From Deficiency to Proficiency in Engineering Education: Gamification for Sustainable Learning with CIAO! Course

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Maria Giulia Ballatore[0000−0002−6216−8939] and
Anita Tabacco[0000−0001−5731−4885]

Abstract The transition to university STEM education often reveals critical gaps in foundational mathematical knowledge, leading to decreased confidence and higher dropout rates. CIAO! (Corso Interattivo di Accompagnamento Online), developed at Politecnico di Torino, addresses these challenges through a gamified learning platform. This study presents CIAO! as an innovative educational intervention with three key impacts: increased student engagement through interactive e-books, immediate feedback systems, and a distinctive virtual escape room assessment; improved academic foundation, with approximately 50% of at-risk students fulfilling their remedial requirements; and enhanced transition support that familiarizes students with university expectations and environments. Beyond addressing mathematical deficiencies, CIAO! contributes to educational research by demonstrating how thoughtfully designed gamification can create more inclusive, engaging, and effective learning environments without requiring advanced technologies. The platform's modular structure and implementation framework provide a scalable model for other disciplines and institutions seeking to support student transitions and reduce attrition in higher education.

1 Introduction

The transition from secondary to higher education in STEM disciplines presents a complex set of academic, personal, and socio-emotional challenges for students. As they enter university, students must navigate increased content complexity, adapt

Maria Giulia Ballatore
Dept. of Mathematical Science "G. Lagrange", Politecnico di Torino, Corso Duca degli Abruzzi 24 – 10129, e-mail: maria.ballatore@polito.it

Anita Tabacco
Dept. of Mathematical Science "G. Lagrange", Politecnico di Torino, Corso Duca degli Abruzzi 24 – 10129 e-mail: anita.tabacco@polito.it

to new study strategies, and develop effective time management skills [10, 15]. These difficulties are further exacerbated for students from disadvantaged or underrepresented backgrounds, who often face additional socio-emotional barriers and inequities in access to high-quality instruction [15, 19]. Research has shown that ethnicity can play a role in students' transition experiences, with black and minority ethnic students facing unique challenges that impact their academic trajectories [19]. To cope with these demands, students rely on academic adaptation strategies and support networks, including family and peers [10]. However, without structured institutional interventions, these coping mechanisms may be insufficient to ensure a smooth transition.

One of the most critical academic barriers in STEM education is the lack of foundational knowledge in mathematics. Mathematics serves as the backbone of engineering and architecture education, underpinning nearly all technical and scientific concepts. However, many incoming students arrive at university with substantial knowledge gaps in key elementary areas including arithmetic, geometry, algebra, analytical geometry, and calculus [4, 6]. These deficiencies often stem from variations in secondary education curricula, differences in instructional quality, and systemic inequities in educational access [2]. The impact of these gaps is profound: students with inadequate mathematical foundations frequently struggle in their first-year courses, experience low academic confidence, and are at greater risk of attrition [12, 13, 21].

In Italy, the challenge is further compounded by the open-access nature of many university programs, which allow students to enroll without strict entrance requirements but later impose rigorous assessments. Politecnico di Torino, a distinguished Italian technical university with engineering and architecture programs, uses the Test in Laib (TIL) as an entrance assessment tool [1]. Additional to its admission role, the TIL was introduced as a diagnostic tool to identify students who may require specific support. However, merely assessing knowledge gaps is insufficient unless accompanied by targeted interventions designed to bridge them. Research suggests that structured preparatory courses and problem-solving skills sessions can play a crucial role in improving student transitions and predicting success in first-year mathematical courses [7, 12, 20].

High attrition rates in first-year programs underscore the urgency of these challenges. Studies report that approximately 30% of first-year engineering students leave their programs, with first-year attrition accounting for up to 79% of overall program dropout rates [5, 11]. The factors contributing to these high dropout rates include academic difficulties, lack of interest, low self-efficacy, and disconnection from the engineering profession. Underrepresented minority students are particularly vulnerable to attrition, highlighting the need for inclusive and equitable educational strategies [5]. Research has also indicated that admission requirements, curriculum design, and program structure significantly influence student retention. Additionally, there is a complex relationship between students' mathematical preparedness, academic confidence, and performance in first-year STEM courses [11]. In particular, academic-preparedness diversity within small learning groups tends to yield positive outcomes, especially for less-prepared students [14]. Addressing these issues

requires a multifaceted approach that not only strengthens academic preparedness but also fosters engagement and motivation.

Innovative pedagogical strategies have gained attention as potential solutions to these challenges, with gamification emerging as a particularly promising approach [9]. Gamification, the integration of game design elements into non-game settings, has been shown to enhance students' motivation, engagement, and learning outcomes in STEM education [17, 18]. By incorporating elements such as leaderboards, badges, and point systems, gamified learning environments can foster a sense of achievement, encourage active participation, and promote a growth mindset [9]. Furthermore, gamification has been found to reduce anxiety around difficult subjects, improve collaboration, and enhance retention of complex concepts. Despite these benefits, gaps remain in understanding the specific impact of individual game elements, highlighting the need for further research in this area [16].

