ISBN: 978-628-95207-8-1. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2024.1.1.1000

Cultivating Creativity: A Journey in the Fundamentals of Information Technology Infrastructure Course

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Abstract*– In the constant search for effective pedagogical strategies aimed at the comprehensive development of skills in students and with the purpose of contributing to social development, teachers must implement innovative approaches for the development of critical thinking, creativity, entrepreneurship, and socially responsible behavior. This research uses a methodology centered on strengthening creativity for systems engineering students in the subject of Fundamentals of Information Technology Infrastructure. By applying a proprietary methodology based on Design Thinking and challenge-based learning to university students, it reveals that 95.6% of students were satisfied with how the subject was conducted, using development boards (Arduino, NodeMCU, and Raspberry Pi), emphasizing how to create their first creative project and collaborate in a team. Additionally, it is evident that students strengthened their soft skills, as they are motivated to participate in different multidisciplinary innovation and/or entrepreneurship contests.

Keywords*— Systems Engineering, Challenge-Based Learning, Design Thinking, Development Board, University Social Responsibility.

I. Introduction

Currently, we find ourselves in a globalized society that demands individuals who are increasingly up-to-date and possess multiple skills enabling them to face challenges and seize opportunities in the interconnected world. Companies seek professionals capable of effectively addressing complex problems, in addition to having a comprehensive approach that facilitates decision-making. The importance of developing comprehensive competencies in the education of university students is emphasized, where soft skills, critical and creative thinking, entrepreneurial mindset, and socially responsible behaviors are also encouraged [1].

In this context, universities face new challenges related to the teaching-learning process, allowing them to align with the demands of current knowledge and technology while also committing to providing quality education [2].
Teachers play a crucial role in this mission; however, a common issue, as described in various studies, is the limited implementation of active educational methodologies that promote students' critical and reflective capabilities, leading to demotivation and dissatisfaction [1]. According to the research by Vries and Navarro [3], it is known that students do not recognize the value and relevance of what they learn, as they do not perceive the direct connection between their learning and what is necessary for their future jobs. This opens up an immense need to generate appropriate learning activities that transfer knowledge to students and enhance their learning experience [4]. From this issue, various methodologies have emerged with the aim of involving and motivating students, improving their learning, and enhancing their ability to build new knowledge. It is considered that current students have all knowledge at their fingertips and tend to be more independent as long as the topic is of interest to them [5]. Emphasizing learning by doing instead of simply knowing [6].

This paper proposes a new framework based on Design Thinking and Challenge-Based Learning [7] for teaching the Fundamentals of Information Technology Infrastructure course. This framework aims to contribute new innovative ways of learning, focusing on creative thinking and problem-solving skills while ensuring that projects are socially responsible.

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II. Background

Hernández, Vallejo, Tudón, Hernández, and Morales [8] state in their research that students' preparation must be competitive to be able to address society's main problems when entering the job market. Active learning is a crucial approach to achieving this goal, providing tangible results quickly, being attractive to students, and easy to implement. In the study conducted by Fidalgo, Sein, and García [9], the challenge-based learning methodology is adapted to an academic subject, integrating both challenge-based learning and challenge-based instruction. The course proposes two types of challenges: a specific challenge in the academic environment and a common challenge on a knowledge management system with proven effectiveness. The results allow for more effective solutions to the challenges proposed, as well as an improvement in the learning process.

Additionally, Membrillo, Ramírez, Caballero, Ganem, Bustamante, Benjamín, and Elizalde [10] expose in their

Digital Object Identifier: (only for full papers, inserted by LACCEI).
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research that challenge-based models promote student participation in challenging and interactive experiences, developing both disciplinary and transversal competencies, supporting engineering education by improving students' ability to solve new problems and transfer knowledge from one context to another. This approach gives education a practical sense and helps develop key skills such as collaborative and multidisciplinary work, decision-making, advanced communications, ethics, and leadership. In addition, Chanin, Pompermaier, Sales, and Prikladnicki [11] state in their research that most universities worldwide have recognized the importance of providing entrepreneurial skills to engineering students, as being competent is essential but not sufficient. The development, marketing, and sale of products and/or services are fundamental for the current reality. The advancement of new technologies has forced students to be prepared for the current business uncertainty, maximizing knowledge and minimizing risks. Therefore, the development of both technical and soft skills is of utmost importance for the formation of entrepreneurial professionals in the current context.

