look for answers to difficult questions, and detect mistakes. Considering the coming era of artificial intelligence, students must acquire a new skill – to "talk" with digital subjects by formulating their questions correctly and precisely. And of course... to remember that no one is perfect, including "Artificial Intelligence"!

Acknowledgment

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Survey on innovative web-based teaching/learning methods and smart technologies applied in the educational process in maritime higher education

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Abstract: *The development of smart technologies in recent years has had a significant impact on the maritime industry as well, allowing the improvement of operational efficiency, the increase of safety, the reduction of costs, and environmental impact. A particularly important element is the alignment of maritime higher education with technological evolution through the continuous improvement of study programs and their continuous correlation with the current requirements of the labor market in the maritime industry. The article presents the results of the evaluative research study on innovative web-based teaching and learning methods and intelligent technologies applied to students from the master's programs of the "Mircea cel Bătrân" Naval Academy. The study has three directions and the results provide the guidelines for improving the educational process in the maritime higher education institutions, to approach technological evolution, and to provide students with the skills and knowledge needed to use smart technologies within the maritime industry.*

Keywords: Innovative web-based teaching/learning methods, Intelligent teaching/learning technologies, Maritime Higher Education.

1. Introduction

Smart technologies are constantly evolving and developing, improving operational efficiency, increasing safety, reducing costs and environmental impact. Economic and industrial competition in the maritime field requires the implementation of intelligent technologies at the company level and the preparation of human capital for their use.

The article presents a scientific research study, regarding the perception of students from the master programs of the "Mircea cel Bătrân" Naval Academy (MBNA) regarding the implementation of innovative methods, the use of tools based on intelligent technologies to improve the education process, and the perception regarding how to involvement of the maritime industry in the training of students. The study was carried out within the project "Romanian-Norwegian Strategic Cooperation in Maritime Higher Education for the Improvement of

Human Capital and the Knowledge Base in the Field of Marine Intelligent Technologies", financed by the SEE Grants program 2014-2021 (Marintech, 2021).

The innovative methods and tools, based on ICT and web technology (simulation, web communication platforms, dedicated software, videos, etc.) were largely implemented within MBNA, with the transition of education from the classical system to the online one, during Covid-19 (Avram & Coşofreţ, 2020). During this period, the university's web platform was the main teaching/learning/assessment tool, allowing students to remotely access teaching resources, participate in online courses and assessments, and communicate with each other and with teachers (Dumbraveanu & Peca, 2022).

Simulation learning is an increasingly used method in naval higher education. It allows the learner to access a virtual environment similar to the real one, being able to simulate real processes within the maritime industry, with the help of smart technologies such as Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) (DNV, 2021).

Another innovative method under study is learning by inquiry. This method uses both innovative teaching/learning methods (TLM) and tools and especially intelligent technologies, such as collection, analysis, and database modeling technologies (machine learning, intelligent sensors, data provision websites, specialized modeling software, etc.), robotics technologies, and autonomous marine vehicles, etc. This method is successfully implemented within the Norwegian University of Science and Technology (NTNU) at the level of bachelor's, master's, and doctoral studies. The results of applying this method are highlighted by increasing the research level of the university and by increasing the involvement of companies in the education process (Wu, et al., 2023). In the implementation of this method, the university has an important role in attracting students to these projects and by identifying companies to participate in research programs, by proposing research topics, supervising and participating in the research stages, and also by financing them. Correspondingly, with a view to involving beneficiaries from the industry in the education process is the development of a web platform, through which communication is carried out between actors in the labor market and the university environment (teachers, students). Through this platform, the beneficiaries contribute to the updating of the curriculum, the implementation of new technologies, propose research topics, request students to carry out cadetship practice, etc. Such a platform is developed at the level of MBNA and NTNU, within the Marintech project (Virtual Learning Platform, 2022).

2. Research method

The target group of the research is the first-year students of the master's programs: "Oceanography and Hydrography" (O&H) and "Naval Electromechanical Systems" (NES). For the analysis of respondents' answers, the evaluative

and cross-sectional research method was chosen. The opinion poll was chosen as the data collection method, the polling technique being the electronic poll. The survey tool used for data collection was the anonymous questionnaire, made with the help of the Google Forms program. The data collection period was: 17.03-03.04.2023. The study participant sample of 48 students is representative of the target group population (52 students), with an admitted error of $\pm 5\%$ and a confidence level of 95%; (Pomohaci & Pârlea, 2008). The stratification of the collected data was carried out on two categories of respondents, namely on the two master's study programs.

The percentage participation of students on the two layers is 24% from O&H and 76% from NES. Statistical techniques for measuring the intensity of students' perception were used for data analysis: mean and standard deviation (data variability within the sample of respondents) and minimum and maximum Likert scales (Cardinal & Aitken, 2013). Four degrees of intensity measurement on the Likert scale were used in the study: Not at all-1, To a small extent-2, To a moderate extent-3 and, To a great extent-4. To compare the responses of the two categories of respondents in the study, the methods of simple ANOVA analysis of variance, Fisher test (F), and Bonferroni t-test were used.

3. Perception of innovative Teaching/Learning Methods and instruments

Any TLM and tool have advantages and disadvantages, as well as the fact that each student involved in the assessment process has his own perception of them, depending on the skills and experiences acquired in the education process (Burlacu, 2020). The study aims to evaluate innovative TLMs and tools in relation to classical ones.

The statistical analysis of the respondent's perception of the innovative methods under study is presented in Table 1.

The answers of the respondents reveal, according to the average values, that both categories of respondents have an above-average position for the use of innovative methods. It is noted that the simulation method is the most agreed upon by the respondents (3.64), and the students from the O&H appreciate it as the main method of teaching/learning (3.77). Compared to the innovative methods, the classical method is appreciated the least by both categories of respondents (3.12 – students from NEC and 3.33 from O&H). No significant differences are found between the two categories of students.

Table 1. Students' Perception of TLMs

TLM	Mean	Std.dev.	Master's students		F	Sign. dif.
			O&H N=9	NES N=39		
Simulation	3.64	0.52	3.77	3.61	0.69	No

Discovery	3.60	0.57	3.66	3.59	0.12	No
Experimental	3.58	0.57	3.55	3.59	0.02	No
Classically	3.16	0.83	3.33	3.12	0.43	No

The statistical analysis of the perception of the two groups of respondents on innovative teaching tools is presented in Table 2.

Table 2. Students' Perception of Teaching Tools

Teaching tools	Mean	Std.dev.	Master's students		F	Sign. dif.
			O&H N=9	NES N=39		
Whiteboard	2.95	0.898	3.000	2.949	0.023	No
PowerPoint	3.354	0.699	3.111	3.410	1.348	Yes
Prezi	2.979	0.812	2.889	3	0.134	No
Videoclips	3.583	0.577	3.556	3.590	0.025	No
Interactive software	3.646	0.526	3.889	3.590	2.442	Yes

From the analysis of the averages of the five teaching tools, the use of videos (3.58) and interactive software (3.64) stands out in preference to teaching on the blackboard and with the help of "PowerPoint" and Prezi. From the comparison of the answers of the 2 groups, significant differences can be observed in the use of "PowerPoint" and interactive software: the students from O&H value "PowerPoint" less (3.11) than those from the NES, valuing interactive software more (3.88). The analysis regarding the use of tools for the use of didactic resources in the learning process is presented in Table 3. The most appreciated tool, by both categories of respondents, is the university's web platform (mean 3.72). Also, resources provided on sites with didactic content and those with didactic videos are appreciated, there being no significant differences between the appreciation of both categories of students.

Resources provided by AI-based information sites (2.72) and those from the university library (2.60) are perceived as below average by both categories of respondents.

Table 3. Learning Tools Students' Perception

Teaching tools	Mean	Std. dev.	Master's students		F	Sign. dif.
			O&H N=9	NES N=39		
University's Web Platform	3.72	0.49	3.77	3.71	0.10	No
University Library	2.60	1.10	3	2.51	1.43	Yes
Videoclips	3.41	0.73	3.55	3.38	0.38	No
Educational Sites	3.41	0.71	3.44	3.41	0.01	No
Educational Software	3.22	0.77	3.77	3.10	6.09	Yes
Artificial Intelligence Sites	2.72	1.12	3.22	2.61	2.18	Yes

4. Perception of the use of smart technologies

Smart technologies are increasingly used in both industry and education (Kiryakova, 2020). Table 4 presents three broad categories of smart technologies that have been analyzed.

Table 4. Smart Technologies Use Students' Perception

Teaching intelligent technologies	Mean	Std. dev.	Master's Students		F	Sign. dif.
			O. & H N=9	NES N=39		
AR and VR	3.56	0.74	3.66	3.53	0.21	No
Database analysis and modeling	3.60	0.61	3.66	3.59	0.09	No
Data collection	3.58	0.68	3.77	3.54	0.86	Yes

It can be seen that both categories of respondents appreciate above average the use of augmented reality (AR) and virtual reality (VR) in the educational process, as well as data collection, analysis, and modeling technologies, such as machine learning. A difference in perception is observed regarding the given collection technologies namely, the students of O&H in relation to those of NES because the former use these technologies more in their field (mean 3.77 versus 3.54).

5. The perception of the beneficiaries' involvement in the education process

Six proposed activities were subjected to the study to find the involvement of beneficiaries from the maritime industry (Figure 1). The most appreciated activity, by both categories of respondents, is the development of a web platform for achieving communication between companies and the university environment (3.71), even though there is a significant difference indicated by the Bonferroni t-test ($F=1.31$). Also, the other activities proposed for evaluation are valued above average by both categories of students. Among these, the involvement of companies in research projects (3.63), the development of mentoring programs in which professionals are mentors for students, and the development of internship programs (3.60) stand out.

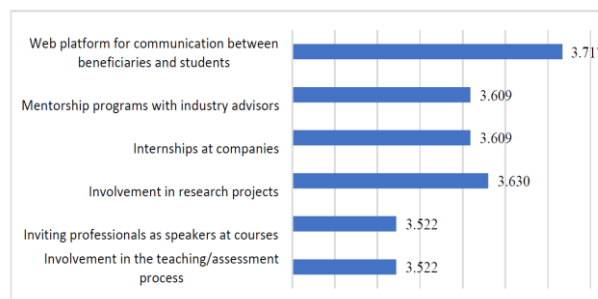


Figure 1. Students' Perception

6. Conclusions

As a result of the analysis, it can be concluded:

- The most suitable innovative TLMs for maritime postgraduate education are the methods of simulation and research that provide both competencies in the field studied and in the adjacent ones and competencies in the use of scientific web resources.
- Students prefer the use of videos, interactive software and tools that use web sources during teaching.
- Didactic learning resources are primarily provided by the university's web platform, but also by sites with didactic videos and those with didactic content. Sites based on artificial intelligence (e.g. GPT chat) and resources provided by the university library are less used by students.
- All respondents consider the use of the following intelligent technologies appropriate: augmented reality (AR), virtual reality (VR), database analysis and modeling technologies, and intelligent data collection technologies.
- Most students consider the involvement of maritime industry beneficiaries very useful in the education process, through the development of a web platform for communication between the university environment and maritime industry beneficiaries, the participation of students in research projects, the development of mentoring programs with professional mentors from the industry, as well as the organization of internships within specialized companies.