In response to these challenges, Politecnico di Torino developed the *Corso Interattivo di Accompagnamento Online / Online Accompanying Interactive Course* (CIAO!/OAIC!) from now on CIAO!, an online interactive preparatory course that leverages gamification to support incoming students. CIAO! serves both as a preparatory tool in the orientation phase, helping students reinforce their knowledge before starting university, and as a remediation tool to address any gaps identified through the entrance test, ultimately enhancing their readiness for the first-year courses. CIAO! aims to bridge mathematical knowledge gaps through engaging and interactive learning experiences, helping students build the foundational skills necessary for success in their studies. By integrating game-based mechanics into the learning process, CIAO! provides a structured yet flexible approach that fosters motivation, persistence, and a deeper understanding of mathematical concepts. This study describes the impact of CIAO! as a model for innovative preparatory education, exploring its potential to enhance student engagement, improve academic performance, and contribute to long-term retention in STEM programs.

Beyond addressing immediate academic challenges, CIAO! also contributes to broader educational sustainability goals, particularly United Nations Sustainable Development Goal 4 (Quality Education). The platform's focus on accessibility, equitable learning opportunities, and reducing educational disparities aligns with global sustainability priorities in higher education. By supporting students from diverse backgrounds in overcoming mathematical barriers to STEM success, CIAO! exemplifies how technological innovation can advance educational equity while promoting sustainable academic practices.

This paper is structured as follows: Section 2 provides a detailed overview of the CIAO! platform, describing its design, features, and gamification elements. Section 3 outlines the implementation process and explores students' experiences with the platform. Section 4 analyzes the impact of CIAO! on student outcomes and discusses its potential for scalability. Finally, Section 5 presents the conclusions, highlighting key findings and future directions for expanding the use of gamified learning strategies in higher education.

2 The CIAO! Platform

Politecnico di Torino boasts over three decades of experience in supporting first-year students in bridging mathematical knowledge gaps [3]. Initially, this support took the form of an intensive in-person week where students were divided into groups and attended classes focused on essential mathematical prerequisites. Over time, keeping pace with advancements in educational technologies, these sessions transitioned to a blended format. Students were provided with video lessons accessible online and had the opportunity to attend in-class tutorials with tutors.

In recent years, the materials, comprising video lessons and exercise PDFs, were made available to students upon enrollment, without a formal structured week of preparation. However, an analysis of usage data revealed that the existing format was not fully meeting the needs of the students. It became evident that the material required further adaptation to enhance its accessibility and impact. To address this, efforts were made to retain as much of the original content as possible while fundamentally transforming its delivery format.

The CIAO! platform, introduced in 2021, represents the culmination of this evolution, offering a comprehensive response to the challenges faced by incoming students. Its design is firmly grounded in two complementary theoretical frameworks: constructivist learning theory and evidence-based gamification principles.

Constructivist learning theory [8] informs CIAO!'s pedagogical approach by emphasizing active knowledge construction rather than passive reception. This manifests in three key design elements: (1) interactive e-books that require engagement rather than passive reading; (2) immediate feedback systems that prompt cognitive adjustment and refinement; and (3) contextual problem-solving that situates mathematical concepts within authentic university environments. Each of these elements reflects the constructivist understanding that knowledge is built through experience, experimentation, and reflection.

Complementing this foundational approach, CIAO! strategically incorporates gamification principles that have demonstrated particular effectiveness in STEM education [9, 17, 18]. The platform's experience points, levels, and achievement systems are not merely superficial entertainment features but carefully selected mechanisms to address specific motivational challenges identified in the literature. Research indicates that visible progress indicators, variable reward schedules, and narrative integration can sustain engagement with challenging material while fostering a growth mindset toward mathematical competence.

The integration of these theoretical approaches results in a platform designed to simultaneously address both cognitive and affective dimensions of the transition to university mathematics. CIAO! serves dual objectives: as a preparatory tool in the pre-orientation phase and as a remediation tool for students with identified knowledge gaps.

This initiative serves both immediate and long-term goals. First and foremost, it seeks to remediate critical gaps in students' foundational mathematical knowledge, which are often barriers to their academic success. Beyond simply addressing defi-

ciencies, CIAO! aims to foster active learning by leveraging gamification techniques that make the learning process more engaging and interactive.

Additionally, the platform is structured to enhance students' confidence by encouraging incremental achievements, which help build self-efficacy and a positive attitude toward their studies. Ultimately, CIAO! aspires to reduce dropout rates by providing targeted academic support early in the university journey, thereby mitigating the frustration and disengagement that can lead to student attrition. Through these objectives, CIAO! reflects a holistic approach to preparing students for the demands of STEM education.

