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CIAO! Online Escape Room: Assessment of Basic Mathematical Skills for Incoming Engineering Students*

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CIAO! ONLINE ESCAPE ROOM: VERIFICA DELLE COMPETENZE MATEMATICHE DI BASE PER LE MATRICOLE DI INGEGNERIA

Abstract

STEM education requires a solid foundation in mathematics, which is often lacking in incoming students. To address these gaps, Politecnico di Torino developed CIAO!/ OAIC! (Corso Interattivo di Accompagnamento Online / Online Accompanying Interactive Course), an online preparatory course featuring a virtual escape room as its final self-assessment activity. This escape room, set in the digitalized spaces of the actual university, tests mathematical prerequisites through problem-solving challenges while providing immediate feedback. The study analyzes two implementations: a pilot with time constraints and prize incentives and an updated version with extended access and no external rewards. Results show that removing competitive elements and extending gameplay duration led to increased student engagement and higher success rates. The findings

* This paper and the research behind are based on the collaborative efforts of all the authors. M.G. Ballatore: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization. A. Tabacco: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing-Review & Editing, Supervision.

demonstrate that reduced time pressure facilitated deeper learning and knowledge consolidation. Additionally, the study reveals that external incentives did not significantly impact participation rates, suggesting that students' intrinsic motivation to assess their mathematical readiness was sufficient to drive engagement with the platform.

Keywords: Engineering students; Escape room; Game design; Maths prerequisites; Self-assessment.

1. Introduction

The increasing complexity of engineering education necessitates robust preparatory programs to address the diverse competency levels of incoming students. A critical challenge faced by universities is ensuring that students possess the requisite foundational knowledge, particularly in mathematics, before embarking on their core studies. Addressing this need, the Politecnico di Torino developed the CIAO!/OAIC! (Corso Interattivo di Accompagnamento Online / Online Accompanying Interactive Course) an innovative online course aimed at bridging the knowledge gaps in mathematics among prospective engineering students (Ballatore & Tabacco, 2025). CIAO! leverages interactive, game-based learning strategies to enhance student engagement and motivation, making it a pivotal tool in reducing attrition rates and fostering academic success.

A distinctive feature of CIAO! is its incorporation of an escape room as the final self-assessment activity. This escape room is not merely a gamified experience but a strategically designed educational tool that challenges students to apply their acquired knowledge in a problem-solving context. By integrating educational content into a playful environment, the escape room encourages active learning and provides immediate feedback, which is crucial for self-evaluation and knowledge consolidation.

This article explores the design, implementation, and effectiveness of the CIAO! escape room as a self-assessment tool. It examines how the escape room aligns with broader educational goals, such as promoting active learning, enhancing student confidence, and ultimately reducing dropout rates. The discussion also considers the challenges and opportunities associated with integrating gamification into higher education, particularly in the context of preparing students for the rigorous demands of engineering studies.

The paper is structured as follows: after exploring the role of escape rooms in education, it details the design process of the CIAO! Escape Room,

followed by an analysis of the results and discussion. The paper concludes with a summary of findings and implications for future educational practices.

2. Escape room in education

Escape rooms, originally designed as immersive puzzle-solving experiences for entertainment, have found increasing applications in educational contexts. These rooms are typically structured around a series of interconnected puzzles, which participants must solve to «escape» from the room or complete a specific challenge within a set time limit. The puzzles often require critical thinking, collaboration, and time management, fostering an environment where players must work together to succeed (Clarke *et al.*, 2020). In educational settings, escape rooms are designed to integrate curricular content, creating an engaging learning experience that promotes problem-solving and active engagement (Fotaris & Mastoras, 2019).

2.1. *Escape rooms as educational tools*

The integration of escape rooms into education is rooted in gamification and game-based learning theories. Gamification involves applying game design elements, such as competition, rewards, and progression, to non-game contexts in order to enhance motivation and engagement (Deterding *et al.*, 2011). In educational escape rooms, students actively engage in learning by solving subject-specific puzzles that align with curricular objectives. This approach not only fosters engagement but also develops critical transversal skills, such as teamwork, communication, and logical reasoning (Pan *et al.*, 2017; Fotaris & Mastoras, 2019; Veldkamp *et al.*, 2020).

