

From Non-STEAM to Innovation: Developing Entrepreneurial and Technological Competencies through Hackathons

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Abstract: In the context of accelerating digital transformation and the increasing demand for transversal competencies, higher education institutions are challenged to adopt innovative pedagogical approaches that foster entrepreneurial mindsets across different fields of study. Hackathons, originally rooted in software development, have evolved into interdisciplinary learning environments that promote creativity, collaboration and problem-solving. This study explores the role of a hackathon—*Digit'all MakerDay*—as a capacity-building mechanism for almost 200 students enrolled in non-STEAM (Science, Technology, Engineering, Arts and Mathematics), professional higher education courses, at Polytechnic University of Cávado and Ave (Portugal). The primary objective of the hackathon was to introduce the participants to emerging fields such as technology and robotics, while simultaneously fostering entrepreneurial skills, innovation capacity, and teamwork. The event was structured during a whole day around key phases, including initial training, challenge presentation, ideation, prototyping, and final project presentation, simulating real-world innovation processes. A quantitative research approach was adopted through the administration of a post-event questionnaire to participating students. The survey aimed to assess the perceived development of both technical and transversal competencies identified by the World Economic Forum, including creativity, communication, adaptability, and problem-solving—skills highlighted as critical for future employability. The findings suggest that participation in the hackathon significantly contributed to the development of entrepreneurial attitudes and a broader set of personal and behavioral competencies. Additionally, students reported increased confidence in engaging with technological concepts such as robotics, despite their non-STEAM background. The collaborative and challenge-based nature of the hackathon environment proved particularly effective in stimulating innovation and experiential learning. This study reinforces the value of hackathons in the preparation of future professionals for responsible innovation. It also highlights their potential to bridge the gap between non-STEAM education and emerging technological domains, contributing to more holistic and future-oriented entrepreneurial education models.

Keywords: Hackathons, Entrepreneurship, Non-STEAM Students, Innovation and Technology, World Economic Forum Skills

1. Introduction

The accelerating pace of digital transformation has fundamentally reshaped the demands placed upon higher education graduates. As automation, artificial intelligence and emerging technologies progressively reconfigure labour markets, the competencies required for professional success are shifting in both nature and urgency. According to the Future of Jobs Report (World Economic Forum, 2023), employers anticipate that 44% of workers' core skills will be disrupted within five years, with analytical thinking, creative reasoning, technological literacy, resilience and adaptability identified as the most critical capabilities for the near-future workforce. Self-efficacy skills — including curiosity and lifelong learning, and motivation and self-awareness — have also emerged as growing priorities, reflecting the increasing premium placed on workers capable of adapting to continuously disrupted workplaces (World Economic Forum, 2023). These developments place higher education institutions at a crossroads: traditional curricula, largely designed around knowledge transmission, are proving increasingly insufficient to prepare graduates for a complex and volatile professional environment (Baierl and Thamm, 2023).

This challenge is particularly acute for students enrolled in non-STEAM (Science, Technology, Engineering, Arts and Mathematics) programmes, fields such as management, social services, communication or health sciences, where engagement with technological and entrepreneurial domains has historically been limited. Yet the boundaries between technical and non-technical professional roles are becoming increasingly blurred, and entrepreneurial thinking, digital fluency and the capacity to collaborate across disciplinary boundaries are no longer the exclusive province of engineers or computer scientists (Garcez, Franco and Silva, 2023). Entrepreneurship education (EE) has emerged as a pivotal response to this challenge, evolving considerably

beyond narrowly vocational frameworks centred on business plan development and towards broader educational models that cultivate entrepreneurial mindsets, attitudes and behaviours across all fields of study (Komodromos, 2025). Research grounded in social learning theory further underscores that entrepreneurial competencies are not innate but are developed through structured practice, observation, mentorship and active participation in entrepreneurial ecosystems — findings that carry significant implications for the design of EE programmes targeting non-STEAM student populations (Rocha et al., 2024).