Thus, it is concluded that the marine higher education system to offer specific skills, by implementing innovative methods and tools based mainly on the web, and on intelligent technologies in the field in order to be efficient and adapted to the current market requirements. Also, the involvement of beneficiaries in the training of students is important both for the permanent updating of the curriculum to the demands of the labor market and for the development of research within the universities.

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Developing and improving the digital competences of students – future teachers

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Abstract: *In the modern digital world, people have to possess new competencies that allow them to be active and successful members of the society. This imposes new requirements on the education and training of adolescents. Innovative information and communication technologies, a connected network of smart devices are implemented to create a smart learning environment. Teachers need knowledge, skills and competences to carry out, manage and integrate effectively different digital tools in the learning process. The strict restrictions imposed during the Covid-19 pandemic and the shift to online learning proved to be a powerful catalyst for using the full potential of digital technologies in education. During the pandemic, digital competencies were critical to the success of both learners and educators.*

The existing frameworks and models of digital competences and the corresponding toolkits are aimed at establishing the level of existence of teachers' digital competences. The relevant questions that arise are related to how to ensure the formation, development and improvement of teachers' professional digital competences. How to achieve the desired level of a given type of competence, what targeted educational activities should be carried out in the training of students - future teachers to develop all important digital competences? The aim of the current article is to make a short review of the existing frameworks of teachers' digital competencies and outline a framework and system of educational activities for their development and enhancement during students' university education. The system of training activities should be embedded in the curriculum of pedagogical specialties in order to prepare specialists who are capable of teaching the digital generation of learners.

Keywords: Development of digital competences, System of educational activities, Future teachers.

1. Introduction

Modern society is building a digital world that is based on the use of innovative Information and communication technologies (ICT) and the connected network of smart devices and strives to become a smart society. To be active and successful members of such a society, people need suitable digital competences. Some of the digital skills are formed through the daily use of digital technologies in various activities. For shaping the required digital competences, specific training

activities are necessary. This imposes new requirements on the education and the training of adolescents. In order to adapt the educational system to the needs of the digital generation learners, ICT are applied to create the necessary learning environments. To be able to manage such environments teachers need knowledge and appropriate digital skills and competences.

Digitization of education is a goal for a long time, but it was approached with slow steps in certain aspects. The strict restrictions and isolation imposed during the Covid-19 pandemic and the shift to online learning proved to be a powerful catalyst for harnessing the full potential of digital technologies in education. The pandemic has tested teachers' digital competence as well as that of students. A number of studies have highlighted the stress of teachers during the transition to distance learning (Guillén-Gámez et al., 2022). Digital competencies have proven to be extremely important to the success of both learners and educators. It turned out that in pandemic situation, without the necessary digital competence of teachers and students, the learning process would be extremely difficult, even impossible.

Today's learners and teachers use different devices and software in their daily lives, including in the learning activities. The question is, are they being used effectively to achieve educational goals? In our digital society, digital literacy is not enough for teachers. They have to possess specific digital competence in order to be good educators of the digital generation of learners. The digital competence refers to a wide range of competences related to the use of digital technologies, not just technical skills and ability to use specific tools (Instefjord, 2015). Teachers need competencies for using digital technologies for organizing and implementing all stages of the learning process, working together with their colleagues in both educational and administrative activities. They have to be able to use digital channels and media for communication and interaction with other subjects in the educational process. At the same time, they are responsible and have to be able to support the development of learners' digital competencies.

The rapid development of digital technologies gives rise to a new problem related to the better digital preparation of students – future teachers. Usually, the curriculum provides separate courses for working with ICT and their integration into the educational process. Their purpose is to help students to acquire basic skills they need to work with digital tools. These skills will help them in developing and using digital learning content and learning activities. In ICT courses, the focus is on building students' confidence and positive attitudes towards using digital resources in teaching and learning and developing the necessary skills to work with them (Falloon, 2020). The question is, is such training sufficient to form the necessary digital competencies in students – future teachers and prepare them for the pedagogical practice? There is no unambiguous answer to this question. Future teachers need not only skills how to use digital technologies and devices, but also they must be taught how to implement them in teaching and learning to achieve the learning objectives as well as how to support the

development of digital skills in their students. The formation of the necessary competencies for working in a digital learning environment can be achieved through targeted training activities.

The aim of the current article is to outline a system of educational activities for development and enhancement of students' digital competencies during their university education. The system of learning activities should be embedded in the curriculum of pedagogical specialties in order to prepare educators who are capable to train the digital generation of learners.

2. Reference frameworks of digital competences

The concepts of digital competence are evolving and changing, since there is a rapid development and penetration of new digital technologies, as well as changes in attitudes and the ways people are using them. According to Janssen (Janssen et al., 2013), digital competence is beyond the skills to use digital devices and applications and includes comprehension of the role of ICT and knowledge about legal and ethical aspects, privacy and security. Ferrari (Ferrari, 2012) views digital competence as a collection of knowledge, skills and attitudes that people need to be able to work in a digital environment. In a context of education, Instefjord (Instefjord, 2015) defines digital competence as a set of knowledge, skills and attitudes that allow people to use digital technologies critically and reflectively for building new knowledge.

At the global and European level, models and frameworks of digital competences are being developed. They describe the key knowledge, skills and competences that each member of the information society needs to be fully and actively integrated. The current priority in this area is to train teachers how to use the full potential of digital technologies to improve teaching and learning and to ensure that students are adequately prepared to live and work in a digital society. Many countries are developing or revising frameworks, self-assessment tools, and training programs to guide teachers' education and the acquisition of the digital competencies they need (Redecker, 2017).

The European Commission has developed a **Reference framework for key competences for lifelong learning** known as Recommendation on key competences for lifelong learning. The framework includes 8 key competences and each of them combines 3 elements – knowledge, skills and attitudes. One of the key competences is *Digital competence*. The basic idea of Digital competence was that people had to know how to use Information technologies (IT) for learning, working and social activities. They have to possess basic skill to find and manage information using computers and communicate and collaborate via services of global network Internet (Sahin, Akbasli & Yelken, 2010). Nowadays, digital competence “includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity),

intellectual property related questions, problem solving and critical thinking“.
(European Commission, 2019).

A **European Framework for Citizens' Digital Competence (DigComp)** is another framework developed by the the European Commission. The framework upgrades the ideas of the digital competence set out in the Reference framework for key competences for lifelong learning. DigComp presents the vision of the competencies that people need to answer to the challenges posed by the digitalization of society (Vuorikari, Kluzer & Punie, 2022). DigComp includes five areas of competence *Information literacy, Communication and collaboration, Digital content creation, Safety and Problem Solving*. The framework has 21 competences with respective levels of mastery. The citizens can test and determine their level of digital competence using an online tool.

The **European Framework for Educators' Digital Competence (DigCompEdu)** is a science-based framework that sets out the specific digital competences for educators in order to respond to rapidly changing demands and the need of innovations in education. DigCompEdu describes specific digital competencies for educators organized into 6 areas: *Professional engagement, Digital resources, Teaching and learning, Assessment, Empowering learners and Supporting learners' digital competences* (Redecker, 2017; Caena & Redecker, 2019; Cabero-Almenara, et al., 2020). There are 6 mastery levels of the competencies – from Newcomer (A1) to Pioneer (C2) and they are cumulative – each subsequent level includes the competencies from the previous ones (Redecker, 2017). The European Framework for Teachers' Digital Competence has been used as a basis for the development of a self-assessment tool (online questionnaire) – DigCompEdu CheckIn.

The **UNESCO ICT Competency Framework for Teachers (ICT CFT)** was developed by UNESCO and is used as a tool to guide the pre- and in-service training of teachers on the use of ICT in education. It also includes sample activities through which these competencies can be developed. The framework includes 18 competences, which are organized according to the 6 aspects of teachers' professional practice and 3 levels of teachers' pedagogical use of ICT (UNESCO, 2018). The aspects of a teacher's professional practice are: *Understanding the role of ICT in education policy, Curriculum and assessment, Pedagogy, Application of digital skills, Organization and administration and Teacher professional learning*. The levels of teachers' pedagogical use of ICT are: *acquiring knowledge* about the use of technology and basic ICT competences, *knowledge deepening* where teachers acquire ICT competences that enable them to provide learning environments and *knowledge creation* where teachers acquire competences to create a learning environment that encourages students to create new knowledge.

In Bulgaria, a **Regulation on the state requirements for acquiring the professional qualification "teacher"** states that the subject "Information and

communication technologies in education and work in a digital environment" is a mandatory subject in the curriculum. In the same regulation, it is indicated that among the elective disciplines, which support the development of the competencies necessary for teaching profession, it is desirable to include subjects such as "Digital competence and digital creativity" and "Development of lessons for learning in an electronic environment" (MON, 2021). The regulation describes in detail the groups of competences that teachers in the various professional qualifications must possess. The groups that are relevant to digital competences are *Educational environment*, *Pedagogical interaction with children*, *Working with parents and family community*, *Educational work*, *Work in a multicultural and inclusive environment and Teaching* (MON, 2021).

3. Developing and improving the digital competences of students – future teachers

There are many frameworks that define what digital competences citizens and educators should possess as well as various instruments to measure them. But providing future teachers with the necessary competences to integrate digital technologies into their future classrooms remains a challenge for teachers' education programs worldwide (Insteffjord, 2015). The specific training activities that support formation and development of digital competences during the training of students are not sufficiently described.

It is necessary to design a system of specific educational activities for the development of students' digital competences, so they can be successful in their pedagogical practice. The digital competences are shaped as a result of integrating various learning activities in different courses. Acquiring theoretical knowledge in the field of ICT and digital skills and applying them in various context in different academic disciplines will ensure the formation of digital competencies in future educators and development of abilities to improve them. At the same time, future teachers will build confidence to support the formation of digital competences in the students they teach.

Educational activities through which the digital competences of students – future teachers can be developed are systematized and summarized in 3 groups.

3.1 Professional interaction with subjects in the educational process

During their training, students can use digital technologies to interact with their colleagues, teachers and administrative staff (Table 1). They have to:

- acquire the necessary skills for working in a digital environment;
- know how to choose the most appropriate channels and means for providing information and making contacts;
- be able to work collaboratively with other people in professional context.

Table 1. Educational activities for developing competences in the field Professional interaction with subjects in the educational process

Educational activities
<p>Work in a cloud environment and use of cloud services that support collaboration and interaction:</p> <ul style="list-style-type: none"> • organizing and managing groups or teams; • communicating via group emails or discussion forums; • organizing and managing events in shared calendars; • coordinating meetings and inviting users to them.
<p>Work with systems for video and web conferences:</p> <ul style="list-style-type: none"> • organizing meetings and inviting users; • giving presentations; • sharing screens; • organizing work in small teams; • recording meetings.
<p>Creation of groups in various social and professional networks and conducting communication and collaboration in them.</p>
<p>Collaboration on various project activities by using cloud office packages:</p> <ul style="list-style-type: none"> • creating and using shared documents, folders and drives; • tracking history of document changes; • using chats and comments during collaboration.

3.2 Creating and working with digital learning resources

The use of existing digital resources and the creation of new ones is among the main activities that future educators will carry out (Table 2). They have to:

- know how to use digital resources for learning purposes;
- know to adapt existing digital resources to specific learners' needs;
- be able to create digital learning resources using different tools.