Research has shown that educational escape rooms are particularly effective in higher education, especially in fields that require problem-solving, such as STEM disciplines. Fotaris and Mastoras (2019) describe educational escape rooms as experiential learning environments where students take on active roles, moving beyond passive content consumption. By integrating educational content into the puzzle-solving process, escape rooms provide an interactive platform where students can apply theoretical knowledge to practical challenges, reinforcing their understanding of the subject matter (Pan *et al.*, 2017). Brookes *et al.* (2021) highlight how escape rooms enhance motivation and engagement in science education, moving beyond traditional didactic teaching methods.

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In addition to improving content knowledge, escape rooms also foster soft skills development. Morrell *et al.* (2020) found that escape rooms encourage the development of leadership, decision-making, and collaboration, skills essential for success in professional environments. Through teamwork, students distribute tasks, communicate effectively, and make decisions under pressure, mimicking real-world problem-solving scenarios (Pan *et al.*, 2017; Fotaris & Mastoras, 2019).

2.2. *The unique role of online escape rooms for self-assessment*

As defined by Rodríguez-Díaz *et al.* (2022), a digital escape room replicates the traditional escape room experience within a virtual environment. This format not only retains the challenge and engagement of the physical escape room but also leverages digital platforms for accessibility and scalability. The growing adoption of digital escape rooms in education has introduced new possibilities for teaching and assessment, particularly as a tool for enhancing engagement and fostering self-assessment (Clarke *et al.*, 2020).

The transition of escape rooms into digital environments has opened new avenues for self-assessment and evaluation. Online escape rooms allow students to engage in self-paced learning, providing them with immediate feedback as they progress through the game. This format is particularly useful in large-scale educational settings, where it offers flexibility, scalability, and accessibility, making it easier to integrate into online learning systems (Eukel *et al.*, 2020). For instance, Licchelli and Barnett (2023) employed an online escape room as a formative assessment tool during a medicine lecture, showcasing its effectiveness in enhancing student engagement and learning outcomes.

Digital escape rooms offer a unique approach to self-assessment, blending the challenge of puzzle-solving with the opportunity for students to evaluate their understanding of course content in a low-stakes environment. As students work through the puzzles, they receive immediate, implicit feedback based on their ability to progress to the next stage of the game. This process allows students to reflect on their learning and identify areas that need improvement without the stress of formal testing (Clarke *et al.*, 2020).

Beyond serving as a learning activity, escape rooms are also explored as an alternative form of assessment. Roig *et al.* (2023) examined their role in active learning contexts as a tool for evaluating student performance, while Willis and ED (2020) argued that escape rooms offer a viable alternative to traditional assessments by promoting deeper learning through application rather than rote memorization. Psyllou (2023) also emphasized

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the benefits of using escape rooms in online learning environments, highlighting their flexibility in formative assessment.

The impact of escape rooms on student well-being is another area of interest. Molina-Torres *et al.* (2021) compared the effects of escape rooms with traditional assessment methods on students' anxiety and stress levels, finding that escape rooms significantly reduced anxiety while maintaining a positive and enjoyable learning experience. This aligns with the notion that game-based learning strategies, including escape rooms, can create a low-stress environment conducive to learning, fostering both motivation and satisfaction (Veldkamp *et al.*, 2020).

Brookes *et al.* (2021) highlighted the effectiveness of online escape rooms as formative assessment tools, providing a platform for students to assess their comprehension in a more engaging and interactive way. In the case of online escape rooms used in subjects like health education or mathematics, students can test their knowledge of key concepts in a practical, hands-on manner, helping to consolidate learning while maintaining student interest (Fotaris & Mastoras, 2019; Eukel *et al.*, 2020).

2.3. *Enhancing learning outcomes through escape rooms*

Escape rooms have demonstrated their potential to enhance learning outcomes by increasing student engagement, improving knowledge retention, and fostering the development of critical skills. The immersive nature of escape rooms makes learning enjoyable, promoting greater involvement in the subject matter. Studies show that students retain information more effectively when they engage in active learning environments like escape rooms, where they can apply theoretical knowledge in practical scenarios (Clarke *et al.*, 2020; Eukel *et al.*, 2020).