In the research conducted by Ahmed, Dannhauser, Philip [12], the development of software is proposed using the Lean Design Thinking methodology to guide the development of modern data projects. The article concludes that there is no correct method, and a single approach is not sufficient; rather, a mix of them, combining different elements from each approach, can help guide innovative data projects. In the work carried out by Gama, Alencar, Calegario, Neves, and Alessio [13], a methodology is presented for organizing a hackathon as a learning tool in an undergraduate course. Hackathons are short events (1 to 3 days), where participants motivated by a common challenge gather in groups to build a software or hardware prototype. The researchers also highlight the importance of hackathons as an informal learning approach for university students. Knowledge acquisition comes as a result of the practice itself, with participants learning from each other. This motivated the researchers to bring this practice to the classroom, offering an undergraduate course where students develop their semester project within a hackathon. The approach combines challenge-based learning and design thinking concepts in a sequence of activities that streamline the ideation process with regular deliveries in short deadlines. This results in objective discussions and quick decision-making, quickly reaching a project idea where students apply what they learned during the semester. They applied this approach in an undergraduate Internet of Things course within a semester project developed in a real 24-hour hackathon.

Finally, to develop the learning process proposed in this research in the subject of Fundamentals of Information Technology Infrastructure it is necessary to meet the competencies of the course, being necessary to analyze, apply and integrate electronic equipment that achieve to develop creative prototypes solving real problems detected by each team of students. Thanks to technological advances it has been seen convenient to use electronic boards such as Arduino [14] or Raspberry pi [15], both electronic boards in recent years present prototypes of creative projects, which demonstrates the possibility of using it in this research by applying the own methodology based on Design Thinking and challenge-based learning.

II. METODOLOGY

For the development of the learning proposal, the use of Design Thinking and Challenge-Based Learning methodology is required.

A. Design Thinking

Nakata and Hwang [16] define Design Thinking as a design-based approach to problem-solving that applies logic, theoretical principles, practical application, various tools, and available models. It focuses on a holistic perspective, visualization, experimentation, and reasoning. Additionally, Nakata and Hwang [16] explain that Design Thinking involves five main steps: defining, ideating, creating, and testing, which can be complemented by tools and attributes specific to the problem being addressed, recognizing that design is multidimensional. Parizi et al. [17] add that the application of Design Thinking in technology supports users in understanding their goals, needs, and constraints, fostering empathy and collaboration in interaction between parties. Furthermore, Veflen and Gonera [18] explain that a common challenge in development and innovation is that people have different ideas and tendencies from their own perspective, allowing the development of novel solutions that encourage the willingness to share information, skills, and resources. Finally, Laferriere, Engeler, and Rixon [19] also state that the most powerful tool is the ability to ask questions, turning both the teacher and students into self-aware design thinkers, learning from themselves, their creativity, and their communication abilities.

The stages applied according to the design thinking methodology were:

1. Empathize: The first phase consisted of understanding the needs of society.
2. Define: In this phase, the information collected during the empathy phase was synthesized to clearly and concisely define the problem. A problem statement was created to guide the creative process.
3. Ideate: The ideation phase seeks to generate a large number of creative ideas to address the defined problem, using techniques such as brainstorming.
4. Prototype: Prototypes were created to test the ideas and obtain user feedback.
5. Test: The prototype was validated with users.

B. Challenge-Based Learning (CBL)

CBL is a methodology for experiential learning that has been incorporated as a teaching and learning strategy for the fields of science and engineering. This strategy enables students to address real challenges and solve problems according to the knowledge and skills acquired in their education, under the guidance of the teacher [20], [21].

The CBL approach aims for the student to identify a challenging topic and seek possible approaches, ultimately proposing solutions that can be implemented within a framework of sustainability and environmental responsibility. Reflection and evaluation are constant aspects at each stage. Colombeli et. al [22] and Martinez et al [23] demonstrate that CBL has shown a positive effect on the development of soft skills and entrepreneurial intention among university students.

The CBL white paper [24] defines Challenge-Based Learning as a process that begins with a great idea, moves to an actionable challenge, and finally, the implementation of a carefully considered solution. The details of each phase are presented in Table 1.

