From Big Idea to Prototype: A Challenge-Based Learning Framework for Hackathons in Higher Education

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Abstract: This paper introduces the Hack4CBL framework, which integrates Challenge-Based Learning (CBL) principles into hackathon design to enhance multidisciplinary education in higher education settings. By aligning the stages of a hackathon—pre-hackathon, hackathon, and post-hackathon—with the CBL domains of engage, investigate, act, and transfer, the framework fosters meaningful collaboration among students pursuing diverse learning outcomes within the same project. We illustrate the effectiveness of Hack4CBL through a binational hackathon centered on Tourism 4.0, involving over 200 undergraduate students from Colombia and Costa Rica across disciplines like systems engineering, computer engineering, business administration, tourism management, and data science. Students formed interdisciplinary teams to tackle real-world challenges provided by industry professionals, leading to the development of Minimum Viable Products (MVPs) over two months. Results indicate that integrating CBL into hackathons enhances collaboration, deepens domain-specific knowledge, and accelerates professional skill development. The Hack4CBL framework offers a replicable model for leveraging hackathons as powerful educational platforms closely aligned with professional realities.

SCIENCE AND TECHNOLOGY PUBLICATIONS

1 INTRODUCTION

Hackathons are short, collaborative events where diverse stakeholders innovate, create solutions, and develop working software or prototypes, typically over one to three days (Komssi et al., 2015). Over time, they have evolved in both format and duration, ranging from strictly in-person to virtual events, with flexible time frames depending on the project's scope.

The complexity of the challenges, the team dynamics, and the logistical aspects of organizing these events all contribute to the development of valuable skills in participants, such as problem-solving, teamwork, communication, adaptability, and technical proficiency. Because of this, hackathons have increasingly been used as an educational strategy for undergraduate and graduate students (Paganini and Gama, 2020). However, achieving these outcomes demands careful planning, strong coordination, and effective communication tools to handle logistical complexities.

The main challenge in large hackathons with students from a wide range of disciplines, courses, and abilities is addressing the different expectations, skill levels, and learning outcomes. In these contexts, one-dimensional or narrowly focused projects risk disengagement and skill under-utilization. To counter this, hackathon challenges should be complex and multifaceted, such as developing an app that streamlines healthcare access for under-served populations, integrating patient data, tele-medicine, social work, and predictive analytics. This approach fosters collaboration, leverages unique perspectives, and promotes interdisciplinary skill development, enabling innovative solutions to emerge.

To address these challenges, we propose a framework for hackathon development based on challenge-based learning (CBL) (Nichols and Karen, 2008), which engages participants in solving real-world

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problems through collaborative, hands-on experiences requiring critical thinking and creativity. CBL-driven hackathons require multidisciplinary collaboration because teams will be facing a real and complex challenge with multiple perspectives–they demand expertise in areas such as technology, social impact, ethics, business, and domain-specific knowledge. This approach allows participants to engage with authentic issues while applying knowledge from their respective fields. As a result, it enhances individual learning outcomes while also fostering purpose and commitment by addressing real-world needs.

The framework is illustrated through a case study involving a large-scale hackathon that engaged university students from two countries and four different disciplines. This case study provides a detailed analysis of the hackathon's design, implementation, and outcomes, highlighting the effectiveness of the CBL framework for hackathon design. Through this approach, we aim to showcase the potential of hackathons not only as tools for rapid prototyping and problem-solving but also as powerful educational platforms for developing interdisciplinary skills and fostering a collaborative mindset.

After this introduction, section 2 discusses CBL as a general pedagogical framework and its relevance for the design of hackathons. Later, section 3 discusses hackathons as a general pedagogical strategy, their potential, and limitations. Section 4 presents the Hack4CBL framework for the development of hackathons based on CBL principles, while section 5 presents how was this framework used to develop a bi-national hackathon between Colombia and Costa Rica centered on tourism 4.0. Finally, sections 6 and 7 discuss the main lessons from the hackathon and conclude the paper.

2 CHALLENGE-BASED LEARNING

Developing soft skills in engineering students is crucial but challenging. With the modernization of engineering education, many guidelines and pedagogical systems have been created to enhance practical, business-focused, real-world, and entrepreneurial training (Martínez and Crusat, 2017). Experiential learning (Kolb, 1983; Jamison et al., 2022), including project-based and service learning (Chanin et al., 2018), has traditionally addressed this need. This work focuses on Challenge-Based learning (Nichols and Karen, 2008).