In this context, experiential and challenge-based learning methodologies have gained growing recognition as more effective approaches to developing the transversal competencies demanded by contemporary employers. Hackathons have emerged as one of the most prominent expressions of this pedagogical shift. Originally rooted in software development culture, they have evolved considerably in scope and format and are now widely adopted across disciplines and institutional contexts as tools for stimulating creativity, entrepreneurial thinking and teamwork (Schulten and Chounta, 2024). Hackathons vary in duration and structure — from single-day events to 48-hour marathons — but share a common emphasis on collaborative challenge-framing, rapid ideation, prototyping and public presentation, which closely mirrors the conditions under which entrepreneurial competencies are naturally activated.

The empirical literature consistently demonstrates that hackathon participation fosters a broad spectrum of competencies. Studies report improvements in teamwork, creativity, communication and real-world problem-solving, making learning more engaging and practically relevant (Oyetade, Zuva and Harmse, 2024). Surendran et al (2023) found that extracurricular hackathons significantly enhance students' awareness of personal and professional skills — including ideation, product development, leadership, resilience and teamwork — whilst also positively impacting employability and entrepreneurial competencies. Szymanska et al. (2020) demonstrated that a single hackathon event can outperform semester-long entrepreneurship courses in developing entrepreneurial self-efficacy, a key antecedent of entrepreneurial intention and behaviour. More recently, hackathons have been linked to the development of technological entrepreneurship, with Grigoreva et al's (2024) finding that, under certain conditions, hackathon outcomes extend beyond immediate learning gains to become drivers for student entrepreneurial ventures. The challenge-based structure of hackathons also aligns naturally with the EntreComp framework (European Commission, 2016), which identifies ideas and opportunities, resources, and into action as the three core areas of entrepreneurial competence to be cultivated across educational contexts (Eimler and Straßmann, 2023).

Despite this growing body of evidence, important gaps remain. Much of the existing research on educational hackathons has focused on students with technical or STEAM backgrounds, leaving underexplored the question of how such events affect students from non-technical disciplines. Moreover, the systematic assessment of learning outcomes — particularly in relation to internationally recognised competency frameworks — continues to vary considerably across studies. There is therefore a need for empirically grounded research that examines the impact of structured hackathon experiences on non-STEAM student populations, explicitly linking outcomes to established employability frameworks and employing rigorous statistical analysis to substantiate perceived competency development. It is within this context that the present study is positioned. This paper reports on the Digit'all MakerDay, a full-day hackathon designed for and implemented with approximately 200 students enrolled in non-STEAM professional higher education programmes at IPCA, in Portugal. The event introduced participants to emerging technological fields, including robotics, whilst creating conditions for the development of entrepreneurial skills, innovation capacity and collaborative competencies. Through a quantitative approach combining pre- and post-event questionnaires, this study examines participants' perceptions of competency development aligned with the World Economic Forum (2023) skills framework, analyses whether hackathon participation produced statistically significant changes in entrepreneurial attitudes, and identifies the key predictors of overall participant satisfaction.

2. Methodology

The present study adopts a quantitative research approach, based on the administration of a structured questionnaire to higher education students. Data collection was carried out in March 2026, within the context of the Digit'all MakerDay — Applied Robotics in Industry hackathon event, held at IPCA, in Portugal.

Data collection was conducted in two stages. In the pre-event phase, 137 students enrolled in Professional Higher Technical Courses, representing different programme areas, completed the questionnaire. In the post-event phase, 85 students completed the questionnaire. To enable longitudinal tracking of individual responses between the two phases, participants were asked to enter their student identification number as an anonymous

linking code, ensuring that pre- and post-event responses from the same individual could be matched for paired analyses whilst preserving confidentiality. The difference between pre- and post-event response rates (137 vs. 85) is attributable to voluntary participation in the post-event phase and to students who were absent or chose not to complete the second questionnaire. Paired analyses — namely the Wilcoxon signed-rank test — were conducted exclusively on the subset of matched responses ($n = 85$), whilst descriptive analyses of pre-event data draw on the full pre-event sample ($n = 137$).