TABLE I
CHALLENGE-BASED LEARNING STAGES [24]

Name	Description
Big Idea	A broad concept that can be explored in multiple ways, is engaging, and has importance to students and the broader society.
Essential Question	A process of personalizing and pinpointing the important concepts within the big idea.
Challenge	A call to action designed by professors and students to créate a solution that can result in concrete action.
Guiding Questions	A series of questions developed by the learning community, identifying and representing the knowledge and skills needed in order to develop a successful solution.
Guiding Activities and Resources	The activities and resources that learners identify, participate in and utilize to answer the guiding questions.
Analysis	A process for exploring the answers to the guiding questions and identifying overarching themes and concepts. This sets the foundation for solutions.
Solution	A concrete, actionable and clearly articulated idea to solve the challenge. Complicated challenges will often have multiple solutions.
Implementation	This in when the solutions are put into action with an authentic audience.
Evaluation	Learners evaluate their process through the results of the implementation and refine their solution

In this context, Yang et al. [25] explain that the model in Fig. 1 is applicable for the implementation of Design Thinking and Challenge-Based Learning in education. The proposal consists of 7 steps:

a) Big idea
b) Essential Question
c) The Challenge
d) Guiding Question
e) Solution
f) Evaluation/Assessment
g) Publishing

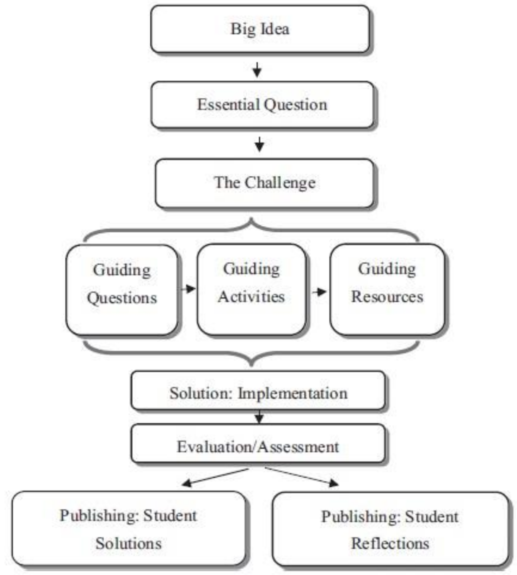

Fig. 1 Challenge Based Learning framework [25].

For the implementation of the proposed methodology, it is necessary to mention that it is a cycle that has the option to be feedbacked over time according to the needs of the subject and the evolution of new technologies (see Fig. 2).

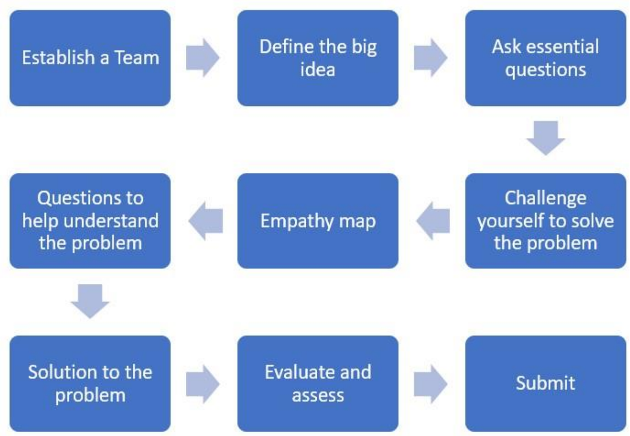

Fig. 2. Proposed Methodology

II. DEVELOPMENT OF THE PROPOSAL

The course "Fundamentals of Information Technology Infrastructure" is offered in the Professional School of Systems Engineering during the third semester. It is a theoretical and practical course designed to cover the fundamental concepts of development boards, virtualization, and cloud computing.

The course consists of 2 hours of theory and 4 hours of practical sessions weekly. During the pandemic, it was conducted in a hybrid format (both in-person and virtual), and post-pandemic, it is conducted in-person. The theoretical part is divided into two theoretical sections, and the laboratory practices accommodate a maximum of 16 students.