CBL is an educational approach that engages students in real, context-related problems by defining a challenge and implementing a solution (Nichols and Karen, 2008). Its emphasis on real-world problems, interdisciplinary collaboration, creativity, active learning, and reflection has made it popular in STEM education (Conde et al., 2021). In CBL, students, professors, and other stakeholders collaborate to solve a challenge in which creative and divergent thinking is encouraged. Furthermore, the focus is not only on the final deliverable but also on the entire process, as students periodically reflect on the evolution of their learning (Chanin et al., 2018).

The reference framework for the Challenge-Based Learning process begins with a big idea and leads to an essential question, a challenge, guiding questions, activities, resources, solution determination and articulation, action through solution, implementation, reflection, evaluation, and publication (Nichols and Karen, 2008). Table 1 describes these components.

The CBL framework is typically implemented as either CBL courses or CBL projects (Doulougeri et al., 2024). In CBL courses, a CBL component promotes active learning of the course subject matter, with the challenge and solution serving as a means to that end. In contrast, CBL projects focus on the challenge and its solution as the ultimate goal, often as graduation projects or extracurricular activities. Hackathons are a common form of extracurricular CBL projects (Doulougeri et al., 2024), but there is limited guidance on adapting the CBL framework to a hackathon format. This gap becomes apparent in multidisciplinary hackathons within higher education, where diverse student learning outcomes must be addressed.

3 HACKATHONS

Hackathons are "events where computer programmers and others collaborate intensively over a short period to develop software projects" (Komssi et al., 2015, p.60). In CBL contexts, including non-programmers like designers and domain experts enhances interdisciplinary collaboration and enriches problem-solving.

They follow a format that begins with team formation and ideation (pre-hackathon or inputs), then progresses to the actual hackathon, and then the post-hackathon stage, where teams decide to continue or discard the idea (Komssi et al., 2015). This is illustrated in Figure 1.

There is no universal or standardized form of hackathon. Instead, the literature, as well as university and corporate settings, display a range of variations depending on the anticipated outcomes (Por-

Table 1: Components and Descriptions of Challenge-Based Learning. Source: (Nichols and Karen, 2008).

Component	Description
Big Idea	Broad concept that can be explored in multiple ways, has the quality of being appealing, and is important to the students and society at large. Examples of big ideas include identity, sustainability, creativity, violence, peace, power, among others.
Essential Question	Questions generated from the big idea. They should reflect the interests of the students and the needs of the community. The essential questions identify what is important to know about the big idea.
The Challenge	A challenge is articulated from each essential question, asking students to create a specific response or solution that can result in concrete and meaningful action.
Guiding Questions	Generated by the students, these questions represent the knowledge students need to discover in order to successfully address the challenge.
Guiding Activities	Lessons, simulations, games, and other types of activities that help students answer the guiding questions and lay the foundation for them to develop innovative, insightful, and realistic solutions.
Guiding Resources	This focused set of resources may include sources, databases, experts, etc., that support the activities and help students develop a solution.
Solutions	Each challenge is broad enough to allow for a variety of solutions. Each solution should be thoughtful, concrete, viable, clearly articulated, and presented in a publishable multimedia format, such as an enhanced podcast or a short video.
Assessment	The solution can be assessed based on its connection to the challenge, the accuracy of the content, the clarity of communication, the applicability for implementation, and the effectiveness of the idea, among other factors. In addition to the solution, the process that individuals and teams went through to reach a solution can also be evaluated, capturing the development of key skills or competencies.
Publication	The challenge process provides multiple opportunities to document the experience and publish it for a wider audience. Students are encouraged to publish their results online and seek feedback. The idea is to expand the learning community and foster discussion about solutions to challenges that are important to students.

ras et al., 2018). These events are often referred to by different names, such as hackfests, code camps, datathons (Anslow et al., 2016), or jams. It is worth noting that jams do not necessarily require programming; however, they may include it and are frequently associated with specific disciplines, such as video game design or service design (Komssi et al., 2015).

This variety calls for a unified framework to guide the design and development of hackathon events in higher education following the CBL framework. This is tackled in the following section and is illustrated with a case study in section 5.