The philosophy underlying CIAO! aligns with the principles of constructivist learning, which emphasizes active engagement and student agency [8]. By blending traditional instructional methods with game-based learning and gamification techniques, CIAO! seeks to create an inclusive and dynamic environment that supports diverse learners.

2.1 Platform Structure and Features

CIAO!, exemplified in Fig. 1 is structured into five core modules, each focusing on essential mathematical topics:

1. Polynomials
2. Elementary Functions
3. Equations and Inequalities
4. Exponentials and Logarithms
5. Trigonometry

Fig. 1 Conceptual diagram of CIAO! learning framework

Each module of the course is carefully structured to target specific knowledge gaps while progressively building the essential skills required for success in STEM studies. Hosted on the university's Moodle platform, the course materials are designed in H5P to offer an engaging and interactive learning experience. Among these resources, interactive e-books stand out by combining concise theoretical explanations with multimedia elements, such as videos and animations, to enhance understanding (Fig. 2).

Students also benefit from immediate feedback exercises, which provide real-time performance assessments. This feature enables learners to quickly identify errors and address them effectively, fostering a more personalized and efficient learning process.

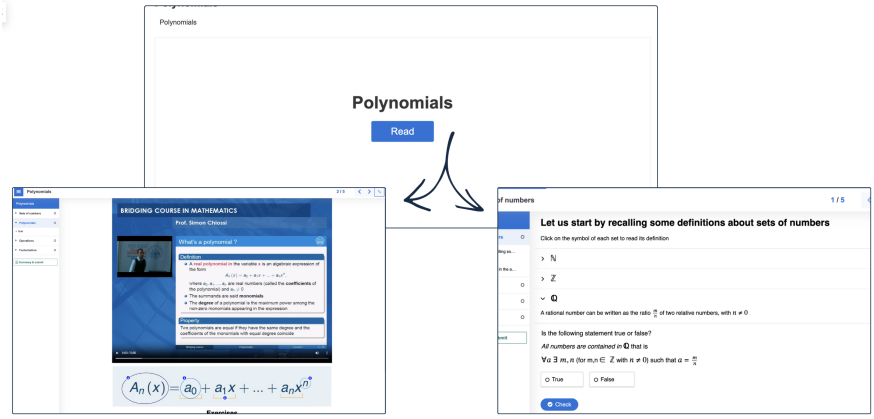

Fig. 2 A book with some examples of video and interactive materials

2.2 Gamification Elements

CIAO! integrates several key gamification elements designed to enhance engagement and motivation. Key gamified elements include experience points and levels, which students earn by completing exercises, watching videos, and interacting with games and course content. Accumulating points allows them to advance through levels, unlocking new challenges and providing a sense of accomplishment. Another unique incentive is the use of lottery tickets, awarded as students progress through levels. These tickets can be entered into prize draws, adding an element of excitement and motivation.

The platform incorporates game-based learning activities (Fig. 3) that transform traditional mathematical exercises into interactive challenges, making abstract concepts more tangible and approachable. These activities are complemented by broader

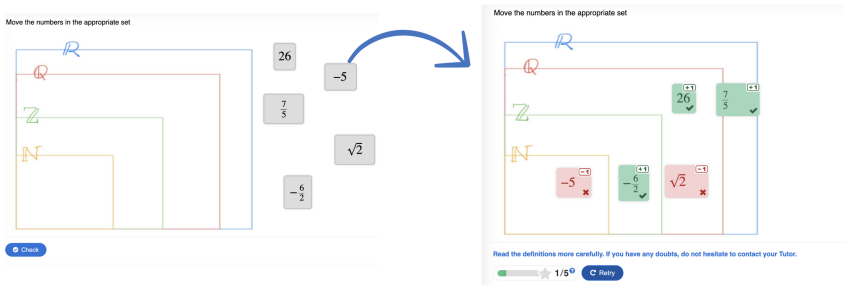

Fig. 3 Example of game exercises in CIAO! course

gamification principles (Fig. 4) that create a cohesive learning environment designed to sustain student interest and participation over time.

2.3 The Virtual Escape Room

The most innovative gamified element of CIAO! is the final self-assessment structured as a virtual escape room challenge (Fig. 5). This immersive experience goes beyond typical game mechanics, functioning simultaneously as an assessment tool and campus orientation guide. Set within the actual spaces of Politecnico di Torino, the escape room symbolically begins in the main lecture hall, where students must 'find their place' - an activity that metaphorically mirrors their entry into the university community while exercising their mathematical skills.