The semester in the Professional School of Systems Engineering is divided into three phases, with three sessions held for each phase. The semester lasts for 6 weeks, and at the end of each phase, a theoretical exam is conducted. In the laboratory sessions, an activity is assigned to be completed during the week and is graded by the lab instructors.

The proposal covers the following topics:

A. **Theory**

- **Phase 1**: Different computer components were taught, and an introduction to development boards was provided. Considering that various systems nowadays use similar hardware components such as CPU (Central Processing Unit), memory, power supplies, among other important parts. In this initial phase, students are encouraged to collaborate creatively in teams to propose a significant idea for solving a problem that can be automated. They are presented with various essential questions to encourage analytical thinking about what they want to solve, fostering curiosity and generating new ideas.

- **Phase 2:** Students are taught how to use the development board with various sensors and actuators, utilizing the Raspberry Pi. They are provided with essential knowledge about an operating system and the programming of the Raspberry Pi along with its corresponding GPIO. Concurrently, each session involves reviewing the progress of their creative project and asking increasingly profound questions to enhance their creative capacity to solve the problem using the components taught in the course. In their creative project, each team is given a format to fully detail their proposal to ensure viability. Additionally, they are required to present a first low-fidelity prototype of their proposal. The team is also asked to interview the person or community experiencing the issue to gain a deeper understanding of the problem.

- **Phase 3:** In this final phase, the fundamentals of virtualization and cloud computing are provided for the most essential components. This enables students to understand that it is possible to create websites and/or web platforms that can be linked to the proposed automation system. Regarding their creative project, it is evaluated, and improvement advice is given. Finally, they create an explanatory video that showcases their proposed solution in 3 to 5 minutes, demonstrating their high-fidelity prototype.

B. **Laboratory Practices:**

Practice 1: Getting to Know Components: PC Hardware and Development Boards.
The components of a desktop PC, laptop, as well as development boards such as Arduino, NodeMCU, and Raspberry Pi have been successfully taught. Soft skills like communication and teamwork have been reinforced through videos.

Practice 2: Applications for Development Boards
Students are taught to use development boards such as Arduino and NodeMCU, along with their respective sensors and actuators, enabling the creation of small prototypes. Furthermore, understanding the use of development boards, a subsequent activity is conducted where the student team identifies a real problem and describes it using the problem tree technique.

Practice 3: Progress of the Creative Project
This practice focuses on showcasing the team's first progress in their creative project. Students are asked to improve their problem tree and then generate the objective tree. Additionally, they are required to describe their proposal in a maximum of 300 words, considering the three parts it should contain: introduction, solution proposal, and expected outcomes.

Practice 4: Linux Distributions (Operating Systems)
Students are taught to use basic commands in a Linux distribution. As it is their first time with a Linux distribution, online (Internet) distributions are used. In the last 30 minutes of the practice, they are asked to make progress on the low-fidelity prototype for their creative project.

Practice 5: Application Development with Raspberry Pi
The Raspberry Pi development board was used, where initial exercises were conducted using GPIO (General Purpose Input/Output), sensors, and actuators. Similarly to the previous practice, in the last 30 minutes, students are asked to interview the person or community facing the issue to further refine their project.

Practice 6: Progress of the Creative Project
In the second update, students are first given tips on how to prepare their presentation. Then, the student team is asked to create a video presenting their low-fidelity prototype (see fig. 3), their empathy map, and the project's feasibility. Finally, they are instructed to

attach evidence of having conducted an interview with the person facing the issue they aim to resolve before submission.

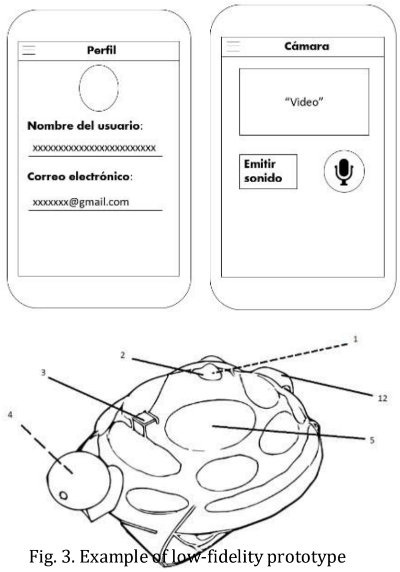

Fig. 3. Example of low-fidelity prototype

Practice 7: Operating System Virtualization

Students are taught to virtualize different operating systems on both Linux and Windows, such as Ubuntu and Windows 10. Additionally, they learn to use cloud computing, understanding that startups commonly utilize this service.