Table 2. Educational activities for developing competences in the field Creation and work with digital learning resources

Educational activities
<p>Use of existing digital resources (with an emphasis on free access materials) in the preparation of assignment or essay on a given topic:</p> <ul style="list-style-type: none"> • searching for digital resources; • developing criteria for comparison and evaluation of the resources; • checking the authenticity of the resources; • using resources in consideration of the copyrights and licenses under which they are distributed.
<p>Use of existing digital resources (with an emphasis on open access materials) in</p>

Educational activities
preparation and development of a curriculum lesson: <ul style="list-style-type: none"> • searching for digital resources; • adapting digital resources to particular educational goals; • adapting digital resources to the educational needs and characteristics of the learners, including for those with special educational needs.
Use of appropriate software tools for the development of own learning resources: <ul style="list-style-type: none"> • identifying appropriate software tools; • training for working with software tools; • creating learning content.
Creation of text documents, presentations, images, audio and video materials, animations, 3D models, augmented and virtual reality projects on given curriculum topics to be used as learning resources.
Creation of interactive learning content using h5p technology.
Creation of digital learning resources in collaboration with other students using cloud services, blogs, wiki systems, discussion forums, social networks and media.
Work with websites: <ul style="list-style-type: none"> • publishing educational content; • developing own websites via different tools.
Create question banks on given topics from the learning content, quizzes and exam tasks with various software tools.

3.3 Teaching activities

The main teachers' professional duties involve teaching and assessing (Table 3). They have to:

- know when and how to use digital resources and tools in learning;
- be able to organize teaching, learning and assessing in a digital environment.

Table 3. Educational activities for developing competences in the field
Teaching activities

Educational activities
Development of learning activities based on the use of digital technologies, which include both individual and collaborative activities in groups (teams): <ul style="list-style-type: none"> • creating a teacher's blog and students' blogs; • creating an educational content in wiki systems; • organizing collaborative work with workshops.
Use of interactive learning activities with active participation of learners: <ul style="list-style-type: none"> • using mobile educational apps; • using activities with gamification elements.

Educational activities
Use of interactive whiteboards, 3D pens, educational robots, Augmented and Virtual reality glasses and head-mounted devices.
Create directional and positive feedback to assessment learning activities in different forms – text comments, audio and video comments or resources, hyperlinks.
Use of digital technologies (spreadsheet software or statistical software) for: <ul style="list-style-type: none"> • analyzing accumulated data on learners' performance and outcomes; • detecting trends and patterns; • visual representating accumulated data.
Create branches in learning content in order to provide an individual and personalized path of knowledge acquisition.

At the present moment, the specified learning activities are applied independently in the training of students from Faculty of Education at Trakia University – Stara Zagora, in different IT courses of curriculum, without being coordinated and linked to each other. To support the development of the digital competences in future teachers, it is needful to organize all activities in a complete system. They have to be coordinated with other educational and creative activities, arranged in a logical sequence and purposefully implemented.

The proposed educational and learning activities can be implemented and automated in a digital environment by using Learning Management Systems (LMS). In addition, LMS Moodle allows teachers to apply frameworks for evaluating students' competencies (Moodle Documentation, 2021). The competency framework in Moodle is an organized collection of competencies (Moodle Documentation, 2021; Titus Learning). The process of applying the competency framework includes: 1) creating the framework and adding competencies; 2) connecting the competency framework to specific electronic courses; 3) connecting the competencies to specific learning activities in the electronic course (it is possible to map more than one competency to a given activity).

4. Future tasks

The designing and structuring of a complete system of specific learning activities and analysing the expected results are the purpose of a scientific project "Development and improvement of the digital competences of students – future teachers" at the Faculty of Education in Trakia University – Stara Zagora. The main goal of the project is to develop and improve the digital competencies of students – future teachers through a system of educational activities. The research hypothesis is that the construction of an accurate profile of necessary digital competences of students – future teachers and the design of a system of specific educational activities will support effectively the development of students' digital competences. The construction of an accurate profile of the necessary digital

competences of future teachers is possible by studying the existing competence frameworks and surveying the opinion of principals and teachers. Based on the results, the necessary educational activities, their logical sequence and interconnection in a single system will be determined and can be used purposefully in the training of future teachers.

5. Conclusion

In the modern world, people need new competencies that will allow them to be active and successful members of the digital society. The development of society invariably leads to the emergence of new jobs. It is not easy to predict what kind of knowledge and skills they will require, but it is certain that digital competences will play a key role in any profession. The COVID-19 pandemic has given an impetus to the digitization in the field of education. The new situation has reinforced the opinion that new generation of learners need to be educated in a completely different way, not by applying traditional teaching and learning methods transferred to a digital environment. The transformation of education in accordance to the new reality requires all participants in the learning process to have the necessary digital competencies. Teachers need specific digital competencies that will allow them to organize and implement an effective training method, professional interaction with their colleagues and professional development. Their education has to include purposefully use of specific educational activities, based on the digital technologies in order to develop and improve their digital competences.

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Metacognition and self-assessment in informatics classes: exploring the impact of assessment criteria, motivation, and task complexity

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Abstract: *Metacognition and self-assessment are important in learning and cognitive development. Metacognition, the awareness and understanding of one's cognitive processes, plays a crucial factor in enhancing learning and performance by enabling students to understand how they think, plan, and monitor their thinking strategies. Self-assessment allows students to become more effective, independent, and adaptable learners.*

This research focuses on exploring the role of metacognition in the context of informatics classes, particularly aiming at self-assessment techniques. The study investigates the correlation between metacognitive awareness and self-assessment, as well as the influence of motivation, task complexity, and assessment criteria on metacognitive processes. Data was collected through a survey of 72 high school students in Chisinau, the Republic of Moldova. The results demonstrate a significant improvement in metacognitive strategies and self-assessment practices, emphasizing the importance of fostering metacognitive skills in informatics education. The study proposes evidence-based recommendations for teachers to enhance metacognition and self-assessment practices, leading to improved learning outcomes and academic achievements in informatics.

Keywords: Metacognition, Self-assessment, Metacognitive Strategies, Assessment Criteria, Motivation.

1. Introduction

Metacognition is a key concept in cognitive psychology and education, referring to the awareness and understanding of one's cognitive processes. It involves reflecting on one's thinking, knowledge of how the mind operates, and the capacity to monitor, control, and regulate cognitive activities. The concept of metacognition gained attention as a distinct research focus in the early 1970s, although educators and psychologists had observed the underlying knowledge and skills for many years. The theoretical contributions of James, Piaget, and Vygotsky established the foundation for this concept. Flavell and Wellman (1975), American psychologists, provided an initial definition of metacognition as "cognition about a

type of human activity" (p. 5), which is associated with social cognition. He categorizes metacognitive knowledge into three types: knowledge of personal variables, task variables, and strategy variables. Further, research on metacognition has expanded, encompassing increasingly broader areas. Researchers commonly employ various working definitions of metacognition and its specific components. These components include reflection on one's thinking (Azevedo, 2020; Rodgers, 2002; Topping, 2018), self-regulated learning (Chytry & Medova, 2022; Drigas & Mitsea, 2021; Rican, Yong & Sokumaran, 2023), critical thinking (Ku & Ho, 2010; Rivas, Saiz & Ossa, 2022; Angelelli et al., 2023), problem-solving (Gick, 1986; Fyfe, Borriello & Merrick, 2023; Renkl & Atkinson, 2003), mindfulness (Daniel et al., 2023; Hirshberg et al., 2020), goal setting (Chang et al., 2018; Vieira & Grantham, 2011), self-assessment (Gutu, 2022a; Wong & Taras 2022; Wride, 2017), and more others. Overall, metacognition encompasses a wide range of concepts within educational research, with a focus on practical implications and applications across various aspects of the learning process. By promoting academic achievement and personal growth, metacognition plays a significant role in education.

Metacognition and self-assessment are closely interconnected in the realm of learning and cognitive processes. Metacognition refers to the higher-order cognitive process of thinking about thinking. It involves being aware of one's own thoughts, knowledge, and learning strategies. It encompasses various activities such as planning, monitoring, and evaluating one's learning experiences. Essentially, metacognition allows students to become active and reflective learners, enabling them to make informed decisions about how to approach different learning tasks and adapt their strategies based on their understanding of the material.

Self-assessment, the factors that affect data processing (Drigas & Mitsea, 2021), within the context of metacognition, is the act of evaluating one's knowledge, skills, and performance. It involves critically reflecting on one's learning progress and outcomes. By engaging in self-assessment, students utilize their metacognitive abilities to assess their level of understanding, identify areas of strength and weakness, and set meaningful learning goals. Through self-assessment, students gain insights into their learning processes and can adjust their strategies to improve their learning outcomes. Thus, self-assessment can serve as a formative assessment tool, allowing teachers to determine students' performance and estimate their learning progress (Gutu, 2023).

The connection between self-assessment and metacognition is evident in how they reinforce and support each other. Engaging in self-assessment requires metacognitive awareness, as students need to be able to accurately monitor and evaluate their performance. On the other hand, self-assessment enhances metacognitive skills by encouraging students to think critically about their learning approaches and adapt their strategies accordingly.

Moreover, self-assessment helps students become more independent learners, as they learn to take control of their learning and make informed decisions

about their studies (Gutu, 2022a). It fosters a deeper understanding of one's strengths and weaknesses, allowing students to focus on areas that need improvement. Additionally, self-assessment promotes a growth mindset, where students see challenges as opportunities for growth and continuous improvement.

Furthermore, self-assessment is an essential element of the metacognitive process. According to Gutu (2022), self-assessment empowers students to become more effective, independent, and adaptable learners, ultimately leading to enhanced academic achievement and lifelong learning success.

Therefore, this research aims to delve into the profound impact of metacognition in informatics classes and its influence on learning outcomes and performance, with a particular emphasis on the utilization of self-assessment techniques. The purpose is to explore how students' awareness and regulation of their cognitive processes shape their learning experiences in the context of informatics. By investigating this intricate relationship, the study endeavours to identify and uncover effective strategies and tools that can effectively enhance metacognitive skills among informatics students. This includes examining the diverse metacognitive processes, such as self-reflection, self-monitoring, and self-assessment, and their specific role in improving learning outcomes and performance in the Informatics. Through a comprehensive analysis, the study aims to contribute valuable insights to optimize metacognitive skills among informatics students. Consequently, it aims to enhance academic achievements in the informatics discipline and promote a varied understanding of the importance of Informatics in everyday life.

2. Methodology

In the realm of education, understanding the factors that contribute to effective learning outcomes has always been a focal point of research. In the context of informatics classes, where students are exposed to complex and dynamic challenges, the role of metacognitive awareness (Jaleel & P., 2016) and self-assessment (Gutu, 2022a) becomes increasingly significant. The study seeks to explore and uncover the correlation between metacognition, self-assessment, and various factors that influence the learning experience in informatics education. It was conducted during one academic semester (January - May 2023) in the Informatics classes at Lyceum "Vasile Vasilache" in Chisinau, the Republic of Moldova. The Informatics subjects are structured into both mandatory modules and optional modules for each academic year (Gutu, 2022a).