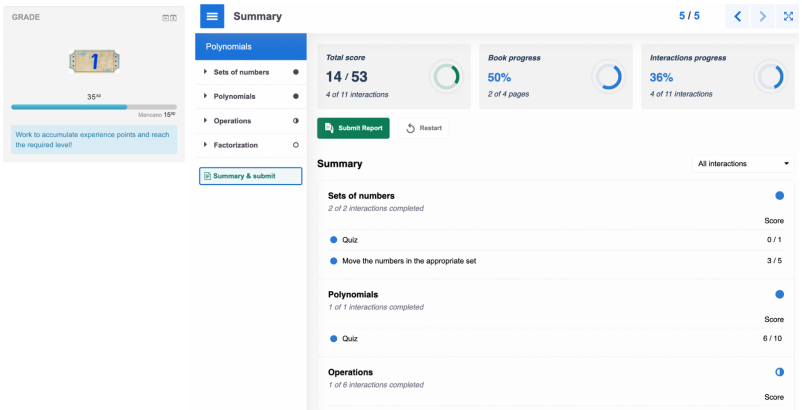

Fig. 4 Example of gamification elements in CIAO! course

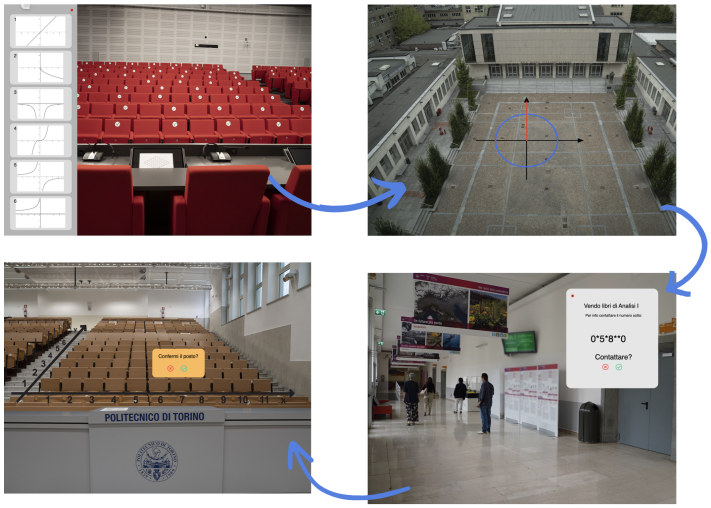

Fig. 5 Screenshots from the EscapeRoom

Throughout the 24-hour challenge, students virtually explore various university spaces such as classrooms, laboratories, and courtyards, solving mathematical puzzles strategically linked to the entire CIAO! curriculum. This contextual integration of educational content with the university's physical space represents a novel approach to gamification that facilitates both mastery of mathematical concepts and familiarization with the university environment.

The collaborative nature of the escape room promotes interaction and group problem-solving, simulating the teamwork dynamics students will encounter in their engineering studies. The immediate feedback system is supported by a hybrid support architecture that combines automated responses with targeted tutor interventions. When the system detects patterns of repeated errors, it proactively suggests students contact their assigned tutor, creating a data-driven personalized support mechanism that intervenes exactly when needed.

3 Implementation and Student Experience

This section presents the practical application of the CIAO! platform, detailing the targeted audience, implementation methodology, pedagogical approaches, and student feedback. The following subsections explore how the theoretical framework described in Section 2 was operationalized to address the challenges faced by students transitioning to university-level mathematics studies, with particular attention to the diverse needs of Politecnico di Torino's student population.

3.1 Target Audience

The CIAO! initiative was specifically developed to meet the diverse needs of students enrolling in engineering and architecture programs at Politecnico di Torino (around 6000 students yearly). Recognizing the varied backgrounds and challenges faced by incoming students, CIAO! aims to provide tailored support, ensuring that every student, regardless of their prior educational experiences, is adequately prepared to embark on their academic journey.

CIAO! is made available to students as soon as they pre-enroll, allowing them to use it as a preparation tool for the entrance test. The platform remains accessible throughout their first academic year, providing continuous support as they consolidate their mathematical foundations and navigate their initial courses.

In particular, one key group that CIAO! targets includes students with gaps in mathematical knowledge. Many individuals entering STEM programs struggle with foundational concepts due to differences in secondary school curricula, interruptions in their academic paths, or disparities in the quality of their previous education [2]. These gaps often involve critical topics such as polynomial manipulation, trigonometric identities, and logarithmic functions, which are essential for succeeding in engineering and architecture coursework.

International students also form an important segment (around 1000 students yearly) of the target audience. With Politecnico di Torino attracting a diverse and global student body, CIAO! has been designed to accommodate this variety by offering its resources in both Italian and English. This ensures inclusivity and provides much-needed support for international students, who may face additional challenges such as language barriers or differences in their prior education systems.

Another crucial group consists of students at risk of attrition. Those who perform below the required threshold in the mathematics section of the TIL are mandated to complete CIAO! as part of the university's Obligatory Additional Training (in Italian Obblighi Formativi Aggiuntivi - OFA) program (in average 1350 students yearly). These students are particularly vulnerable, as they are more likely to face difficulties in their first-year courses and are at a higher risk of dropping out.

Lastly, CIAO! also serves as a valuable resource for students in general. Even those without significant knowledge gaps can use the course as a means of reviewing key concepts or bridging the transition between their previous studies and the demands of university-level education.