Practice 8: Creative Project Review.

The first draft of the scientific article is developed, showcasing various articles that utilize the Arduino, NodeMCU, or Raspberry Pi development boards. The practice leader provides guidance on how each team's project should be oriented, with 15 minutes allocated for each. Teams are also asked to present progress on their high-fidelity prototype, providing more details on their intended development. Finally, examples are given on how they should present their project, allowing interested parties to demonstrate the project's viability.

Practice 9: Creative Project Presentation

Teams must create a 3 to 5-minute video showcasing their high-fidelity prototype (see fig. 4). The best projects are submitted to the university's grant competition, where students can decide which faculty member they would like to collaborate with to further develop their project.

Fig. 4. Example of High-Fidelity Prototype

To initiate the proposed approach mentioned above and promote the strengthening of creativity in each team of students (3 to 5 students), the university's social responsibility department was invited to discuss the different projects developed by each of the Professional Schools. Additionally, common issues in Latin American cities were also mentioned.

IV. Results and Discussion

The purpose of this document is to demonstrate the learning experience achieved by applying the concepts of Challenge-Based Learning methodology accompanied by the Design Thinking methodology in the Fundamentals of Information Technology Infrastructure Course.

Lin et al. [26] point out that engineering students should possess capabilities related to problem-solving, information gathering, and decision-making, which will strengthen their competencies in the engineering design field. In this context, Lynch et al. [27] highlight the need for future engineers to not only exhibit skills related to technological knowledge but also to develop soft skills, including decision-making, creative thinking, oral and written communication, and teamwork, fostering an entrepreneurial vision. However, various studies indicate that these skills are not being acquired by university students [7].

According to the study by Cyril et al. [28], it has been demonstrated that students who fail to develop the aforementioned skills often attribute it to the use of traditional teaching-learning strategies. Therefore, the mentioned authors recommend the implementation of project-based methodologies. Additionally, Caeiro et al. [29] identifies pedagogical strategies necessary for soft skills development in engineering students, including Challenge-Based Learning, Design Thinking, competency-based learning, cooperative learning, blended learning, gamification, and flipped classroom.

On the other hand, Zhang et al. [30] demonstrate that experiential learning with challenge-based teaching methods promotes the development of personal skills such as systematic thinking and the ability for independent innovation. This is in contrast to students who undergo learning based on traditional educational methods.

The results of this study show that the implementation of pedagogical strategies aligned with experiential learning, such as Design Thinking and Challenge-Based Learning, contributes to student satisfaction (see Table II). In Table II, it is observed that at the beginning of the course presentation, there is a fear of the course not being very interesting, with student satisfaction at 69.6%. However, upon completing the course, a final survey was conducted, resulting in a satisfaction rate of 95.6%.

TABLE II
STUDENT SATISFACTION SURVEY IN THE COURSE

Initial Survey					
Will the course meet your expectations?	VS	S	I	LS	NS
Responded 113	7,6%	62%	27%	3,5%	0%
Final survey					
Did you like the development of the course?	VS	S	I	LS	NS
Responded 113	76,1%	19,5%	4,4%	0%	0%

VS: very satisfying **S**: Satisfying **I:** Intermediate
LS: Little satisfying **NS**: Not satisfying

To assess the main impact of the course, a specific question was asked regarding whether they enjoyed developing a creative project in teams. Before starting the course, students had a satisfaction rate of 36%, but after completing the course, satisfaction increased to 89%. There is a margin of 5% indicating that some students did not have a successful teamwork experience to complete the course.