4 METHODOLOGY

A unifying framework was created for this hackathon by integrating the three hackathon stages (pre-, hackathon, post-) shown in Figure 1, the CBL framework (see Table 1), and the three domains from (Chanin et al., 2018)–engage, investigate, act. A fourth domain, 'transfer,' was added to ensure that learning and outcomes extend beyond the event, fostering long-term impact and knowledge sharing.

The Hack4CBL framework, shown in Figure 2, structures hackathons for challenge-based learning in three stages: pre-hackathon, hackathon, and post-hackathon. Each stage includes activities in four domains, which may be executed in any order, preferably in parallel. Once outputs of a stage are secured, the team can move on, and multiple iterations may be conducted at each stage as needed.

The main contribution of CBL to the Hack4CBL framework is the opportunity for multi-learning-outcome (multi-LO) processes. That is, learning processes in which students from multiple disciplines pursue different learning outcomes while participating in the same project (Nicolescu, 2014). With its focus on real challenges, the CBL framework emphasizes contextualized and validated solutions for real-life complex problems, something hard to achieve with traditional educational hackathons that are bound to a classroom context, subject-matter, and narrow learning outcomes. A natural consequence of this focus is that teams have to be multidisciplinary, combining knowledge and expertise in the domain of the big question (in CBL terms) and the technologies relevant for the challenges.

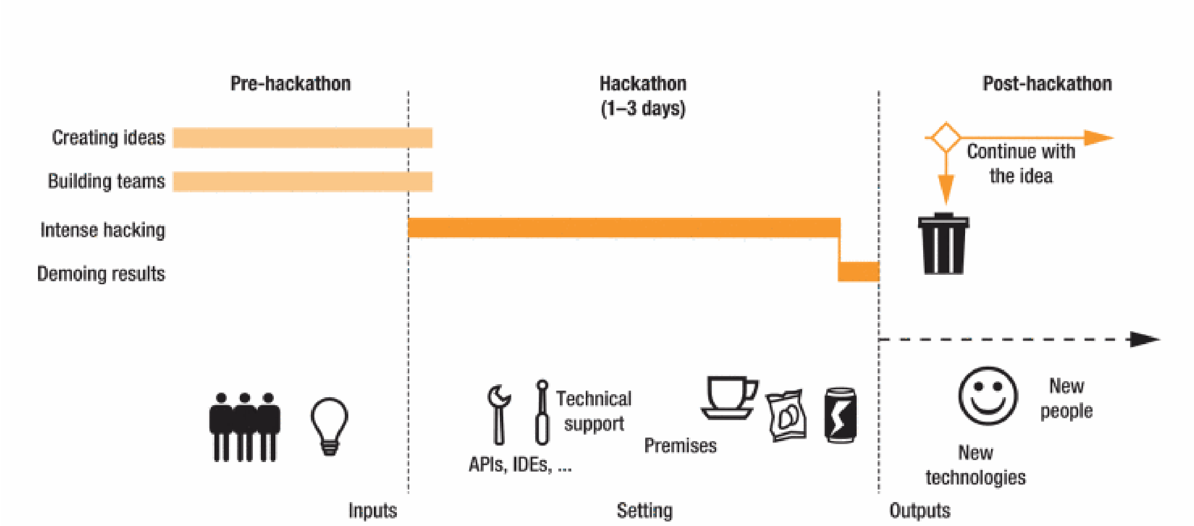

Figure 1: The typical hackathon process, in terms of essential activities, stages, and supporting elements. Source: (Komssi et al., 2015).

With over 200 students from two countries and three different study programs participating (see Section 5.1 for details), the event offered a unique real-life learning opportunity since it was student-organized. A dedicated group of students managed the event logistics and served as project managers for the hackathon teams, gaining hands-on experience in both coordination and leadership. The organizational structure behind this setup is discussed in the following section.

5 CASE STUDY AND RESULTS

This section presents how the Hack4CBL framework was used for the development of a binational hackathon with challenges centered on the **big idea** of tourism 4.0. Several iterations were conducted within each step of the framework to refine results and move to the next block.

5.1 Pre-Hackathon

While the hackathon stage receives the most attention, the pre-hackathon stage does all the heavy-lifting needed for the event to succeed. This stage is charged with setting up the hackathon, scoping the challenges, and doing the necessary team-building exercises prior to the event. The participants also need to prepare for the hackathon.