The audience's heterogeneity presents specific challenges that CIAO! addresses through its flexible, dual-language and inclusive design. Another dimension of diversity lies in the variability in engagement levels among students. While some learners require structured interventions to actively engage with mathematical concepts, others thrive with self-paced learning tools that allow them to progress independently.

Psychological barriers also play a significant role. For many students, gaps in mathematical knowledge are exacerbated by a lack of confidence in their abilities, which can create feelings of anxiety and intimidation. To address this, CIAO! fosters a supportive and encouraging learning environment. Feedback is carefully designed

to motivate and reassure students, emphasizing progress and providing constructive guidance when difficulties arise.

3.2 Implementation Process

The implementation of CIAO! followed a staged approach that will be now discuss in detail to favour the adoption of similar instruments in other contexts.

1. ***Platform Selection*** - Choosing Moodle for its flexibility and familiarity to students together with H5P for its ability to support active learning. This combination provides:
   - Seamless integration with existing university systems
   - Rich interactive content capabilities
   - Built-in learning analytics
   - Mobile-friendly accessibility
2. ***Content Structure*** - Breaking down math concepts into digestible modules, ensuring:
   - Progressive complexity alignment with university requirements
   - Clear prerequisites and learning pathways
   - Flexible entry points based on student knowledge
   - Regular assessment opportunities
3. ***New design of contents*** - Review the material in a playful learning approach through:
   - Interactive visualizations of mathematical concepts
   - Immediate feedback mechanisms
   - Scenario-based problem solving
   - Multi-modal content delivery (text, video, interactive exercises)
4. ***Gamification Layer*** - Implementing points, levels and challenges via:
   - Experience points for completed activities
   - Achievement badges for mastery
   - Progressive unlocking of advanced content
   - Competitive and collaborative challenges
5. ***Support System*** - Establishing the peer tutoring network through:
   - Selection and training of student tutors
   - Multiple communication channels (chat, virtual classrooms)
   - Scheduled availability during peak usage times
   - Regular feedback collection and system adjustment

The tutor figure is an essential component of CIAO!'s support structure. Tutors are Politecnico di Torino students who provide targeted assistance to their peers. They are available on demand via chat or virtual classrooms, offering timely support, answering questions, and helping students navigate complex topics. This peer-to-peer interaction not only enhances learning outcomes but also creates a sense of community, reinforcing the idea that students are not alone in their academic journey.

3.3 Pedagogical Design

The modular structure of CIAO! is deeply rooted in a constructivist approach, with a particular focus on scaffolding, i.e. gradually building each student's knowledge and skills in a way that supports their individual learning journey.

Each module is designed to offer personalized pathways, enabling students to concentrate on their specific areas of weakness. This flexibility promotes self-directed learning, allowing students to prioritize topics where they need the most support while progressing at their own pace. By addressing individual needs, CIAO! empowers students to take ownership of their learning process, which is particularly crucial for those transitioning to the rigor of university-level studies.

The design of the modules incorporates an incremental challenge approach, where the content progresses from foundational exercises to more advanced and complex applications. This careful scaffolding ensures that students first solidify their understanding of the basics before moving on to higher-level problem-solving. By breaking down the learning process into manageable steps, students experience a sense of achievement as they advance, which further enhances their confidence and motivation.

By embedding continuous feedback loops into exercises, students are encouraged to engage actively with the material. This immediate feedback allows them to recognize and correct errors in real-time, reinforcing a growth mindset. The process helps students develop a stronger ability to self-assess and enhances their perception of their own metacognition. These elements are crucial for successfully navigating university studies, where, unlike in secondary education, students are expected to take greater responsibility for their learning, including ongoing self-evaluation.

CIAO! also places significant emphasis on accessibility and inclusivity, ensuring that the course adapts to the diverse needs of its audience. Hosted on the istitutional Moodle platform, the course allows students to learn whenever and wherever it suits them, accommodating those with external commitments or varying schedules.

3.4 Student Feedback and Qualitative Insights

Our study employed a mixed-methods approach to evaluate CIAO!'s effectiveness, combining qualitative interviews with quantitative platform usage data. We con-

ducted semi-structured interviews with students representing diverse backgrounds: those with mandatory OFA requirements, international students, and domestic students who voluntarily engaged with the platform. These interviews were complemented by data from the Moodle platform tracking engagement patterns, module completion rates, and academic outcomes.

The qualitative data was analyzed using thematic analysis to identify patterns in student experiences, focusing on engagement with gamified elements, mathematical confidence development, support for educational transition, and development of independent learning skills.

Gamification emerged as a transformative feature of CIAO!, with interviewed students frequently citing game elements as their primary motivation for sustained engagement. The escape room proved particularly effective in both testing mathematical knowledge and introducing students to the university environment. One international student highlighted: "The escape room was challenging but fun. It tested our math skills while also showing us important places at the university. It was the first time I felt I belonged here."