The first objective of this study is to delve into the relationship between metacognitive awareness and self-assessment in informatics classes. It entails an investigation into how students' awareness of their cognitive processes influences their ability to assess accurately their learning progress and performance.

The second objective is to identify the impact of students' engagement,

motivation, and self-regulated learning on metacognitive processes within the context of the informatics discipline.

The third objective aims to explore how students adapt their metacognitive approaches when faced with tasks of varying levels of difficulty or complexity in informatics classes. Understanding how students tackle challenges of different complexities will enable us to make informed recommendations on tailoring instructional methods to enhance metacognition for specific tasks.

The fourth objective focuses on evaluating the effectiveness of assessment criteria in fostering metacognition and self-assessment in informatics classes. Efforts have been made to understand how students' comprehension of assessment standards influences their ability to critically evaluate their performance and identify areas for improvement. This insight will be instrumental in refining assessment practices to better support metacognitive development.

Finally, the fifth objective of this study is to propose evidence-based recommendations for teachers and educational institutions to enhance metacognition and self-assessment practices in informatics classes. By drawing on the findings from the preceding objectives, we aspire to provide actionable insights for teachers to foster a more effective and self-directed learning experience for students. These recommendations will contribute to the continuous improvement of informatics education and empower students to become proficient and confident learners.

Building upon the study objectives, several hypotheses have been developed to investigate rigorously the relationships between various variables in informatics education as follows:

Hypothesis 1: There is a significant positive relationship between metacognitive awareness and self-assessment among students in informatics classes.

Hypothesis 2: Motivation significantly affects students' metacognitive processes and self-assessment practices in informatics classes, with higher levels of motivation leading to more effective metacognition and self-assessment.

Hypothesis 3: Learning task complexity significantly affects students' metacognitive strategies and self-assessment accuracy in informatics classes, with higher complexity tasks leading to more adaptive metacognitive approaches.

Hypothesis 4: The assessment criteria significantly affect students' metacognitive awareness and accuracy in self-assessment in informatics classes, with well-defined assessment criteria leading to improved metacognition and self-assessment practices.

Metacognition encompasses a range of cognitive processes that facilitate self-awareness, self-regulation, and self-directed learning. Consequently, the research is focused on the following three metacognitive processes such as self-reflection, self-monitoring and self-assessment. Self-reflection is a metacognitive

process (Azevedo, 2020) that involves introspection and critical examination of one's cognitive processes, knowledge, and experiences. It requires students to engage in a thoughtful analysis of their thoughts, engagements, and learning outcomes. Through self-reflection, students can gain a deeper understanding of their strengths and weaknesses, identify areas for improvement, and recognize patterns or preferences in their thinking. This introspective process encourages students to evaluate their learning strategies, set meaningful goals, and make knowledgeable decisions about future learning accomplishments.

Self-monitoring is another essential metacognitive process (Yong & Sokumaran, 2023) that entails the continuous observation and evaluation of one's cognitive processes during a learning task. It involves being actively aware of own attention, comprehension, and progress about the task. By engaging in self-monitoring, students can identify potential gaps in their understanding, detect errors or misconceptions, and regulate their learning strategies accordingly (Wirth & Leutner, 2008). This ongoing monitoring allows students to adapt their approaches, redirect their attention, and seek clarification or additional resources when necessary.

Self-assessment is a metacognitive process that involves evaluating and judging one's learning outcomes and performance (Wride, 2017). It enables students to critically analyze the quality, accuracy and effectiveness of their work. Through self-assessment, students can assess the extent to which their learning objectives have been achieved, assess the appropriateness of their strategies, and recognize areas where further improvement is needed (Gutu, 2022a). By engaging in this reflection process, students obtain valuable feedback, provided by the teacher or the student alone, by reflecting on the task completed by him/her in accordance with the assessment criteria, which can inform future learning efforts and help them to improve metacognitive strategies. Moreover, analyzing grading against the assessment criteria and specific student work also establishes a meaningful dialogue between students and teachers (Wong & Taras, 2022).

These metacognitive processes are interdependent and mutually reinforcing, as each process informs and influences the others. Self-reflection initiates the metacognitive cycle by encouraging students to engage in introspection and analysis, leading to a heightened awareness of their cognitive processes. This awareness then facilitates self-monitoring, enabling students to actively observe and regulate their thinking during a learning task. Finally, self-assessment completes the cycle by allowing students to assess the outcomes of their efforts and make decisions about future learning goals.

The teacher can facilitate the development of these metacognitive skills by providing opportunities for reflection, promoting self-monitoring practices, and fostering a culture of constructive self-assessment within educational settings. Certainly, the essential role of guiding the students in the learning process belongs to the teacher. Therefore, the application of metacognitive processes requires the

involvement of well-established criteria provided by teachers or students for each task. In addition, a diverse range of tutorials, encompassing text-based, video-based, presentation-based, and podcast-based formats, should be available for each topic, created or selected by the teacher and delivered to students. These tutorials have to provide diverse levels of difficulty and complexity, adapting to students' learning styles. Additionally, a comprehensive set of learning strategies should be designed to align with each student's identified learning styles.

Moreover, an essential feature in triggering metacognitive processes in students is their awareness and understanding of their learning style. Understanding own learning style is an essential aspect of metacognition because it allows students to recognize how they best absorb and process information. By recognizing their learning style, students can tailor their study techniques to align with their strengths. This self-awareness empowers students to choose learning methods that resonate with them, making the learning process more enjoyable and effective. Furthermore, students can become more effective and autonomous learners, empowering them to achieve better academic results and fostering a lifelong love for learning.

Significantly, the application of learning style questionnaires in schools for students is highly beneficial in understanding individual learning preferences and tailoring instruction accordingly (Gutu, 2022b). Therefore, in the case of this research, it was selected three widely recognized learning style questionnaires that can be used in schools: the Index of Learning Styles Questionnaire, the Honey and Mumford Learning Styles Questionnaire, and the Learning Style Inventory Questionnaire. The application of these learning style questionnaires in schools enables teachers to gain insights into students' preferred learning styles. By incorporating this knowledge into their teaching practices, teachers can create a more inclusive and engaging learning environment, ensuring that instruction aligns with students' individual preferences and maximizing their learning outcomes.

Another essential factor in fostering metacognitive processes involves offering students a compilation of metacognitive methods and strategies. In the context of this experiment, the following metacognitive strategies were provided as follows: Self-Assessment, Goal Setting, Think-Aloud Technique, Learning Journals, Concept Mapping, Breakdown of Complex Problems, Peer Discussions and Feedback, Error Analysis, Time Management, Regular Reviews, Scaffolding, Conceptual Questions, Visualization and Analogies, Learning Reflections, Self-Explanation, Mindful Learning, Use of Study Tools, Collaborative Learning, Celebrate Progress, Revision Strategies, Growth Mindset, and more. To make these strategies visible, they were integrated with the proposed tasks, whether in the classroom or outside of it. The selection of strategies was based on the specific activity to be taught, the student's learning style, the level of information acquisition, prior knowledge, engagement, monitoring, and motivation. Additionally, it was implemented flipped classroom strategy and transmedia learning activities (Gutu, 2019) for fostering self-reflection, self-monitoring, and self-assessment.

3. Results

In order to contextualize the findings, in this study, the survey method was employed to investigate how assessment criteria, student motivation, and task complexity influence metacognitive processes. The survey method was employed to collect data from 72 high school students (33 students from the humanistic profile and 39 students from the science profile), utilizing a questionnaire consisting of 32 questions categorized into four sections. The sections include "Metacognitive Awareness and Self-Assessment in Informatics Classes", "Motivation and Metacognitive Processes in Informatics Classes", "Learning Task Complexity and Metacognitive Strategies in Informatics Classes", and "Assessment Criteria and Metacognitive Awareness in Self-Assessment". Each section comprises eight questions (See Table 1 for details). The questionnaire items were formulated using a combination of Likert Scale and Rating Scale. Pre-test and post-test data were collected. A five-point scale was utilized for responding to the questions, with one denoting strong disagreement, two indicating disagreement, three representing weak agreement, four signifying agreement, and five representing strong agreement. The questionnaire was designed to gather anonymous and voluntary feedback from the students.

Table 1. Questionnaire Items and Categories

No	The questionnaire Items and Sections
<i>Section 1. Metacognitive Awareness and Self-Assessment in Informatics Classes</i>	
1.	I am aware of the strategies I use to solve problems in informatics.
2.	I reflect on my informatics learning experiences to improve my future performance.
3.	I struggle to evaluate objectively the quality of my informatics assignments.
4.	I am confident in my ability to assess my understanding of informatics concepts accurately.
5.	My self-assessment of my informatics skills aligns with external feedback (e.g., grades, teacher feedback, and classmate's feedback).
6.	I regularly review my self-assessment and adjust my learning strategies.
7.	I am aware of my learning and actively participate in self-assessment activities.
8.	I actively monitor my understanding of informatics concepts during learning activities.
<i>Section 2. Motivation and Metacognitive Processes in Informatics Classes</i>	
1.	I am motivated to excel in my informatics studies.
2.	I am interested in pursuing a career related to informatics.
3.	I am fearless in seeking help when I encounter difficulties with informatics topics.
4.	I actively seek to understand complex informatics concepts.
5.	I believe that my efforts and persistence will lead to better learning outcomes.

6.	I set specific goals to enhance my understanding of informatics topics.
7.	I am engaged in informatics self-assessment activities because they are personally meaningful to me.
8.	I am willing to put in extra effort to improve my informatics learning.
<i>Section 3. Learning Task Complexity and Metacognitive Strategies in Informatics Classes</i>	
1.	I use different metacognitive strategies when facing complex informatics tasks.
2.	I find it challenging to self-assess my performance in highly complex informatics tasks.
3.	I can assess accurately my performance on highly complex learning tasks.
4.	I am confident in my ability to identify effective metacognitive strategies for different levels of task complexity.
5.	I believe that metacognitive strategies are crucial for succeeding in Informatics tasks of varying complexities.
6.	It takes me more time than usual to reflect on my understanding when dealing with complex informatics concepts.
7.	I adjust my learning approaches based on the complexity of informatics assignments.
8.	I think the accuracy of my self-assessment on complex learning tasks improves with experience and practice.
<i>Section 4. Assessment Criteria and Metacognitive Awareness in Self-Assessment</i>	
1.	The assessment criteria provided by teachers influence my metacognitive awareness while working on learning tasks.
2.	Well-defined assessment criteria help me understand what is expected in my informatics assignments/evaluations.
3.	Clear and specific assessment criteria help me evaluate my achievements more easily, leading to more accurate self-assessments over time.
4.	I actively consider the assessment criteria while assessing my performance in the informatics tasks.
5.	Clear assessment criteria help me identify areas of improvement and areas where I excel in my learning tasks.
6.	I adjust my self-assessment process based on the provided assessment criteria.
7.	I am confident in applying metacognitive strategies effectively when the assessment criteria are ambiguous or undefined.
8.	Transparent and well-communicated assessment criteria contribute to a fair and reliable self-assessment process.