As mentioned earlier, the big idea of this hackathon was the concept of Tourism 4.0. Digital transformation has led the tourism sector to engage in various innovations, giving rise to terms like Tourism 4.0 or Smart Tourism. Tourism 4.0 is defined as the new tourism value ecosystem based on the high-tech service production paradigm characterized by adopting the basic principles of Industry 4.0 (Pencarelli, 2020): interoperability, virtualization, decentralization, service orientation, data analytics, and modularity.

The concept of Tourism 4.0 focuses on the intensive use of digital technologies, such as specialized interactive systems; IoT; big data and data analytics; artificial intelligence; blockchain; virtual, augmented, and hybrid reality; among others. This approach has driven full automation in the production and delivery of tourism goods and services, potentially causing technological disruptions in the sector (Ivanov, 2020). Digital technologies are not limited to basic automation; they have the potential to reshape service strategies and customer experiences, enhancing efficiency, scalability, and reliability while enabling rapid responses to customer needs (Zaki, 2019).

Following this big idea, it was decided to include two countries in this hackathon: Colombia and Costa Rica. These countries were selected because their tourism sectors significantly contribute to the national GDP–2.3% and 8%, respectively (UN Tourism, 2024; Ortíz-Pabón et al., 2024)–and because they are in a similar time zone and have no language or cultural barriers. Finally, the university leading the hackathon is located in Colombia.

A total of 210 undergraduate students from the Pontificia Universidad Javeriana in Colombia and the Instituto Tecnológico de Costa Rica, Campus San Carlos, participated in this hackathon. They were divided into 27 interdisciplinary teams, with each team

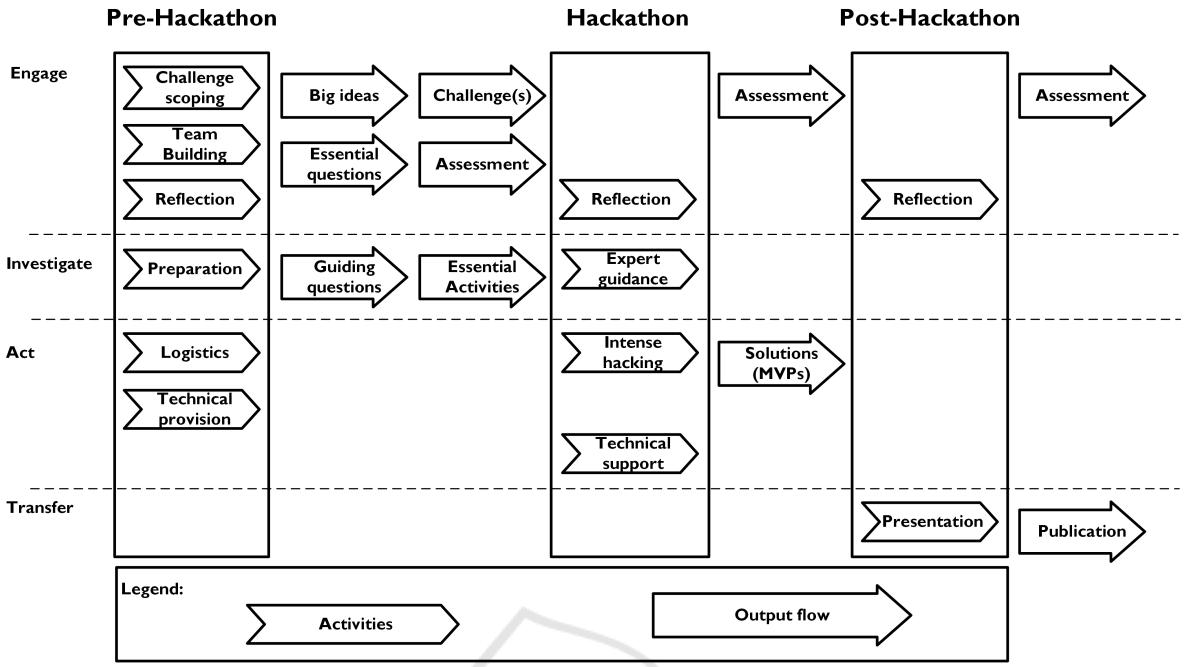

Figure 2: The Hack4CBL framework.

comprising six to seven members. The students represented various fields, including systems engineering (Colombia), computer engineering (Costa Rica), business administration (Colombia), tourism management (Costa Rica), and data science (Colombia). Team formation was overseen by a project management team formed by students.