The data collection instrument consisted of a structured questionnaire administered in two stages: before and after the hackathon event. The pre-event section focused on participants' initial expectations regarding the hackathon experience and their anticipated development of entrepreneurial competencies. The post-event section assessed participants' perceptions of the experience across several dimensions, including digital skills, pitch presentation abilities, and the expected impact on their academic and professional trajectory. The entrepreneurial competencies assessed were based on the framework established by the World Economic Forum (2023), and motivational factors underlying participation were also explored.

Data collection was conducted via a QR code made available to participants after the event. The collected data were subsequently processed and analysed using descriptive statistical techniques, with the aim of characterising the sample and identifying patterns in students' perceptions. Where appropriate, inferential comparative analyses were conducted between the pre- and post-event questionnaire responses, including the Wilcoxon signed-rank test for paired samples, Spearman correlation analysis, and multiple linear regression, to identify the key predictors of overall participant satisfaction. Regression analyses were conducted on the post-event dataset ($n = 85$), as all predictor variables — facilitator support quality, contribution of guidance to the final pitch, final project presentation experience, and contact with industry partner ESI Robotics — were measured exclusively in the post-event questionnaire. Listwise deletion was applied, resulting in a final analytical sample of 85 participants for the regression models.

3. Results

3.1 Descriptive Analysis of General Dimensions

Table 1 presents the descriptive statistics relating to participants' perceptions across the key dimensions of the hackathon experience. Overall, the results reveal positive evaluations across all variables analysed, with mean scores exceeding 3.7 on a five-point Likert scale (1 = very poor; 5 = excellent).

Table 1: Descriptive statistics: general evaluation of the hackathon experience

Variable	Mean	Median	SD	Min	Max	Q1	Q2	Q3
To what extent were your initial expectations of the hackathon met?	3.80	4.00	0.870	1	5	3.00	4.00	4.00
How do you evaluate the quality of support provided by the facilitators?	3.96	4.00	0.837	2	5	3.00	4.00	5.00
How did the guidance received at the hackathon contribute positively to the final pitch?	3.80	4.00	0.856	2	5	3.00	4.00	4.00
How do you evaluate the contribution of the topics covered to your personal competency development?	3.79	4.00	0.952	1	5	3.00	4.00	5.00
How do you evaluate the contribution of the topics covered to your professional and academic development?	3.81	4.00	0.809	2	5	3.00	4.00	4.00
How do you evaluate the experience of presenting the final project at the hackathon?	3.74	4.00	0.897	1	5	3.00	4.00	4.00
How do you evaluate the contact with ESI Robotics for your professional future?	3.81	4.00	0.805	2	5	3.00	4.00	4.00

The highest mean was recorded for the quality of facilitator support ($M = 3.96$, $SD = 0.837$), suggesting a highly favourable perception of the mentoring provided during the event. The contribution to professional and academic development ($M = 3.81$, $SD = 0.809$) and the contact with industry partner ESI Robotics ($M = 3.81$, $SD = 0.805$) were also rated highly, indicating that participants recognised concrete practical value and potential career impact from the experience. The realisation of initial expectations ($M = 3.80$, $SD = 0.870$) and the contribution of guidance to the final pitch ($M = 3.80$, $SD = 0.856$) obtained equally positive scores. The variable

with the greatest response dispersion was the contribution to personal development ($SD = 0.952$), suggesting more differentiated perceptions of the hackathon's personal impact among participants. The experience of presenting the final project recorded the lowest mean ($M = 3.74$, $SD = 0.897$), though this remained within the positive range; this result may reflect varying levels of confidence and prior experience with public presentations. Notably, the median was 4 across all variables, with the majority of responses concentrated between values 3 and 5, reinforcing the overall pattern of positive perceptions.

3.2 Evolution of Perceived Entrepreneurial Competencies Between Pre- and Post-Hackathon

Prior to the hackathon, participants reported favourable expectations regarding the overall experience ($M = 3.55$, $SD = 0.730$) and the final project presentation/pitch ($M = 3.29$, $SD = 0.729$). Following the event, both dimensions recorded higher mean scores — the realisation of initial expectations ($M = 3.76$, $SD = 0.951$) and the final presentation experience ($M = 3.75$, $SD = 1.036$). Table 2 presents the descriptive comparison between pre- and post-event assessments.