The first section (Hypothesis 1) of the questionnaire (Table 1) focused on exploring the level of metacognitive awareness among students and its influence on self-assessment in the Informatics classes. Based on the provided data for Hypothesis 1 (science profile) and using a paired two-sample t-test for means, the analysis reveals that the p-value (0.000183968) is significantly less than 0.05. Therefore, these results indicate a significant difference between the means of the

pre-test and post-test scores for Hypothesis 1 (science profile). The post-test mean is higher than the pre-test mean (see Table 2), which affirms a definite improvement in the variable being measured. Moreover, the analysis of the data for Hypothesis 1 (humanistic profile), similarly shows a significant difference between the means of the pre-test and post-test scores (see Table 3) and the p-value (0.000019527) is significantly less than 0.05.

Table 2. Paired Two Sample t-Test Results - Science Profile

	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4
Pre-test Mean	2.804487179	2.910256410	2.858974358	3.663461538
Post-test Mean	3.041666667	3.150641025	3.019230769	3.923076923
p-value	0.000183968	0.000019527	0.001371241	0.000209954

Table 3. Paired Two Sample t-Test Results - Humanistic Profile

	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4
Pre-test Mean	2.541666667	2.674242424	2.518939393	3.530303030
Post-test Mean	2.825757576	2.931818181	2.704545454	3.803030303
p-value	0.000019527	0.000007920	0.000131879	0.000025771

The second section of the questionnaire (Table 1) delved into the interaction between student motivation and metacognitive processes within the context of informatics classes. Based on the provided data for Hypothesis 2, science profile (Table 2), and humanistic profile (Table 3), the analysis reveals that the post-test mean is higher than the pre-test mean for both profiles, suggesting an improvement in the variable being measured. Furthermore, both p-values are significantly less than 0.05, indicating an improvement in metacognitive processes and self-assessment practices. This provides evidence in favour of Hypothesis 2, suggesting that higher motivation levels are associated with more effective metacognition and self-assessment.

The third section of the questionnaire (Table 1) aimed to investigate the effect of learning task complexity on students' metacognitive strategies. The analysis of the data for Hypothesis 3, in both the science profile (Table 2) and humanistic profile (Table 3), indicates that the post-test mean surpasses the pre-test mean, indicating an improvement in the measured variable. Moreover, both p-values are considerably less than 0.05, further supporting these findings. The data demonstrates that the post-test mean is higher than the pre-test mean, which suggests an improvement in metacognitive strategies and self-assessment accuracy. This supports Hypothesis 3, indicating that learning task complexity influences metacognitive approaches.

The fourth and final section of the questionnaire (Table 1) examined the correlation between assessment criteria and metacognitive awareness in the context of self-assessment. The examination of the data for Hypothesis 4, in both the science profile (Table 2) and humanistic profile (Table 3), reveals that the post-test mean exceeds the pre-test mean, indicating a noticeable improvement in the

measured variable. Additionally, both p-values are markedly less than 0.05, suggesting improvement in metacognitive awareness and self-assessment accuracy. The data unmistakably illustrates that the post-test mean is higher than the pre-test mean, thereby confirming hypothesis 4.

Completely, both analyses indicate a significant difference between the means of the pre-test and post-test scores for Hypothesis 1 in both the humanistic and science profiles. In both cases, the post-test means are higher than the pre-test means, suggesting an improvement in the variables being measured for both groups. The strong positive correlations between the pre-test and post-test scores further support this finding.

In the overall analysis of the average increased points per hypothesis for both the Science Profile and Humanistic Profile, as depicted in Figure 1, it is evident that both profiles exhibit an overall positive trend in the average increased points for each hypothesis. The results suggest noteworthy improvements in students' metacognitive strategies and self-assessment practices across the hypotheses in both profiles. These findings highlight the effectiveness of the interventions and the importance of fostering metacognitive skills and self-assessment practices in informatics classes, regardless of the profile. These improvements are likely to contribute to better learning outcomes and academic success for students in these classes.

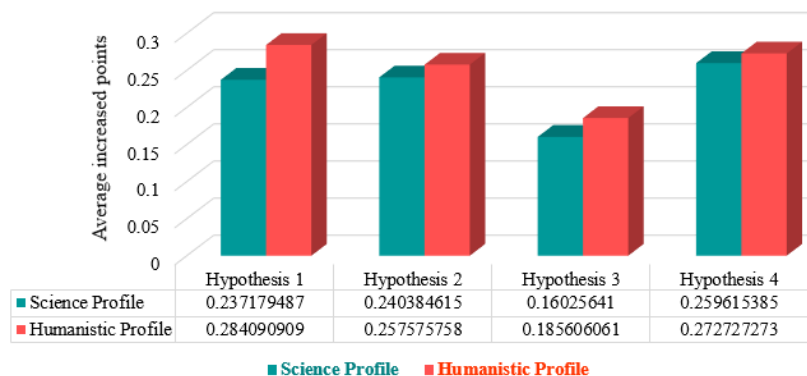


Figure 1. Average Increased Points per Hypothesis

Additionally, a comprehensive questionnaire was distributed to gather students' perspectives, aiming to acquire detailed information, insights, and opinions on various aspects of metacognitive processes, self-assessment, assessment criteria, motivation, and handling complex learning tasks within informatics classes. The primary goal was to design and refine the future teaching-learning approach to cater to the specific needs of the students.

The questionnaire comprised 17 questions and was voluntarily completed by students who actively participated in the effort to improve the teaching-learning approach. It gathered well-motivated and coherent responses, which offered

valuable insights into various aspects related to academic performance and the learning experience in Informatics classes. Nonetheless, it is important to note that some answers were vague, biased, or lacked clarity and meaning.

Conducting a qualitative analysis of the distributed questionnaire and the collected answers has provided us with a profound understanding of the influence of metacognition strategies and self-assessment on students' outcomes. These valuable insights will be significant in improving teaching practices, learning activities, and curriculum development in the Informatics classes. Consequently, the analysis of the collected answers is presented on a per-question basis, as outlined below:

1. Have you noticed any changes in your academic performance in the Informatics discipline since becoming more aware of metacognitive strategies? If yes, please write about it.

Students generally agreed that metacognitive strategies positively influenced their academic performance in the Informatics. They expressed that being more aware of these strategies led to improvements in their learning approach and understanding of the subject matter.

2. Which metacognitive strategies do you find most effective in improving your learning and problem-solving? You can choose multiple options. Journaling; Setting clear goals and objectives; Monitoring your understanding and progress; Using specific learning techniques (e.g., summarization, self-questioning); Seeking help or guidance when faced with difficulties; Taking breaks and allowing time for reflection; Using metacognitive apps or tools; Seeking feedback from others (e.g., friends, parents, teachers); Other (please specify).

The most commonly mentioned effective metacognitive strategies were journaling, seeking help/guidance when faced with difficulties, and goal setting. Students appreciated the benefits of journaling, which helped them reflect on their progress and solidify their understanding. Setting clear goals was seen as essential for staying focused and motivated throughout their studies. Seeking help or guidance when faced with difficulties helps them to overcome difficulties and reach their full potential. Additionally, students mentioned other metacognitive strategies, including time management, revising and reviewing, peer teaching, self-assessment, and scaffolding learning.

3. When faced with challenging tasks in your informatics classes, how do you apply metacognitive strategies to regulate your learning process and make informed decisions? Please describe the steps you take and any particular metacognitive techniques you find most helpful.

When facing challenging tasks in Informatics, students relied on metacognitive strategies to overcome obstacles. Breaking down complex problems into smaller parts and seeking help from teachers, peers, or online communities were common approaches mentioned by students.

4. Are you comfortable with self-assessment in your informatics classes?
Not at all comfortable; Slightly comfortable; Moderately comfortable;
Very comfortable; Extremely comfortable.

The students varied in their comfort level with self-assessment. While most felt moderately or highly comfortable with it, a few students were at the extremes, either not comfortable at all or exceptionally comfortable with the self-assessment process.

5. Have you noticed any significant changes in your self-assessment accuracy over time? If yes, what factors do you attribute these changes to?

Students reported improvements in their self-assessment accuracy. Regular practice and feedback from teachers were cited as contributing factors to this growth.

6. Can you identify any specific instances where self-assessment has played a significant role in improving your understanding of the subject matter and academic performance?

Self-assessment was identified as a key factor in improving academic performance. Students shared how evaluating their work against assessment criteria helped them identify strengths and weaknesses, leading to targeted improvements.

7. When you receive feedback on your academic work, how do you use metacognitive strategies to reflect on the assessment criteria and understand where you met or missed the expected standards?

Students used metacognitive strategies to analyze feedback on their academic work. They emphasized the importance of aligning feedback with assessment criteria to gain insights into their performance and identify areas for improvement.

8. Can you provide examples of how metacognitive awareness has influenced the way you interpret feedback, make adjustments in your subsequent work, and continuously improve your performance in alignment with the assessment criteria?

Metacognitive awareness significantly influenced students' interpretation of feedback. They expressed how aligning feedback with assessment criteria allowed them to make meaningful adjustments in subsequent work, leading to continuous improvement. Most of the examples provided were taken from programming modules, thus suggesting that the topics covered in these modules are the ones causing the most concern among students.

9. When faced with project-based learning or complex tasks, how do you engage in setting your assessment criteria to guide your self-assessment process?

Some students considered their learning process by establishing their assessment criteria, based on a clear understanding of the project requirements. They highlighted the importance of breaking down complex tasks into smaller

components and creating distinct assessment criteria for each one. Whereas other students acknowledged seeking support from their peers, teachers, or online communities to accomplish the task.

10. How has the practice of setting personal assessment criteria influenced your learning outcomes and overall academic performance?

Students emphasized that establishing personalized assessment criteria had a positive impact on their learning outcomes. This motivation prompted them to assume responsibility for their learning process and actively pursue a comprehensive understanding of the subject matter. While some students found it challenging to establish personal assessment criteria, they recognized that doing so made accomplishing tasks easier and facilitated a deeper understanding of the topic compared to using the criteria provided by teachers.

11. What factors contribute most to your motivation? You can choose multiple options. Intrinsic factors (e.g., personal interest, enjoyment); Extrinsic factors (e.g., rewards, recognition); Support from others (e.g., family, friends, teachers, classmates); Clear and achievable goals; Previous success experiences; Assessment criteria given by the teacher; Other (please specify).

On this particular question, we couldn't get clarity since nearly all students selected all the bullet points from the provided list. This entails that the teachers have to consider all these factors during the teaching-learning process.

12. How does your motivation change after engaging in self-assessment and identifying areas for improvement? Becomes more focused and determined; Remains the same; Decreases slightly; Decreases significantly; Not applicable (I haven't noticed any change).

Engaging in self-assessment consistently motivated participants to improve. Most of the students confirmed that they became more focused and determined in their work.

13. Can you share examples of how being motivated has influenced your ability to plan, monitor, and regulate your learning strategies effectively?

Students highlighted that motivation significantly influenced their learning strategies, e.g. planning their study, seeking additional resources, and dedicating sufficient time and effort to achieve their academic goals. They also noted that when motivated, they were able to work for extended periods and felt satisfaction with the outcomes they attained. The majority of the provided examples were related to project-based learning, case studies, problem-solving, or complex tasks.

14. Reflecting on your informatics learning experiences, can you identify any specific factors that have consistently motivated you to engage in metacognitive processes and self-regulated learning?