A panel of tourism industry professionals and entrepreneurs from both countries were charged with coming up with the **essential questions** and a total of 17 specific **challenges** to tackle during the hackathon stage. Each team selected the most attractive challenge, implying that some challenges were selected by more than one team, while others were not selected by any team.

Each team was provided with ample documentation about tourism 4.0 for preparation, and a workspace in Microsoft Teams for file management and communication.

As preparation for the hackathon stage, teams invested six weeks analyzing the tourism sector in general, gaining specific knowledge about Tourism 4.0. In this preparation, students developed skills for problem contextualization and alignment with the specif socio-economic contexts of the tourism sectors in Colombia and Costa Rica. This involved a combination of virtual and in-person modes. These were used for teamwork, validations, and interactions with academics and tourism industry professionals from both countries.

During this preparation, crucial support was provided to ensure the successful development of the exercise. A space was created for interaction with tourism industry experts (entrepreneurs, consultants, and academics) through bi-weekly webinar sessions in which teams were able to deepen their knowledge of the tourism sector and integrate agile feedback into their workflow. These bi-weekly webinar continued into the hackathon stage. The interaction with experts led to the emergence of a broad set of **guiding questions**, **guiding activities**, **guiding resources**, and the drafting of solutions.

The logistics and technical provision aspects of the project were handled by five teams of five students, each responsible for project management and coordination of different aspects of the hackathon. They formed an organizational structure guided by functional areas and roles (Figure 3). This responsibility was assigned to a Strategic IT Management class[1], which was in charge of managing the project called "Smart Tourism 4.0 Hackathon, Colombia – Costa Rica."[2] A parallel organizational structure was replicated to oversee project management, which was

[1]Strategic IT Management is a core course in the Systems Engineering program at the Pontificia Universidad Javeriana. Two classes, each with 20 students, took the course during the first semester of 2023; one class was responsible for project management, while the other focused on overseeing the management.

[2]https://ingenieria.javeriana.edu.co/hackathon

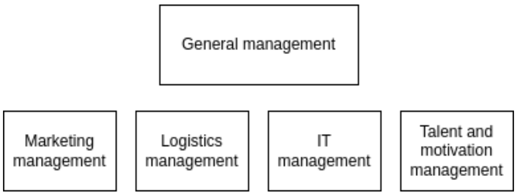

Figure 3: Organizational structure for the management of the project.

responsible for monitoring the project, controlling schedules, reviewing results, ensuring the quality of documented evidence, and addressing team needs.

5.2 Hackathon

This stage lasted two months, which was longer than typical hackathons, to allow for multiple iterations, enough interaction with industry experts, and deeper domain-specific learning. Additionally, since the hackathon was conducted alongside other academic duties, students required more time to integrate this into their schedules without risking burnout or disengagement.

The hackathon stage was divided into two parts. The first part was dedicated to requirement definition, while the second part focused on prototype design (mockups), user validations, business modeling, and the construction of the first two versions of Minimum Viable Products (MVPs).

This stage began with the preliminary research conducted by each participant team during the pre-hackathon, which led to the contextualization of the problem or family of problems related to the selected challenge. From there, each team constructed its own scenario, selected the necessary reference frameworks, and chose the most appropriate tools and software development frameworks. They also secured the necessary application programming interfaces (APIs) and prepared their collaborative work environment.

In this stage of the hackathon, the teams conducted several iterations of design, development, and validation of their MVPs, incorporating structured feedback sessions from professors and industry experts to refine their solutions. This iterative process led to continuous improvement of the MVPs and allowed teams to adapt their approaches based on the feedback received. This was done with a combination of remote and in-person work sessions.

Each team created three MVP versions. Version 0.0 defined the problem context, introduced the initial business model, and prioritized solution requirements (both functional and non-functional). Version 1.0 included final functionalities, a validated business model, and significant progress in design and development. Version 2.0 delivered fully developed, tested functionalities and additional validations, backed by a business profile with revenue projections, market analysis, and financial estimates.

5.3 Post-Hackathon

The final stage focused on presenting results, evaluation, and delivering the MVPs in their 2.0 version. Based on this 2.0 version of the MVP, participants developed a short video (between three and five minutes) featuring a pitch and a short demo.