Eukel *et al.* (2020) found that educational escape rooms significantly increase student motivation and engagement. The interactive and hands-on nature of the puzzles encourages students to actively participate in their learning, making the process enjoyable and memorable. Psyllou (2023) adds that the challenge of solving puzzles in a game-based environment promotes critical thinking and problem-solving skills, which are essential for long-term knowledge retention.

In professional fields such as healthcare and engineering, escape rooms have been used to teach both subject-specific content and soft skills. For instance, pharmacy and nursing programs have employed escape rooms to simulate real-world scenarios, allowing students to practice decision-making, teamwork, and crisis management in a safe environment. These

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activities help students develop not only the content knowledge required for their disciplines but also the professional skills needed for their future careers (Eukel *et al.*, 2020; Molina-Torres *et al.*, 2021; Wettergreen *et al.*, 2022). Helbing *et al.* (2022) found that both in-person and virtual escape rooms contribute to team-based learning in health professions education, reinforcing collaborative problem-solving skills.

2.4. *Challenges and opportunities in educational escape rooms*

While educational escape rooms offer clear benefits, their implementation presents several challenges. Designing an effective escape room requires careful planning to ensure that the puzzles are aligned with learning objectives. If the puzzles are too difficult or disconnected from the course content, students may become frustrated and disengage. On the other hand, if the puzzles are too simple, the educational value may be diminished (Clarke *et al.*, 2020). Balancing these factors is essential for creating an escape room that is both educational and engaging (Fotaris & Mastoras, 2019).

Another challenge lies in the time and resources required to design and implement escape rooms. Developing an educational escape room, whether physical or digital, requires significant effort in terms of content development, technological setup, and testing. However, once established, escape rooms offer a flexible and reusable learning tool that can be adapted across different courses and disciplines (Pan *et al.*, 2017). Manojlovic (2022) emphasized the versatility of escape rooms in educational settings, noting their adaptability to different subjects and learning objectives.

Despite these challenges, escape rooms present significant opportunities for enhancing student engagement and learning outcomes. Their interactive and immersive nature makes them an ideal tool for fostering active learning, promoting teamwork, and improving critical thinking skills. As they continue to gain traction in educational settings, escape rooms have the potential to revolutionize how students engage with content and assess their own understanding (Roig *et al.*, 2023; Trager *et al.*, 2023).

2.5. *Focus of the present study*

While the existing literature demonstrates the effectiveness of escape rooms in enhancing engagement, promoting active learning, and developing critical thinking skills across various educational contexts (Pan *et al.*, 2017; Fotaris & Mastoras, 2019; Clarke *et al.*, 2020), there is limited exploration

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of their application specifically as a tool for self-assessment in preparatory courses. Moreover, few studies have addressed how game design and gamification elements, such as progressive challenges, implicit feedback, and intrinsic motivation, can support the self-assessment process in an online educational setting, particularly in mathematics for engineering students.

To address this gap, this study investigates the following research question: How can game design and gamification elements within an escape room be leveraged to support self-assessment in an online preparatory mathematics course for engineering students? By analyzing the impact of the escape room's design, game mechanics, and feedback systems on student engagement, learning outcomes, and self-reflection, this study seeks to provide insights into the effective integration of gamified self-assessment tools in higher education.

3. Game design

The design of the CIAO! escape room was carefully crafted to align with both educational and motivational goals. Its structure was based on guiding students through a series of mathematical puzzles, each linked to real-world scenarios within a university setting. These puzzles allowed students to demonstrate their mastery of essential mathematical concepts while engaging with an interactive, gamified environment. The scoring system in the escape room was another crucial element, as it provided implicit feedback and incentivized students to think critically and avoid careless mistakes.

3.1. *Educational objectives*

The escape room within the CIAO! course was conceived as a final self-assessment tool for freshmen, specifically targeting the mastery of essential mathematical prerequisites necessary for engineering studies at the Politecnico di Torino. These prerequisites include topics such as polynomials, elementary functions, logarithms and exponentials, trigonometry, and equations and inequalities. To successfully navigate through the escape room, students needed to demonstrate a solid understanding of these mathematical concepts, progressing from one room to the next. The game begins with a welcome video from the Rector in the Main Hall, inviting students to embark on a journey to find their correct classroom and seat.

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Figure 1. – Storyline of the escape room: Main Hall, Central Courtyard, Corridor, Classroom.