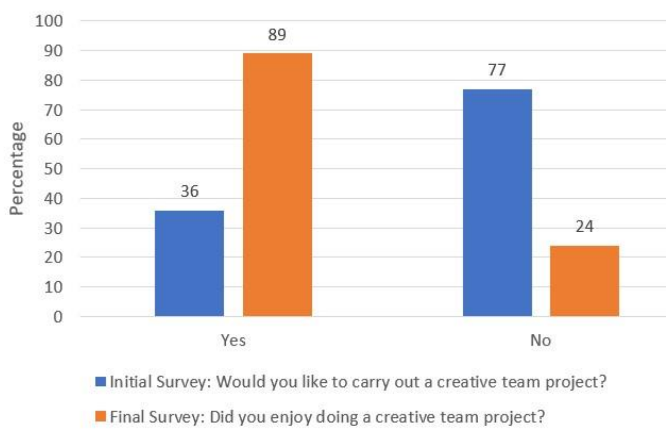

Fig. 5. Comparative satisfaction chart

This proposal is consistent with the approach outlined by Portuguez Castro et al. [31], emphasizing that the implementation of the CBL methodology corresponds to a more active learning with a higher level of understanding because students can reflect on the practical application of their knowledge and its significance. Linton et al. [32] also suggest that the implementation of active learning contributes to the student's ability to create new solutions to problems with which they identify. This allows us to establish a connection between the teacher and the student, which is deepened by the inclusion of the Design Thinking methodology.

Through this experience, students had the opportunity to create a final low-cost theoretical prototype along with a draft of a scientific article. According to Khaled et al. [33], these processes enable students to focus their ideas and achieve greater learning about the user experience, breaking down a significant challenge into a functional solution.

Furthermore, by incorporating processes related to Hackathon culture, creativity and entrepreneurship are encouraged in students, achieving enthusiasm and commitment, as mentioned by Kiev Gama et al. [13]. Additionally, organizers of various entrepreneurship and innovation events use multiple tools and different activities to engage university students and provide proposals for solving societal problems [34].

This pedagogical approach allows us to leverage the student's interests and preferences for a practical purpose. It adds value through multidisciplinary teamwork, decision-making, leadership, and communication [35]. This experience can be applied to other undergraduate students from differents areas, as mentioned by Van den Beent et al. [36]. The challenge-based learning methodology contributes to academic achievement in meeting the objectives of sustainable development. Additionally, it contributes to the development of adaptation and innovation capabilities in undergraduate students to meet industry requirements. Romero [37] demonstrates that applying challenge-based learning with design thinking in undergraduate university students facilitates technological development, enhances research and innovation production. Similarly, it leads to learning outcomes and the acquisition of generic skills, regardless of the students' chosen profession.

Finally, after the course, students enroll in various extracurricular contests at the university because formulating a technological project that can impact society does not seem difficult to them (see Fig. 6).

Fig. 6. Participation in entrepreneurship and innovation events

V. CONCLUSION

In response to the need to contribute to social development and considering the demands of a digital technological context, it is essential for the university, through the teaching-learning process, to effectively contribute to the comprehensive education of its students. This should be considered from the early years of study. Therefore, the present methodological proposal, based on Design Thinking and Challenge-Based Learning, demonstrates its contribution to strengthening creativity in the comprehensive education of systems engineering students. These achievements are evident through the 95.6% satisfaction rate reported by students regarding the development of the Fundamentals of Information Technology Infrastructure course. This proposal focused on teaching skills related to the use of development boards (Arduino and Raspberry Pi), searching scientific databases, identifying social issues, and developing and formulating possible solutions. The proposal generated significant student interest in the development of their technological projects. Ultimately, this approach allowed for the identification of students affirming and increasing their passion and empowerment through the participation and presentation of socially impactful projects in extracurricular competitions. However, it is worth noting that the limitations of the study encompass the absence of a control group. It is essential to highlight that the study aims to showcase the implementation of the Design Thinking methodology and Challenge-Based Learning in the Fundamentals of Information Technology Infrastructure Course.

VI. FUTURE WORK

In 2024, additional measures are proposed beyond focusing solely on student satisfaction, such as enhancing competencies aligned with the course syllabus. This initiative aims to enhance skills related to critical and creative thinking, and also to foster the development of soft skills among undergraduate systems engineering students. In addition, it is planned to analyze in depth other educational contexts applied with the methodologies developed in this research.

ACKNOWLEDGMENT

We would like to express our gratitude to the Graduate School and the School of Systems Engineering for allowing us to conduct various surveys. Special thanks to the University Social Responsibility Department at the Catholic University of Santa María for their involvement, time, and guidance in explaining and advising the students' projects.

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