With these MVP versions and their respective documentary supports, the results were evaluated by a panel of entrepreneurs from both countries. In two rounds of evaluation, the entrepreneurs reviewed the solutions and rendered their verdict on the best ones. The first round selected the top 10 solutions that, in the entrepreneurs' judgment, best addressed the challenge they were tackling. The second round of evaluation was conducted through a simulated investment process. Each evaluating entrepreneur was fictitiously allocated $150,000, which they had to invest in three of the solutions from the first round. Each evaluator was required to invest the full amount in the proportions they considered most appropriate. At the end of the exercise, the three finalists with the highest investments were identified (first, second, and third place).

The results were published on the hackathon website (https://ingenieria.javeriana.edu.co/hackathon), which was created by the management team as a communication tool and to track the project's progress. It also served as a platform for each team to present themselves through a short video.

Regarding the transfer of results, a meeting was scheduled to hold the award ceremony for the winners, attended by entrepreneurs (Figure 4). In this setting, the corresponding awards were presented, and an interaction space was created between hackathon teams and entrepreneurs, aimed at generating mechanisms for continuing the development of the winning ideas.

6 DISCUSSION

In this paper, we propose the Hack4CBL framework for the development of hackathons as an educational strategy for multidisciplinary teams with diverse learning outcomes. This framework was illustrated with a case study of a bi-national hackthon between Colombia and Costa Rica. The hackathon served not only as a space for technological innovation but also as a valuable pedagogical experi-

Figure 4: Hackathon award ceremony.

ment in multidisciplinary challenge-based learning. This aligns with prior research by (Adinda et al., 2024), which highlights the benefits of educational hackathons on collaboration skills and the influence of student characteristics and team composition on performance.

Throughout the hackathon development, we observed that students not only developed technical skills but also competencies in project management, communication, and teamwork. This experience was further enriched by interactions with industry experts, who provided valuable and realistic feedback. The focus on creating functional minimum viable products (MVPs) allowed students to experience the full cycle of product development, from ideation to implementation and evaluation. Additionally, the organizational structure (run by students) emulated a corporate environment, adding another dimension of learning for those involved in this structure. These findings are consistent with numerous studies that emphasize how collaboration in the workplace enhances innovation and successful outcomes (Granados and Pareja-Eastaway, 2019; Fanousse et al., 2021; Rosell et al., 2014). Similarly, Adinda et al. (Adinda et al., 2024) observe that collaborative leadership within an organizational structure has a strong impact on collaborative competency and performance.

The active participation of entrepreneurs in the evaluation of projects and the opportunity to receive simulated funding for their projects provided additional motivation and a real-world market experience. However, our observations also revealed emotional challenges faced by students during the hackathon, notably frustration and difficulties that led to conflicts. As Kazemitabar et al. (Kazemitabar et al., 2023) highlight, these conflicts can be internal–relating to personal deficiencies and teamwork incompetence–or external–pertaining to task or team dynamics. Additionally, cultural dimensions, particularly in terms of ways of thinking and solutions as proposed by Hu et al. (Hu et al., 2022), can influence students' communication, collaboration, and innovation. These findings suggest a need to integrate more explicit instructional and collaborative guidance, especially for first-year students.

In summary, the hackathon proved to be an effective tool for practical training and the strengthening of soft skills in an academic context, with a positive impact on students' preparedness for entrepreneurship environments or the labor market.

7 CONCLUSION

In this paper, we presented the Hack4CBL framework, a hackathon developmnent framework for educational purposes based con the CBL framework. A case study of a bi-national hackathon between Colombia and Costa Rica centered on tourism 4.0, and developed with the Hack4CBL framework, was also presented.

As a mechanism for action that brings together different stakeholders around the development of solutions in an MVP format, hackathons help accelerate students' professional learning processes by achieving learning outcomes that closely align with the realities they will encounter in their professional lives. For students coming from digital disciplines (i.e., systems engineering, computer engineering, data science), the main lesson on this regard is that technology does not happen, nor is it developed, in isolation. Students from other disciplines (i.e., business administration, tourism management) got a deeper understanding on how digital technology can impact their respective fields. Furthermore, when combined with CBL principles, hackathons are an effective pedagogical strategy to tackle a wide range of learning outcomes. This implies that, even while participating in the same team, students can be pursuing different learning outcomes with their participation in the hackathon. This is an ideal context for multidisciplinary learning, one that is seldom achieved with other pedagogical strategies.

While we highlight the immediate educational benefits of hackathons in this paper, more work is needed on their long-term effects through longitudinal studies, focusing on their influence on participants' professional trajectories and career development.

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