The escape room's design aligns closely with the educational objectives of the CIAO! course. Each room is themed around different mathematical topics covered in the course. For example, the first room (Main Hall) tests basic knowledge of elementary functions and the properties of logarithms and exponentials, while also requiring problem-solving skills. Subsequent rooms progressively challenge the students with topics like trigonometry in the Central Courtyard, logarithms and exponentials in the Corridor, and systems of inequalities in the final Classroom. *Figure 1* shows the storyline of the escape room.

3.2. *Conceptual design, game mechanics and technological implementation*

The goal is for each student to find their correct classroom and seat by solving a series of mathematical puzzles. This narrative not only provides a relatable context for the students but also integrates seamlessly with the academic environment they are about to enter. Each room represents a different location within the university, and progression through the escape room mimics the process of navigating through the campus, from the Main Hall to the final Classroom.

The escape room incorporates various game mechanics tailored to the educational content. Puzzles include matching exercises, acronym decoding, and number composition tasks, all designed to reinforce the mathematical concepts taught in CIAO! For instance, matching graphs to their corresponding functions directly engages students with the material in a practical, hands-on way.

The scoring system was a key feature of the game mechanics, rewarding correct answers and penalizing errors, encouraging students to approach each task thoughtfully. The total score was 300 and each room had its own scoring system based on the type of puzzle:

- *Main Hall* – A maximum score of 100 points was possible, distributed across tasks like matching graphs to functions, identifying key objects, and solving word puzzles. Incorrect answers resulted in a deduction of points (e.g., each wrong match reduced the score by 4 points).
- *Central Courtyard* – With a maximum score of 100, this room focused on domain-function matching and graphical associations, where incorrect answers deducted 5 points.
- *Corridor* – The total possible score was 50 points. This room tested students' ability to pair graphs and functions and included a numerical puzzle, with each wrong answer leading to deductions of 2 to 5 points depending on the mistake.

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- *Final Classroom* – The final room offered 50 points, primarily focused on identifying the correct seat based on earlier clues. Mistakes in selecting the seat resulted in a loss of 5 points.

While there are no formal levels or stages, students must complete each room before progressing to the next, simulating a journey through the university's physical spaces. In 2021 the pilot of the escape room was accessible for 24 hours (Friday before the start of classes, remaining active from midnight to midnight), allowing students to take as much time as needed within this window to complete the challenge. In 2022 the time access was revised as described in 3.5.

The escape room was developed as a SCORM (Sharable Content Object Reference Model) package and integrated into the university's Moodle platform, ensuring easy access for all students.

3.3. *Interactivity, feedback and gamification elements*

Students interacted with the game by exploring and clicking on various elements to solve puzzles, without receiving hints during the game. This approach was designed to encourage self-reliance and problem-solving. Despite the interactive nature of the game, no direct feedback was given during the experience. Instead, students could review the mathematical topics covered in CIAO! as they progressed through the game. This lack of explicit guidance was intended to simulate a real-world problem-solving environment, where students must rely on their knowledge and reasoning skills.

To enhance motivation, the CIAO! course included gamification elements such as earning lottery tickets. Students could accumulate tickets based on the percentage of activities completed within the CIAO! course. In 2021, completing the escape room granted them the opportunity to participate in a real lottery, with prizes including 20 smart notebooks. This incentive structure was design to drive student engagement, not only with the escape room but with the entire CIAO! course. This was not implemented in 2022 as discussed below in 3.5. To further ensure fairness and limit the dissemination of solutions, three different versions of the escape room were created and randomly assigned to students.

3.4. *Design process*

The design and development of the escape room involved a collaborative effort among first-year engineering mathematics instructors, tutors, a game

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designer, and two ICT students as developers. The team faced challenges in faithfully recreating the university environments and crafting puzzles that were educationally relevant while also engaging and enjoyable. This required careful balancing between difficulty and playability, making the escape room a successful team project.

Before full implementation, the escape room was pilot-tested by a group of faculty members and students, leading to minor adjustments based on their feedback, ensuring that the final version was both challenging, accessible, and aligned well with the educational goals of the CIAO! course.