Table 2: Pre- and post-hackathon descriptive comparison

	Pre-Hackathon: General expectation	Pre-Hackathon: Pitch expectation	Post- Hackathon: Expectations met	Post- Hackathon: Pitch experience
Mean	3.55	3.29	3.76	3.75
Median	4	3	4	4
SD	0.730	0.729	0.951	1.036
Min	2	2	1	1
Max	5	5	5	5
Q1	3	3	3	3
Q2	4	3	4	4
Q3	4	4	5	5

The Wilcoxon signed-rank test for paired samples was applied to assess pre- to post-hackathon differences. No statistically significant difference was found between initial expectations and their subsequent realisation ($Z = -1.455$; $p = 0.146$), suggesting that the hackathon broadly met participants' prior expectations. However, a statistically significant difference was identified between the initial expectation regarding the pitch presentation and the actual experience of presenting the final project ($Z = -3.192$; $p = 0.001$), indicating that the real pitch experience substantially exceeded participants' initial expectations. This interpretation is reinforced by the rank analysis, which revealed a substantially higher number of positive ranks ($n = 28$) compared to negative ranks ($n = 8$) for the pitch experience variable.

Regarding the entrepreneurial competencies identified by the World Economic Forum (2023), participants highlighted — prior to the hackathon — creative thinking ($n = 37$), curiosity and lifelong learning ($n = 28$) and analytical thinking ($n = 24$) as the competencies they most expected to develop. Following the event, creative thinking remained the most valued competency ($n = 36$), but notable increases were observed in resilience, flexibility and agility (from $n = 17$ to $n = 25$), technological literacy (from $n = 14$ to $n = 17$) and empathy and active listening (from $n = 15$ to $n = 19$). These results suggest that the practical and collaborative nature of the hackathon contributed to broadening participants' awareness of transversal competencies associated with adaptability, interpersonal interaction and technological capacity.

3.3 Relationship Between Initial Expectations and Overall Satisfaction

Spearman correlation analysis revealed a strong and statistically significant positive association between the realisation of initial expectations and overall participant satisfaction ($\rho = 0.704$; $p < 0.001$). This result indicates that participants whose expectations were more fully met tended to report higher levels of overall satisfaction with the experience. The magnitude of the correlation suggests that expectation management and fulfilment constitute a central factor in participants' positive evaluation of the hackathon.

3.4 Relationship Between Personal Development and Professional/Academic Competency Development

A strong and statistically significant positive correlation was found between the perceived contribution of the hackathon to personal competency development and its contribution to professional and academic competencies ($p = 0.791$; $p < 0.001$). This result suggests that participants tend to perceive personal and professional/academic development as interlinked dimensions of the formative experience provided by the hackathon: the more positively participants evaluated the personal impact, the more positively they also tended to evaluate the academic and professional impact.

3.5 Variables with the Greatest Influence on Overall Participant Satisfaction

Spearman correlation analysis revealed moderate to strong positive associations between overall satisfaction and all variables examined: facilitator support quality ($p = 0.608$; $p < 0.001$), contribution of guidance to the final pitch ($p = 0.679$; $p < 0.001$), final project presentation experience ($p = 0.643$; $p < 0.001$), and contact with industry partner ESI Robotics ($p = 0.596$; $p < 0.001$).

Given that all variables entering the regression model were drawn from the post-event questionnaire, the analysis was conducted on the post-event sample ($n = 85$). After listwise deletion of cases with missing values on any of the model variables, the effective analytical sample comprised 85 participants, consistent with the degrees of freedom reported in the regression output ($F(4,80)$ and $F(2,82)$).

A multiple linear regression analysis was subsequently conducted to identify which variables had the greatest predictive capacity for overall satisfaction. The full model was statistically significant ($F(4,80) = 23.721$; $p < 0.001$), explaining approximately 54.3% of the variance in overall satisfaction ($R^2 = 0.543$). However, only two variables contributed significantly in the final model: the perceived contribution of guidance to the final pitch ($\beta = 0.291$; $p = 0.050$) and the final project presentation experience ($\beta = 0.281$; $p = 0.027$). Facilitator quality and industry contact did not yield significant independent contributions when considered alongside the remaining variables.