Students expressed a consistent motivation to engage in metacognitive

processes and self-regulated learning due to their desire to excel academically and thrive in the field of informatics. The most frequently mentioned factor was the involvement of technology in all areas of daily life, and the students regarded this discipline as highly significant. However, there were also some contradictions in the responses; a few students mentioned that they do not find the relevance of studying informatics because they consider what they learn in the informatics classes is not significant.

15. How often do you encounter learning tasks that you find challenging or complex? (Very Often; Often; Sometimes; Rarely; Never.)

The analysis of the responses to the question revealed a broad spectrum of answers. Most participants selected options ranging from "often" to "rarely," indicating that they encountered challenging or complex learning tasks with varying frequency. Specifically, five students chose "very often," while two students opted for "never." The majority of responses fell within the categories of "often," "sometimes," and "rarely".

16. In your opinion, do the complexity levels of learning tasks align well with the assessment criteria used to evaluate your performance? Yes, perfectly; Yes, to some extent; I am not sure; No, not really; No, not at all.

The analysis of responses to the question indicates that the majority of students expressed satisfaction with the alignment between the complexity levels of learning tasks and the assessment criteria. Specifically, most students chose the option "Yes, perfectly," indicating a strong agreement with the suitability of the assessment criteria. Only a few students selected the option "Yes, to some extent," suggesting a moderate level of alignment for this group. Notably, none of the students were uncertain about the alignment ("I'm not sure"), and no students chose the options "No, not really" or "No, not at all".

17. Do you have any additional comments or suggestions regarding the complexity of learning tasks and the assessment criteria?

Students perceived challenging tasks as opportunities for personal growth. These tasks encouraged critical thinking, the development of problem-solving skills, and the expansion of their knowledge in informatics. Some students mentioned that providing more explicit assessment criteria for learning tasks could enhance their understanding. Additionally, others recommended that teachers offer more guidance on the complexity of tasks and the underlying rationale behind the assessment criteria.

In conclusion, the qualitative analysis of the distributed questionnaire revealed that metacognitive strategies, self-assessment, and motivation played crucial roles in shaping students' academic performance in the Informatics. The insights provided by the students highlighted the significance of incorporating metacognitive strategies and fostering a supportive learning environment in Informatics education.

4. Recommendations

Metacognition is a fundamental concept in cognitive psychology and education, influencing learning outcomes and academic achievements. This research has demonstrated the significant impact of metacognition on informatics education, particularly in terms of self-assessment practices. By examining the relationship between metacognitive awareness and self-assessment, as well as the role of motivation, task complexity, and assessment criteria, the study offers valuable insights for teachers.

The results indicate that fostering metacognitive skills through self-assessment positively influences students' learning experiences in informatics classes. The findings support the notion that metacognitive processes enhance students' abilities to understand, monitor, and regulate their cognitive activities, leading to improved learning outcomes and performance.

Based on the confirming hypotheses that demonstrate a strong correlation between metacognitive processes, self-assessment, assessment criteria, motivation, and complex learning tasks in informatics classes, along with the findings from the additional questionnaire, we present evidence-based recommendations for teachers and educational institutions to enhance metacognition and self-assessment practices:

1. **Promote Metacognitive Strategies in the Curriculum:** Educational institutions should integrate metacognitive strategies, such as self-assessment, into the curriculum. Providing students with tools and guidance to develop metacognitive skills will empower them to take a more active role in their learning process and improve their understanding of complex concepts.
2. **Offer Metacognitive Training for Students:** Conduct workshops or training sessions on metacognitive strategies for students. These sessions can help students understand the benefits of metacognition and how to apply these strategies effectively in their studies.
3. **Provide Feedback on Metacognitive Practices:** Teachers should provide feedback on students' metacognitive practices, encouraging them to refine their approach. Constructive feedback can further enhance students' metacognitive skills and foster continuous improvement.
4. **Cultivate a Culture of Self-Assessment:** Encourage students to engage in self-assessment regularly. Schools and teachers can guide students on how to critically evaluate their work and provide opportunities for self-assessment as part of the learning process.
5. **Offer Training on Objective Self-Assessment:** Provide training to students on objective self-assessment techniques. Teaching them how to overcome biases and accurately evaluate their work will lead to more meaningful self-assessment outcomes.

6. **Strengthen the Feedback Process:** Teachers should provide timely and constructive feedback on students' academic work. Clear and specific feedback, aligned with assessment criteria, will help students understand their strengths and areas for improvement.
7. **Enhance Student Motivation:** Schools should recognize and celebrate students' achievements in Informatics, fostering intrinsic motivation. Additionally, teachers and parents can provide continuous support and encouragement to maintain students' motivation to excel.
8. **Personalized Learning:** Encourage students to set their assessment criteria for project-based learning and complex tasks. This personalized approach will empower students to take control of their learning and pursue a comprehensive understanding of the subject.
9. **Offer Challenging Learning Opportunities:** Provide students with challenging learning tasks that require critical thinking and problem-solving skills. These tasks can serve as opportunities for intellectual growth and deeper comprehension of the subject.
10. **Foster Open Communication:** Create an environment where students feel comfortable discussing their academic challenges and seeking help when needed. Encouraging open communication between students and teachers can enhance the learning experience and support system.
11. **Align Learning Tasks with Assessment Criteria:** Ensure that learning tasks align clearly with assessment criteria. Providing explicit explanations of the alignment will enhance students' understanding of the evaluation process and promote a fair assessment.
12. **Continuous Professional Development for Teachers:** Offer continuous professional development opportunities for teachers to enhance their understanding of metacognitive strategies, self-assessment techniques, and motivational techniques. Well-trained teachers are more capable of providing better support to students in their academic endeavours.
13. **Advantage Technology for Self-Assessment:** Explore the use of technology tools and platforms that facilitate self-assessment and peer assessment. Digital platforms can provide students with immediate feedback and aid in self-reflection.
14. **Create Learning Communities:** Foster learning communities where students can collaborate and support each other. Peer-to-peer interactions can enhance metacognitive skills and motivation through knowledge sharing and encouragement.

By implementing these evidence-based recommendations, teachers and educational institutions can foster a culture of metacognition and self-assessment in classes, leading to improved learning outcomes and student success.

5. Conclusion

The study highlights the importance of metacognition in education and its potential to enhance students' academic achievements and personal growth. By integrating metacognitive training, tailoring instructional methods to individual learning styles and providing a variety of metacognitive strategies, teachers can create a more effective and self-directed learning environment for students. Furthermore, by nurturing metacognitive skills in informatics classes, teachers can empower students to become proficient and confident learners, preparing them for success in their academic and professional pursuits. However, further research and investigations are warranted to delve deeper into the underlying factors and potential variations across different educational contexts.

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A cyber security mass education perspective

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Abstract: *Cyber security education is extremely important for a digital society. The research aims to identify some benchmarks and formulate some proposals for the realization of an adequate mass education in the field of cyber security.*

Keywords: Cyber security, Mass education, Education through entertainment.

1. Introduction

Ensuring cyber security is a major concern for any digital society. In the view of the President of Romania, Klaus Iohannis, the new organizational models of the educational system must be able to respond to the majority of contemporary social changes (President of Romania, 2018).

Romania's first cyber security strategy (2013) established a series of objectives for the protection of cyber infrastructures belonging to governmental, public and private institutions (H.G. no. 271/2013). In 2021, the new strategy aims to increase the level of resilience and the formation of a solid culture of population security (Government of Romania, 2022).

Our research aims to identify some benchmarks and formulate some proposals for the realization of an adequate education in the field of cyber security.

2. Critical analysis of the state of national cyber security

The last few years have seen a staggering evolution of cyber threats (Zamfiroiu, 2022) on the Internet. Malware, IoT malware and cryptojacking, ransomware, as well as AI and quantum attacks, supported by new languages and powerful platforms, have enabled an expansion of cyber-attack tactics forcing specialists to identify advanced solutions for an infrastructure to be prepared to bear and to revitalize them.

Specialized structures continuously monitor and systematically publish analyses of all identified cyber threats. Specialists at SonicWall Capture Labs pointed out that ransomware threats have grown at an annual rate of 21%, of which Ransomware-as-a-Service (RaaS) is the most present.

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The Network and Information Security (NIS) Directive on cyber security (revised), adopted in July 2016, allowed many European states to replace their existing legislation to facilitate cyber risk management and created the framework for forming a cooperative network for mutual learning based on best practices (EUR-Lex, 2016).

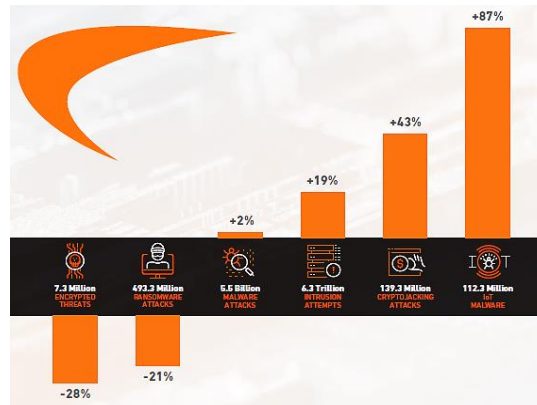


Figure 1. Cyber threat analysis for the year 2022 (SonicWall, 2023)

In order to ensure a state of normality in the cyber space, Romania proposes the establishment and operationalization of a National Cyber Security System (Government, 2022). According to GEO no. 104/2021, the National Cyber Security Directorate was established, which took over the duties of CERT-RO and can face, dynamically, the challenges in the field of cyber security through efficient, flexible and proactive mechanisms, procedures and capabilities (Government of Romania, GEO no. 104/2021).

A strong support of cybersecurity innovation and research is achieved through the establishment of the European Cybersecurity Competence Center as the authority responsible for managing EU funds for the adoption of cybersecurity work programmes. (GSG, 2021).

With the launch of Russia's Special Operation on Ukraine (2022), cyber threats have diversified. Their convergence with electronic warfare has made it easy for phishing attacks to move out of the spam e-mail realm of the Internet into products applicable to any social communication platform. Smishing messages (SMS phishing) have a rate of approx. 98% (Sara, 2020). The State of the Phish report shows that the average for 2022 was 300,000-400,000 daily attempts to deliver mobile-oriented attacks, with August peaking at 600,000 attacks per day (proofprint, 2023). On the Ukrainian front, the cyber-attacks identified (Schwart M.J., 2023), especially in the first phases of the fighting, were voice phishing (vishing). Originating from the environment of organized crime, they facilitated the identification of commanders and the degradation of troop morale. The victim is encouraged to provide personal data over the phone based on a narrative story (Barza, 2018).

Under these conditions, European states and NATO have adopted a series of urgent security and proactive cyber defense measures. Among these is the need to allocate funds for investment in cyber security education.

Reforms in education were proposed and implemented, the legal framework was created for the training of specialists, cyber security strategies were adapted and modernized, which generated a lot of plans and measures to maintain a state of normalcy in cyberspace.

Centres and institutions were created with the role of monitoring and rapid specialized intervention with the role not only of limiting cybercrime but also of informing about new threats in cyberspace.