Accessibility was a key consideration, with all engineering students being informed about the escape room well in advance and provided with ample time to participate. While the escape room was designed in Italian, language barriers were minimized (only one puzzle required minimal language skills, in addition to the introductory and concluding videos from the Rector), and the primary focus was on mathematical content. However, specific accommodations for disabilities were not implemented, as the primary aim was to ensure a fair and consistent assessment of mathematical knowledge.

3.5. *Further implementations*

After the first edition in September 2021, the CIAO! escape room was reframed to reflect different approaches to student engagement and self-assessment.

As mentioned, in the first edition (2021), the escape room was available for a limited window of 24 hours on the Friday before the start of classes. This edition included a gamified incentive structure, where students who successfully completed the escape room were entered into a lottery to win one of 20 smart notebooks. This time constraint, coupled with the tangible rewards, was intended to drive both urgency and engagement among participants.

In the 2022 edition, the escape room was available for an extended period of three days. This version was designed purely as a self-assessment tool, without any associated prizes. The removal of the incentive structure and the extended availability period were aimed at encouraging students to engage with the material at their own pace, focusing on knowledge consolidation rather than competition.

The variations in these two editions provided valuable insights into how different design choices, such as the inclusion of rewards and the

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duration of availability, can influence student participation and performance. The data from these two implementations is discussed further in the following section, where we examine the impact of these differences on student engagement and learning outcomes.

4. Results and discussion

In 2021, the implementation of the CIAO! escape room was conducted as a pilot project, with participation limited to 160 students. The goal of this exploratory phase was to test the effectiveness of the game dynamics and the structure of the escape room as a self-assessment tool. During this phase, the emphasis was not on promoting widespread participation but rather on gathering insights into the student experience and evaluating the escape room's potential to foster active learning.

Although only a small number of students participated, the results showed a significant distinction between those who participated in the escape room and those who did not. It is important to interpret these results within the context of a small, self-selected group of participants, as those who chose to participate may have been more motivated or better prepared.

The primary focus of this phase was on assessing the impact of the escape room's design on learning dynamics, particularly in providing immediate feedback and promoting a problem-solving environment. This pilot provided valuable insights for improving the design and expanding the escape room in subsequent iterations.

In 2022, the escape room was fully integrated into the CIAO! course, which targeted all students. Participation was higher than the year before, with 1,340 students engaging with the escape room.

This broader participation allowed for the exploration of game dynamics on a larger scale. One interesting finding from the 2022 data is that, even without external incentives like prizes, students actively participated in and completed the escape room. This suggests that students were motivated by the desire to self-assess their skills and improve their performance ahead of the Mathematical Analysis 1 course.

Students who completed the escape room demonstrated stronger mastery of the required mathematical concepts, with improved performance both in the game and in the subsequent math course. However, it is important to note that, although there was a significant correlation between performance in the escape room and success in the math course

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(B = 0.532, SE = 0.082, $p < 0.001$ for 2022), completing the escape room alone was not a definitive predictor of academic success. This suggests that other factors, such as intrinsic motivation and independent study habits, also played a role.

A key aspect of the design was the use of «implicit feedback». While no direct hints were provided during the game, students received feedback on the correctness of their answers by progressing through the rooms. This lack of explicit feedback encouraged students to critically reflect and review their knowledge independently, a crucial skill for problem-solving in engineering courses.

Although the quantitative data suggests a correlation between participation in the escape room and improved academic performance, the true strength of the escape room lies in the learning dynamics it fosters. The game allowed students to engage with mathematical problems in a playful yet challenging environment, prompting them to reflect and apply their knowledge in new ways.

In terms of performance, students who completed the escape room in 2021 had an average score of 173.9 (Standard Deviation 44.1), while those in 2022 had a slightly higher average score of 179.5 (Standard Deviation 43.1). Interestingly, in 2022, the percentage of students who scored in the upper range (201-300 points) increased to 32%, compared to 27.8% in 2021, suggesting that the modifications made to the structure of the game may have encouraged deeper engagement and better retention of mathematical concepts.

The success of the escape room cannot be measured solely by scores but rather in its ability to engage students, stimulate intrinsic motivation, and foster a positive attitude toward solving mathematical problems. Its effectiveness lies in transforming how students interact with educational content, leading to deeper and more lasting learning experiences.