A recurring theme in students' feedback was the transformation of mathematical anxiety into growing confidence. The immediate feedback system was frequently cited as crucial for this development, allowing students to identify and correct errors in real-time without external intervention.

CIAO!'s role in facilitating the transition to university education was particularly evident for international students, who faced unique challenges in adapting to a new educational system. The platform's interactive and inclusive design promoted peer interaction through gamification elements, fostering both informal competition and collaboration.

Beyond content mastery, CIAO! fostered critical competencies for university success. The modular structure encouraged self-directed learning, with many interviewed students reporting improved ability to manage their own learning process. Students particularly valued how the program combined structured learning with autonomy, equipping them with both the knowledge and mindset needed for higher education success.

Quantitative data supports this success, with approximately 50% of students fulfilling their OFA requirements through the platform. The platform analytics showed that students progressively developed more efficient study patterns, suggesting improved metacognitive awareness.

Students' participation in feedback interviews was voluntary. Since the quantitative data used in this study consisted only of institutional records on student progression and resource utilization already collected by Politecnico di Torino as part of standard educational operations, no additional specific consent was required for this analysis. All quantitative usage data was analyzed in anonymized form in accordance with institutional privacy policies and relevant data protection regulations.

4 Impact and Scalability

The implementation of CIAO! has yielded significant outcomes in terms of engagement, retention, and academic preparation. These benefits demonstrate the efficacy of gamified learning approaches in addressing fundamental gaps in mathematical knowledge while fostering positive attitudes toward STEM education.

4.1 Educational Outcomes

CIAO!'s use of gamification principles has led to marked improvements in student participation. Students actively interact with course content through H5P exercises, gamified feedback loops, and the escape room challenge. Surveys indicate that students found these features highly motivating, with many highlighting the program as more engaging than traditional preparatory courses. While, the incremental nature of challenges, paired with visible progress indicators, encourages students to return to the platform regularly. Data from the Moodle platform shows a high rate of repeated logins and module completion.

Despite its success, the CIAO! initiative faces challenges that must be addressed to further optimize its effectiveness. Initial analyses are limited to a very specific population, while the program has yielded promising results, broader datasets are required to generalize its impact. The results primarily reflect the experiences of students flagged as at-risk based on TIL scores. Future iterations could benefit from data on a wider range of students, including those who score above average but still benefit from preparatory resources.

4.2 Student Experience

Reflecting the literature evidence, gamified approaches like CIAO! challenge the traditional, lecture-based model by emphasizing interactivity and personalization. In particular it increase intrinsic motivation, as students perceive learning as a rewarding process and foster a sense of achievement, which positively impacts self-efficacy and persistence.

4.3 Broader Educational Goals

CIAO! aligns with several United Nations Sustainable Development Goals (SDGs), demonstrating its broader significance in promoting equitable and inclusive education. By leveraging innovative pedagogical approaches, the initiative contributes to building a more accessible, diverse, and sustainable academic environment.

CIAO! directly supports SDG 4: Quality Education by ensuring that all students, regardless of their educational background, have access to the fundamental mathematical knowledge required for success in STEM fields. By addressing gaps in mathematical preparedness, the program creates a more equitable learning environment, reducing the risk that students with weaker foundations are left behind. Additionally, its gamified and interactive approach aligns with modern educational methodologies that emphasize active engagement and lifelong learning, challenging traditional, passive modes of instruction.

The underrepresentation of women in STEM remains a global challenge, and SDG 5: Gender Equality emphasizes the need to empower female students in these fields. CIAO! fosters an inclusive and supportive learning environment, helping to build confidence in mathematical skills, an area where self-doubt can disproportionately affect female students due to societal stereotypes. By lowering barriers to entry and encouraging participation, CIAO! contributes to greater gender diversity in engineering and technical disciplines.

Education is a key driver of social mobility, but disparities in pre-university preparation can create obstacles for students from different socio-economic backgrounds. In line with SDG 10: Reduced Inequalities, CIAO! levels the playing field by providing free, flexible, and accessible learning resources. Regardless of their prior education, whether from a well-resourced institution or an underserved school, students can strengthen their foundational knowledge and enter university with greater confidence.

4.4 Scalability and Cross-Disciplinary Applications

Although CIAO! is primarily focused on mathematics, its underlying principles can be effectively extended to other disciplines where students face similar transitional challenges. The name itself, Online Accompanying Interactive Course, reflects its purpose of guiding students through educational transitions, particularly the critical shift from secondary to tertiary education.