EduRank classifies as the best six universities in Romania that offer specialist training programs for cyber security as follows (EduRank, 2023): the Polytechnic University of Bucharest (121st place in Europe and 403rd in the world); the Polytechnic University of Timișoara (222nd place in Europe and 674th in the world); the Alexandru Ioan Cuza University in Iași (230th place in Europe and 713th in the world); the Technical University of Cluj-Napoca (245th place in Europe and 781st in the world); the Bucharest Academy of Economic Studies (259th place in Europe and 820th in the world); the Bucharest University (276th place in Europe and 890th in the world). The ranking is based on the universities' performance in scientific research in the field, based on publication ratings, without distinguishing between undergraduate and postgraduate programs.

2. Education markers according to the age of the population

Through education, the citizens of a state develop their knowledge and skills in various fields that belong to the real sciences and/or humanities, ethics and morals, but also in other contexts such as: in the family, through the media, through the Internet, through discussions with friends, etc.

The particularities of education classified by age are (Eurydice, 2022):

1. Pre-schoolers: Retain isolated words and accept routine; Not being able to write, instructions are memorized through pictures, real objects, songs etc.; They need a protector (educator, pedagogue, teacher, etc.) who gives them parental affection in order to feel comfortable; Technology is a novelty that attracts them with colour and movement.

2. Schoolchildren/children: Learn from drama activities and short stories to keep them interested; Competitiveness is stimulated through games, contests and competitions; The technology is used for games.

3. Adolescents/Young People: They are pragmatic and need to understand what they are learning for; Appreciates freedom of expression and autonomy in selecting topics; They need external stimuli: interesting subject, dynamic and engaging knowledge transfer style, appreciation of results; Use technology for learning and networking.

4. Adults: Are self-motivated to achieve performance for a well-defined target determined by their performance and social status; Learning is based on schemes, rules and logical explanations; They pay attention to the quality and performance of technology and use it mainly for professional purposes, for networking and entertainment.

5. Seniors: Do not learn out of obligation; Prefers short and well-directed forms of learning to find answers to problems arising in daily activity; Values review and recapitulation as a form of repeated exposition of knowledge for long-term fixation; Appreciates informal discussions in the native language; Use technology only when needed.

3. Research results

The results obtained are based on the interpretation of statistical data published in various profile reports and discussions with specialists. We note that:

1. Cyberattacks aimed exclusively at children are relatively few. With parental control functions, the responsibility of ensuring cyber security rests with parents, family and tutors (for institutionalized education).
2. For teenagers a ban without proper justification will attract them and not deter them. They will not have the patience to understand the effects of the action but will seek to stand out by demonstrating that they have the skills to achieve a goal. Many open-source tools are available on the Internet. Networking is mainly on social media platforms. Looking at cyber security learns about specific events in which members of the social groups they activate are involved.
3. Adults understand the need to apply cyber security measures. Their expectations are that IT and computing applications include cyber security and that identified vulnerabilities are automatically corrected through patch solutions. Most adults follow the rules of cyber security. However, due to professional, social or family grievances or, simply, by elusions the cyber hygiene rules, they can create cyber security breaches.
4. Seniors initially reject cybersecurity solutions. Self-direction and self-determination become the main factors of organizing their evolution. Past experiences cannot be bypassed. Information technologies are considered complementary and not supplementary elements.

4. Conclusions and proposals

Another future work would consist in finding solutions to others methods (developments of actual methods) and collecting more important information about the enterprises (Dumitrache, 2020) and their educational particularities.

A mass education in the field of cyber security is possible if it is organized distinctly, through programs by categories of learning ages.

We propose the following solutions:

1. For children (school and preschoolers) specific education can be achieved through physical and online games. Kids can control a character on an itinerary with various suggestive challenges. Games must educate them to follow the rules of internet navigation and parental controls.
2. Teenagers are big consumers of cyber services and applications. Strategy games can be a solution. We give the example of the "Hacker Evolution" series which, even though the game is based on the simulated use of hacking techniques, teaches users where the vulnerabilities and cyber security problems are. Following the players networks it can create new scenarios or improve them.
3. For adults, education in the field of cyber security must follow two priority directions: education in support of his profession and societal education. An adult has a wide range of physical and online data libraries at his disposal. In addition to its education, we propose the use the TV entertainment. For example, "MasterChef Romania" (MasterChef International franchise) raised the level of education in the art of cooking. "Romanians have talent" (Reality TV Show Got Talent franchise) identifies and prepare potential artists. Fashion education is done through "Bravo, you have style!" (concept TV Show "My Style Rocks"). We believe the same recipe can be applied to cybersecurity education. When a televiewer sees how quickly access to a poorly protected account can be broken, they will understand the need to use complex key password. Moreover, the cyber security spectacle will deter hackers from further using their skills on an educated community.
4. The writing of instructions and user manuals of all products for seniors must be in the native language, well organized and with a legible narrative content, because many vision problems appear with advancing age. Seniors are no longer willing to learn what is required of them. In addition, in order to avoid becoming victims of phishing attacks, a radio show should be created that systematically repeats tips from lessons learned and the experience of others.

The solutions offered are a start for identifying new forms of mass education in the field of cyber security, in support of traditional education. These prospects require entrepreneurs willing to take large doses of risk in the future. However, investing in education is and will be the most profitable business for a healthy environment.

Acknowledgment

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Doctors' opinion before and after an eLearning course about surgical stress modulation

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Abstract: *Surgical stress is a topic of interest in the literature, from multiple perspectives. The aim of this research was to evaluate doctors' opinion before and after an elearning course about surgical stress modulation. Preparing medical staff to manage the modulation of this form of stress is very brief in our country. On the other hand, postgraduate eLearning training courses for physicians represent a form of training on various medical topics or topics with medical connections. Such a course was dedicated to the physicians training on a topic of modulation of surgical stress, in which we were also interested in assessing the participants' opinion before and after the course.*

Keywords: doctors, eLearning, surgical stress, stress modulation.

1. Introduction

Selye used the term "stress" to represent the effects of anything that seriously threatens the homeostasis of the body (Selye, 1956). The neuroendocrine, metabolic and inflammatory changes produced as a result of an injury are part of the "stress response", most frequently studied in relation to surgery: suppression of the secretion of anabolic hormones, activation of the sympathetic nervous system, immunological and haematological changes (Burton et al., 2004). Generally, the magnitude of the metabolic response is proportional to the severity of the surgical trauma, and physiological events are accompanied by psychological and behavioural changes (Burton et al., 2004; Lorenz, 2021).

2. Particularities of surgical stress

Surgical interventions are accompanied by peri-operative stress (Sobczak et al., 2023), which involves complex mechanisms and variable intensity. These mechanisms consist of a cascade of reactions that, schematically, unfold as follows (Finnerty et al., 2013): following surgical trauma, the nervous system activates the stress response, sending impulses from the site of the injury to hypothalamus; then,

the hypothalamus either overrides the inhibition on the pituitary gland or releases hormones that stimulate the production and/or release of pituitary hormones; in turn, pituitary hormones (such as corticotropin - ACTH and growth hormone - STH) act on target organs, causing the release of other hormones (such as cortisol) and having, therefore, particularly important metabolic consequences; the increase in stress hormones (cortisol, glucagon, catecholamines), as well as inflammatory cytokines, further accentuates the stress response. The anticipation of surgery is often correlated with high levels of anxiety (Davidson & McKenzie, 2011). Preoperative anxiety is associated with the development of postoperative maladaptive behaviours, including separation anxiety and sleep difficulties (Caumo et al., 2000; Kain et al., 1996; Kain et al., 1999). Also, increased preoperative anxiety has been associated with increased postoperative pain and analgesic dosage, (Kain et al., 1999) longer and more complicated postoperative recovery (Kain et al., 2006; McCann & Kain, 2001) and postoperative anxiety as an intensified state (Caumo et al., 2000). The common prevalence of anxiety in patients undergoing surgery has led to the attempt to routinely identify patients with higher anxiety (Ziętek et al., 2014). It was concluded that preoperative laboratory testing, which may harm patients, should be performed only after anamnesis and physical examination, identification of surgical severity components and comorbidities, so that the benefit of the tests is greater than risk (Edwards & Forest, 2018). Due to these mechanisms, salivary cortisol (S Cortisol) and salivary alpha-amylase (SAA) are often used as a valid biomarker of stress (Grigoropoulou et al., 2023).

3. Methods of surgical stress modulation

3.1. Conventional methods of modulation

1. *Anaesthesia* can influence some aspects of the response to surgical stress, by:

a) *opioids*: opioids suppress the secretion of hypothalamic and pituitary hormones (Burton, Nicholson & Hall, 2004) and bi-directional effect on the immune system (Lisowska et al., 2020).

b) *anaesthetic drugs*: for example, etomidate suppresses the production of corticosteroids in the adrenal cortex and blocks the synthesis of aldosterone and cortisol for up to 8 hours; clonidine may decrease sympathoadrenal and cardiovascular responses to surgery (Burton, Nicholson & Hall, 2004); some anaesthetics (e.g., halogenated anaesthetics), stimulate the production of reactive oxygen species, while others (eg. Propofol), have antioxidant properties (Tomsic & Nemec Svete, 2022).

c) *regional anaesthesia*: epidural/spinal anaesthesia can reduce changes in blood glucose, ACTH, cortisol, growth hormone and epinephrine values (Burton, Nicholson & Hall, 2004); regional anaesthesia may be part of multimodal analgesia regimens that reduced surgical stress response (Sertcakacilar et al., 2022).

2. *Surgical technique*: refinement of surgical techniques may have some advantages in reducing inflammatory responses; thus, cytokine release is reduced in less invasive surgery such as laparoscopic techniques leading to faster recovery and discharge (Burton, Nicholson & Hall, 2004); the inflammatory-immune, as a part of a pathophysiological response to surgical injury, may be harmful, leading to dysregulated state (Bain et al., 2023).

3. *Maintenance of normothermia*: is also beneficial in reducing the intensity of the metabolic response to a surgical intervention (Burton, Nicholson & Hall, 2004), knowing the fact that anaesthesia leads to impairments in central and peripheral thermoregulatory responses (Koh et al., 2021).

4. *Nutrition*: can play an important role in preventing the adverse effects of the stress response (Burton, Nicholson & Hall, 2004); nutritional status is a strong predictor of postoperative outcomes and important in surgical recovery programs (Hirsch et al., 2021).

3.2. Psychological methods of modulation

In children, preoperative psychological preparation (PPP), which consists primarily of providing information and training in parent-child coping skills before induction of anaesthesia, is the main non-pharmacological approach used by various paediatric healthcare institutions to reduce paediatric preoperative anxiety (Capurso & Ragni 2016). Interventions to reduce anxiety included the presence of parents in the operating room during the induction of anaesthesia, sedative drugs administered preoperatively, verbal distraction techniques performed by hospital staff (Wright et al., 2007). In addition, there are hospitals that use preoperative videos (Vernon & Bailey, 1974). More, distraction applied to children in the preoperative period significantly reduced anxiety and separation anxiety (Aytekin et al., 2016). Use of behaviour modification techniques in dentistry, to overcome the child's anxiety before the start of a dental extraction can be useful in reducing the stress level (Chaturvedi et al., 2018).