The experience gained from the escape room as a pilot in 2021 provided a solid foundation for its broader implementation in 2022. While overall participation rates remain a challenge, the results suggest that the escape room has the potential to be a powerful self-assessment and active learning tool. Interestingly, the removal of prizes and incentives in 2022 did not hinder student participation. In fact, relaxing competition and time constraints allowed students to engage more thoroughly with the escape room, likely in multiple sessions, resulting in more accurate outcomes, as reflected by the slight increase in average scores and the more consistent performance distribution in 2022 compared to 2021.

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5. Conclusion

The CIAO! escape room demonstrates the powerful potential of game-based learning in a formal educational context, particularly in the field of engineering education. By combining interactive puzzles of essential mathematical concepts immersed in real Politecnico environment, the escape room has proven to be an effective tool for promoting both self-assessment and active learning. Its design aligns with the constructivist educational practices that emphasize learner engagement and intrinsic motivation, offering a playful yet rigorous environment for students to apply theoretical knowledge in a problem-solving context.

The results of the two editions, in 2021 and 2022, show that the integration of a gamified approach in formal learning environments can effectively boost student engagement and performance. Notably, the elimination of external rewards such as prizes in the 2022 edition did not diminish student participation or success. On the contrary, students were able to engage more deeply with the content at their own pace, as reflected in the slightly improved average scores and more consistent performance. This points to the ability of well-designed games to transcend traditional motivations like competition, instead fostering a genuine desire for learning and mastery.

The educational value of the CIAO! escape room extends beyond simply improving scores. It facilitates the development of transversal skills such as problem-solving, critical thinking, and self-directed learning, all of which are crucial in the transition from secondary school to higher education, especially in demanding disciplines like engineering. By providing a structured yet playful framework for learning, the escape room mirrors the dynamic educational environment that games can offer across various contexts, including professional training and informal learning spaces.

However, the success of this approach underscores the importance of thoughtful game design and integration into the curriculum. Educators must take into account not only the cognitive demands of the game but also how it can support broader educational goals without compromising accessibility or inclusivity. The CIAO! escape room has shown that digital games, when designed with pedagogical intent, can serve as powerful tools for learning, transcending the boundaries of entertainment to offer valuable educational experiences.

As the use of games in education continues to grow, it is essential for educators and researchers to explore their full potential across different learning environments. The insights gained from the CIAO! escape room provide valuable lessons on how games can promote both disciplinary

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learning and transversal skill development. Future iterations could focus on further refining the balance between game mechanics and educational outcomes, ensuring that games remain not just an engaging tool but also an effective one for fostering deeper, more meaningful learning.

In conclusion, the CIAO! escape room illustrates how well-designed educational games can create dynamic learning opportunities that promote both academic success and personal growth. By continuing to explore and refine the use of games in formal, non-formal, and informal learning contexts, we can unlock their full potential to enhance learning throughout the life cycle.

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Riassunto

La formazione STEM richiede una solida competenza matematica di base, spesso carente negli studenti in ingresso. Per colmare queste lacune, il Politecnico di Torino ha sviluppato CIAO!/OAIC! (Corso Interattivo di Accompagnamento Online / Online Accompanying Interactive Course), un corso preparatorio online che include una virtual escape room come attività finale di autovalutazione. Essa, ambientata nella versione digitalizzata degli spazi dell'ateneo, verifica i prerequisiti matematici attraverso sfide di problem-solving offrendo feedback immediato. Lo studio analizza due implementazioni: un progetto pilota con vincoli temporali e incentivi premianti, e una versione aggiornata con accesso esteso e senza ricompense esterne. I risultati mostrano che l'eliminazione degli elementi competitivi e l'estensione della durata del gioco hanno portato a un maggiore coinvolgimento degli studenti e a tassi di successo più elevati. I risultati dimostrano che la ridotta pressione temporale ha facilitato un apprendimento più profondo

e il consolidamento delle conoscenze. Inoltre, lo studio rivela che gli incentivi esterni non hanno influenzato significativamente i tassi di partecipazione, suggerendo che la motivazione intrinseca degli studenti nel valutare la propria preparazione matematica è stata sufficiente a stimolare l'engagement con la piattaforma.

Parole chiave: Autovalutazione; Escape room; Game design; Prerequisiti matematici; Studenti di Ingegneria.

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