In humanities and social sciences programs, a CIAO!-inspired approach could address common transitional gaps in academic writing, research methodology, and critical analysis. For example, first-year arts or social science students often struggle with the transition from descriptive to analytical writing; a gamified module could progressively develop these skills through interactive challenges that provide immediate feedback on argumentation structure and evidence use. For language degree programs, the framework could support the transition between general language proficiency and academic or specialized language competence. Interactive modules might help students navigate discipline-specific vocabulary, academic writing conventions, and analytical frameworks particular to linguistic studies. In professional degree programs like law, business, or education, the CIAO! model could bridge the gap between theoretical knowledge and applied professional competencies. Gamified scenarios might simulate professional decision-making contexts that require

the application of theoretical principles, helping students transition from knowledge acquisition to practical implementation.

The core strength of CIAO!—its ability to identify and address knowledge gaps during critical educational transitions—remains central to these adaptations. While the specific content would change to reflect disciplinary needs, the underlying pedagogical approach of using gamification to support students through challenging educational transitions maintains its relevance across diverse academic contexts.

4.5 Implementation Framework

The successful implementation of a gamified preparatory course like CIAO! requires careful planning of resources, infrastructure, and timeline. Our experience has shown that several key elements are crucial for institutions seeking to develop similar initiatives. From a technical perspective, the foundation of such a program requires a Learning Management System that seamlessly integrates interactive content development tools like H5P. This must be complemented by reliable communication channels between students and tutors, including platforms for online consultations and virtual classrooms when needed.

The human resource component is equally critical. The development team should include at least two faculty members dedicated to reviewing and reimagining existing course materials through a gamification lens. A project coordinator plays a vital role in bridging technical and pedagogical aspects while managing student-faculty relationships. The tutoring system, which is a support system used just in case of doubts, in our experience, has an optimal ratio of one tutor per 150-200 students. This is mainly because only 10-15% need personalized human support if the tool is well designed.

Implementation typically follows a nine-month cycle. The first four months focus on content restructuring and platform development, followed by a two-month pre-enrollment phase where early access and testing occur. The period between enrollment and course start, typically two months, is crucial for intensive student support and system refinement. An additional month of support during the initial course period helps students integrate their preparatory work with formal coursework.

Through CIAO!, we have identified several potential pitfalls that institutions should be aware of. One common challenge is overcomplicating the gamification elements, while engaging features are important, they should not overshadow the learning objectives. Another crucial consideration is content preparation time; institutions often underestimate the effort required to transform traditional materials into interactive, gamified content. Additionally, maintaining the right balance between automated support and human intervention is essential - while the system should promote autonomy, students should still have clear pathways to access help when needed.

Success can be monitored through various indicators. Platform engagement metrics, including access frequency and module completion rates, provide immediate feedback on student participation. Student progress through the platform levels and their interactions with tutors offer insights into learning effectiveness. Academic performance metrics, such as the completion of remedial requirements, help validate the program's impact on student success.

Our experience has also highlighted the importance of maintaining regular communication with all stakeholders and ensuring that the support system remains responsive to student needs throughout the implementation process. This comprehensive approach helps create a sustainable and effective preparatory program that truly serves student needs while meeting institutional objectives.

The scalability of CIAO! positions it as a model for other disciplines and institutions seeking to support student transitions. The modular structure and gamified elements of CIAO! can be adapted to different subject areas or can provide a blueprint for institutions aiming to implement preparatory programs. Cross-institutional collaboration could lead to shared resources and best practices, reducing development costs and promoting innovation.

CIAO!'s success also highlights the potential for collaboration between universities, educational organizations, and policymakers, reinforcing SDG 17: Partnerships for the Goals. The effectiveness of gamified learning in improving student engagement and retention opens avenues for scaling similar initiatives across different institutions. By sharing insights and best practices, CIAO! can contribute to a broader movement toward innovative, student-centered education, making learning more engaging and inclusive on a global scale.

In this way, CIAO! is not just an educational tool: it is a sustainable, scalable model for addressing educational challenges, ensuring that all students, regardless of background, can thrive in their academic journey.

5 Conclusion

CIAO! has demonstrated its effectiveness as an innovative intervention in higher education. By integrating gamification with established pedagogical principles, CIAO! has successfully addressed gaps in mathematical knowledge, enhanced student engagement, and contributed to reducing early dropout rates. This initiative represents a proactive response to one of the most critical challenges in STEM education: the transition from secondary school to university-level learning.

The key contributions of CIAO! can be summarized as follows:

- Increased Access and Equity: The program offers flexible, self-paced learning opportunities, ensuring that students from diverse educational backgrounds can access high-quality preparatory support.
- Enhanced Motivation and Engagement: Gamified features (such as immediate feedback, progress tracking, and escape room challenges) promote an interactive and enjoyable learning experience.

- Strengthened Academic Foundations: By focusing on essential mathematical prerequisites, CIAO! equips students with the skills and confidence necessary for the rigors of their education.
- Improved Student Retention and Orientation: Beyond academic preparation, CIAO! facilitates the transition to university life, reducing feelings of intimidation and fostering a sense of belonging.

CIAO! stands as a model for leveraging digital tools and gamification to enhance preparatory education and improve student orientation. Its success highlights the potential of innovative learning strategies to address long-standing challenges in higher education.