Currently, it appears that the evidence is insufficient to be sure that preoperative psychological interventions are beneficial or to know which interventions are the most effective, as their impact over time has been heterogeneous; there is an urgent need for high-quality prospective studies with baseline psychological assessment, well-described interventions, and agreement on the most appropriate psychological, physiological, and quality-of-life measures (Levett & Grimmer, 2019). Recently it was found that psychological counselling coupled with visual aids before the endoscopic procedures can alleviate anxiety, acute stress and fear related to this procedure (Khan et al., 2023). Surgical coaching is a new approach based on live or video observation of procedures, with potential benefits such as collaborative analysis, technical skills improvements (Willemot et al., 2023).

3.3. Integrative methods of modulation

Also known as integrative therapies. Natural sources of therapy can be very helpful in modulating stress.

1. *Phytotherapy*. The results of a relatively review (Tsuchiya, 2017) show that plant preparations and their phytochemicals contain the potential to become local anaesthetics, general anaesthetics, antinociceptive, analgesic or sedative; although clinical trials are still limited, there is a possibility that certain phytochemicals may be used in anaesthesia; thus, terpenoids, alkaloids, and flavonoids are expected to become new aesthetic agents of plant origin because they meet the mechanical requirements to interact with receptors, channels, and membranes and have characteristic molecular structures different from conventional drugs. Phytochemicals, naturally occurring molecules, have an imperative role in modulating favourable the immune responses (Behl et al., 2021).

2. *Adaptogens*. The beneficial stress-protective activity of adaptogens has been shown to be associated with the hypothalamic-pituitary-adrenal axis (HPA) and the regulation of key mediators of the stress response (Jurcău & Jurcău, 2018; Jurcău et al., 2017; Jurcău et al., 2013; Jurcău et al., 2018; Panossian & Wikman, 2010). E.g., rutin has adoptogenic potential via normalization of HPA, oxidative / nitrenergic, and neuroinflammatory inhibitions (Emudainohwo et al., 2023). e.g., Korean Red Ginseng (KRG) plays a key role in heme oxygenase (HO)-1 induction under physical and moderate oxidative stress conditions.

3. *Acupuncture*. Perioperative acupuncture not only reduces the consumption of anaesthetics and analgesics, but also anaesthesia-related complications and protects organs in the perioperative period; thus, acupuncture represents a promising approach in perioperative management, especially for improving surgical recovery and for particular categories of patients such as the elderly (Lu et al., 2015). Electroacupuncture (EA) can effectively reduce surgical stress-induced HPA axis dysfunction and promote postoperative recovery by activating the oxytocin and oxytocin receptor signalling pathway (Wu et al., 2023).

4. *Music therapy*. Music therapy is a non-pharmacological, inexpensive and non-invasive technique that can significantly increase patients' satisfaction and reduce their unpleasant experiences related to pain and perioperative stress (Kahloula et al., 2016). Thus, music therapy can be used as a complementary no-drug intervention alongside standard surgical care before, during and after medical procedures (Giordano et al., 2023).

4. Objective

The objective of this study was to test the knowledge of doctors regarding modulation of surgical stress (MSC), before the eLearning course, and the effectiveness of the course, at the end of its implementation.

5. Methods

Participant. The subjects were 49 doctors from different specialties: 19 men and 30 women. The average age of the participants was: 40, 3 ± 1 years, for men and 49, 3 ± 10 years, for women.

Instruments. All participants answered the same questionnaire (see Appendix), which contained 13 items.

Design. All participants attended a post-graduate eLearning course on MSC in the summer of 2023. The course was part of a postgraduate training program and took place during one day of this program, for 6 hours. In this MSC course, relevant information was presented regarding: a) Stress: definition, framing, factors, physio pathological mechanisms, functional implications; b) Surgical stress: psychological; aesthetic; pre-intra-post-operative; the categories involved - patients, doctors, medical staff; c) Modulation of stress: mechanisms, modalities, implications. The eLearning course was taught by the course coordinators, two specialist doctors with training in Physiopathology, teaching staff at UMF Cluj-Napoca, in collaboration with a doctor specializing in Surgery, also teaching staff at UMF Cluj-Napoca and a psychologist. The study and measurements were conducted in July 2018. All subjects' participation in the research was voluntary. Participants answered the first 12 items of the questionnaire 15 minutes before the class and the last item, 13, 15 minutes after the class ended. For the data analysis, the absolute frequency and the ratio of the participants to the total of those who answered the item (R), who gave the respective answer, were determined for each answer variant of each item.

6. Result

Results are presented in the order of the items in the questionnaire.

1) What does the MSC mean?

Most of the participants (R=0.6) mentioned that they do not know what MSC entails, and the fewest (R=0.04) mentioned other methods (for example, informing patients). Psychological methods were selected by more participants (R=0.24) than medical ones (R=0.12).

2) How many MSC courses have you attended?

All participants (R=1) mentioned that they had not attended another course on MSC.

3) How many MSC ways do you know?

Most participants (R=0.49) answered that they do not know any method, and the fewest mentioned herbal therapy (R=0.12). An important percentage of participants (R=0.21) mentioned psychological procedures, for example, counselling, psychotherapy.

4) What MSC modalities have you seen in practice?

Most participants ($R=0.71$) answered that they did not see any method applied practically, and the fewest mentioned patient counselling, done by the surgeon, anaesthesiologist or the average staff ($R=0.19$). The other participants did not give any answer ($R=0.10$).

5) What are the basic mechanisms of MSC?

Most of the participants ($R=0.43$) answered that MSC reduces surgical stress, and the fewest mentioned the hypothalamus-pituitary-adrenal (HHA) axis as being involved ($R=0.17$). The other participants ($R=0.40$) gave varied answers, for example, reduction of anxiety, decrease of sympathetic action, reduction of cortisol.

6) What are the main functional effects of MSCs?

Most participants ($R=0.69$) mentioned cardiovascular effects, as a whole, and the fewest noted that improvement in sympathetic activity occurs ($R=0.12$). The other participants ($R=0.19$) gave varied answers, for example, blood pressure reduction, heart rate reduction, respiratory rate reduction.

7) What are the main biological effects of MSCs?

The most participants ($R=0.49$) mentioned the reduction of cortisol, and the fewest noted the reduction of adrenaline ($R=0.12$). The other participants ($R=0.39$) gave varied answers, for example, reduction of blood sugar, biochemical changes in stress parameters.

8) What are the main psychological effects of MSC?

The most participants ($R=0.43$) mentioned the reduction of anxiety, and the fewest noted the reduction of fear ($R=0.17$). The other participants ($R=0.40$) gave varied answers, for example, inducing a sense of peace, trust, and optimism.

9) What are the main evaluation markers of MSC?

Most participants ($R=0.42$) answered that they don't know, and the fewest noted adrenaline ($R=0.19$). The other participants ($R=0.39$) gave varied answers, for example, anxiety, heart rate, blood sugar, cortisol.

10) On a scale of 1-10, how much can MSC improve the quality of surgery?

Most participants ($R=0.42$) answered with 6, and the fewest ($R=0.10$) answered with 2 and 3, respectively. The highest mentioned was 6.

11) At what point in the surgical operation can MSC be applied?

Most participants ($R=0.49$) mentioned the pre-operative time, and the fewest ($R=0.04$) noted the postoperative period and that any pre- or postoperative time can be used ($R=0.04$). An average percentage of participants ($R=0.43$) answered that they do not know.

12) Given the information you have so far, would you choose an MSC in practice?

Most participants ($R=0.49$) answered Yes, the least No ($R=0.10$), and an average percentage of participants ($R=0.41$) answered I don't know.

13) *On a scale of 1-10 how much did this eLearning course help you learn more about MSC.*

The most participants ($R=0.49$) answered 10 for how much the eLearning course helped them in understanding MSC, and the fewest ($R=0.04$) answered 6. There was no answer between 1 and 5.

Gender and age differences were irrelevant for all items analysed. However, overall, the most answers in favour of using MSC and the most knowledge about MSC were given by female participants and those aged 40-49.

7. Discussions

Specifications

Operative stress is a reality faced by many medical specialties that involve surgical interventions. That is why the modulation of surgical stress is a medical goal, which requires at least basic knowledge on the subject of operative stress, in order to be achievable. Stress is a complex field of interference, due to the multitude of factors, mechanisms and connections involved. Surgical interventions assume a diversity of aspects: the nature of the condition, the operating team, the complexity of the surgical act, the individual characteristics of the patient, etc. As a result, the modulation of peri-operative stress requires, in turn, complex approaches, such as addressability and intervention. This article is a continuation of the author's previous research on stress and stress modulation (Jurcău & Jurcău, 2018; Jurcău et al., 2013; Jurcău et al., 2017; Jurcău et al., 2018).

Analysis of questionnaire responses

This study was attended by a large number of doctors (49) a fact that proves that the subject of the course was an interesting one. For a postgraduate course, this is an important number of participants, the minimum allowed being 5.

The participating doctors had different specialties, more than half of which were surgical specialties, such as surgery, otolaryngology, urology, ophthalmology.

The course participants were of both genders, but female doctors predominated. Comparable answers given by men and women, regardless of their age, do not allow us to make a particular comment regarding differences in answers in relation to participants gender or age.

Following the application of the questionnaire, we could find that the participants have little information about the MSC. This aspect could be understood by the fact that there is currently no specific education for doctors in the field of stress modulation. The approach to this subject in practice is limited by the crowded professional schedule of doctors and by the rather empirical

understanding of intervention methods. However, a moderate percentage of participants knew MSC, through the lens of mechanisms, effects or evaluations.

All participants declared that it was the first eLearning course on MSC that they attended. This online course has proven to be a very practical option, which can save a lot of time spent in the classical way and which allows a much larger number of doctors to participate in this training. The e-learning format represents an additional explanation of the important number of participants who chose this course.

What is more encouraging, regarding the position of the participants in the course, towards MSC, is the answer to the last item, which represented the question at the end of the eLearning course. This answer shows that the information provided in the eLearning course helped most to understand MSC.

8. Conclusion

This postgraduate eLearning course seems to be the first related to MSC. Initially, most participants had little knowledge of MSC. Taking into account the final evaluation of this eLearning course, we could consider that the information presented was positively appreciated by the learners. Further elearning training on MSC is needed, as the use of this type of modulation could improve the quality of the medical act.

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Appendix

The questionnaire used in the research

Items	Answers
1) What does the MSC mean?	I don't know Medical techniques Psychological techniques Other
2) How many MSC courses have you attended?	To none 1 2 3
3) How many MSC ways do you know?	None I know - list:
4) What MSC modalities have you seen in practice?	None I know - list:
5) What are the basic mechanisms of MSC?	I don't know I know – list:
6) What are the main functional effects of MSCs?	I don't know I know – list:
7) What are the main biological effects of MSCs?	I don't know I know – list:
8) What are the main psychological effects of MSC?	I don't know I know – list:
9) What are the main evaluation markers of MSC?	I don't know I know – list:
10) On a scale of 1-10, how much can MSC improve the quality of surgery?	1 2 3 4 5 6 7 8 9 10
11) At what point in the surgical operation can MSC be applied?	I don't know I know – list:
12) Given the information you have so far, would you choose an MSC in practice?	Not I don't know Yes
13) On a scale of 1-10 how much did this eLearning course help you learn more about MSC	1 2 3 4 5 6 7 8 9 10
<i>The legend, MSC = modulation of surgical stress</i>	

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