Despite CIAO!'s demonstrated success, it is important to acknowledge certain limitations of both the platform and this study. From a methodological perspective, our evaluation relies primarily on key metrics such as OFA completion rates and platform engagement which, while providing compelling evidence of the program's positive impact, could be complemented by more robust quantitative measures of learning outcomes and longitudinal tracking of student performance. The platform itself faces technological constraints, particularly in the sophistication of its adaptive learning capabilities, which currently cannot fully personalize content based on individual learning patterns or misconceptions. Additionally, while gamification elements have proven effective, their impact may vary across different student populations, with some potentially finding certain game mechanics less engaging than others. The escape room assessment, while innovative, requires significant development resources that may challenge institutions with limited technical support. Furthermore, the platform's effectiveness for students with specific learning disabilities or those requiring specialized accommodations requires further investigation. Acknowledging these limitations provides critical direction for future refinements and research, ensuring that subsequent iterations of CIAO! and similar gamified learning environments continue to evolve in addressing the complex challenges of STEM education transitions.

CIAO! has been built on several critical factors that emerged through our implementation experience. At its core, the strategic integration of gamification elements with pedagogical objectives proved essential - ensuring that playful features enhanced rather than distracted from learning outcomes. The flexible, modular approach allowed students to progress at their own pace while maintaining clear learning pathways, a balance that proved crucial for accommodating diverse learning needs.

Another key factor was the carefully calibrated support system that combined automated feedback with targeted human intervention. This approach provided assistance when needed without creating dependency, encouraging student autonomy while ensuring no one fell behind. The active involvement of all stakeholders - faculty, tutors, and students - throughout the development and implementation process created a sense of shared ownership and continuous improvement. Clear communication channels and transparent expectations for both students and support staff facilitated smooth operation and timely adjustments when needed.

The technical reliability of the platform and continuous monitoring of student engagement proved equally vital. Regular assessment of progress and participation enabled timely interventions and platform refinements, ensuring the system remained responsive to student needs while maintaining its educational effectiveness.

CIAO! makes several contributions to both the Scholarship of Teaching and Learning (SoTL) and Serious Games research. From a SoTL perspective, the initiative offers valuable insights into how gamification can address specific pedagogical challenges in STEM education, particularly in supporting the secondary-to-tertiary transition. The modular structure and incremental approach to mathematical concept development provides a model for scaffolding complex STEM content that could be adapted across disciplines. Additionally, CIAO!'s implementation and evaluation framework contributes to our understanding of how institutional support structures can be effectively integrated with digital learning tools to create comprehensive student support ecosystems.

From a Serious Games research standpoint, CIAO! demonstrates how carefully designed game mechanics can be aligned with specific learning objectives without relying on advanced technologies. The escape room challenge, in particular, illustrates an innovative approach to assessment that combines spatial awareness, collaborative problem-solving, and content mastery in a contextually relevant environment. By documenting the design decisions, implementation challenges, and student responses to these gamified elements, this study provides valuable data for researchers investigating the efficacy of game-based learning in higher education contexts.

Building on the achievements of CIAO!, future developments should focus on expanding the reach and impact of gamified preparatory courses. Potential areas for growth include:

- Broadening Disciplinary Scope: Adapting CIAO!'s methodology to additional subject areas, such as physics, chemistry, programming, and the humanities, to provide comprehensive support for incoming students.
- Enhancing Personalization: Leveraging learning analytics and artificial intelligence to develop adaptive modules that respond dynamically to students' individual progress and needs.
- Longitudinal Impact Assessment: Conducting long-term studies to evaluate the sustained effectiveness of gamified preparatory courses in academic performance, retention, and student success.
- Implementation of adaptive learning techniques: While the current version of CIAO! offers flexible learning paths and immediate feedback, a natural evolution would be the incorporation of AI-based adaptive systems. These systems could analyze student error patterns, identify specific conceptual gaps, and automatically generate personalized content, challenges, and exercises calibrated to each student's individual proficiency level. This evolution toward a more intelligent learning system could further enhance CIAO!'s effectiveness in bridging students' mathematical gaps, augmenting the already robust gamified foundation with an advanced layer of algorithmic personalization.

Furthermore, CIAO!'s scalability presents opportunities for collaboration between universities, educational organizations, and policymakers. By sharing resources and best practices, institutions can drive the widespread adoption of gamified strategies, fostering a global movement toward more engaging and effective educational experiences.

CIAO! exemplifies the transformative potential of playful learning and gamification principles in addressing the challenges of higher education. As institutions worldwide seek to enhance access, equity, and student outcomes, initiatives like CIAO! offer a scalable and adaptable blueprint for creating inclusive and engaging learning environments. By fostering continuous innovation and collaboration, the education sector can unlock new pathways for student success, ensuring that learners are well-equipped to thrive in the 21st century.

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