A more parsimonious regression model, retaining only the two significant predictors, was also estimated. This model maintained high statistical significance ($F(2,82) = 45.857$; $p < 0.001$) and explained approximately 52.1% of the variance in overall satisfaction. Table 3 presents the results of this parsimonious model.

Table 3: Parsimonious regression model: predictors of overall satisfaction

Predictor Variable of Overall Satisfaction	Coefficient (β)	P value (variable)	p value (model)	R^2
Constant	0.896	0.004	< 0.001	0.521
Contribution of hackathon guidance to the final pitch	0.422	0.001		
Experience of presenting the final project	0.322	0.005		

These results confirm that the most determinant factors for overall participant satisfaction were the perceived utility of the guidance received during the hackathon for the preparation of the final pitch ($\beta = 0.428$; $p = 0.001$) and the final project presentation experience ($\beta = 0.343$; $p = 0.005$). The practical component associated with the development and delivery of the pitch thus appears to occupy a central role in participants' holistic evaluation of the hackathon experience.

4. Discussion

The results of this study are broadly consistent with the existing literature on the educational value of hackathons, whilst offering novel evidence specific to non-STEAM student populations. Across all dimensions evaluated, mean scores exceeded 3.7 on a five-point scale — a pattern of favourable perception that mirrors findings reported by Surendran et al (2023), whose extracurricular hackathon study similarly documented high participant appreciation of personal skill development, leadership and teamwork. The highest-rated dimension — facilitator support quality ($M = 3.96$) — reinforces the argument of Kolb and Kolb (2022) that a skilled mediator between challenge and action is a central determinant of experiential learning quality. The perceived contribution to professional and academic development ($M = 3.81$) and the industry contact with ESI Robotics ($M = 3.81$) further suggest that participants recognised concrete, future-oriented value in the experience,

corroborating evidence that industry-embedded hackathon formats strengthen the perceived connection between academic training and professional practice (Grigoreva et al, 2024).

The pre- to post-event analysis produced two complementary findings. The absence of a statistically significant difference between initial expectations and their realisation ($Z = -1.455$; $p = 0.146$) indicates that the hackathon broadly met what participants anticipated. By contrast, a statistically significant improvement was found in the pitch presentation experience relative to prior expectations ($Z = -3.192$; $p = 0.001$), with positive ranks substantially outnumbering negative ones ($n = 28$ vs. $n = 8$). This finding is particularly meaningful for non-STEAM students, who typically have limited exposure to entrepreneurial public presentation. It resonates directly with Szymanska et al. (2020), who demonstrated that immersive, time-pressured hackathon settings generate marked gains in entrepreneurial self-efficacy by pushing participants beyond their comfort zone through action rather than instruction.

The shifts observed in World Economic Forum-aligned entrepreneurial competencies between pre- and post-event further enrich this picture. Whilst creative thinking remained the most valued competency at both moments, post-event data showed notable increases in resilience, flexibility and agility (from $n = 17$ to $n = 25$), technological literacy (from $n = 14$ to $n = 17$) and empathy and active listening (from $n = 15$ to $n = 19$). These shifts suggest that the collaborative, challenge-based format expanded participants' awareness of relational and adaptive competencies — precisely those that the World Economic Forum (2023) identifies as among the fastest-growing in labour market importance. This pattern is consistent with Oyetade, Zuva and Harmse (2024), who argue that hackathon participation activates competency awareness that extends beyond technical problem-solving to encompass the interpersonal and adaptive dimensions of professional practice.

The regression analysis identified guidance for the pitch ($\beta = 0.428$; $p = 0.001$) and the final presentation experience ($\beta = 0.343$; $p = 0.005$) as the two significant predictors of overall satisfaction, together explaining 52.1% of its variance. This finding positions the pitch as the integrative capstone of the hackathon — the moment in which participants synthesise their learning and demonstrate their competencies publicly. It aligns with Grigoreva et al (2024) argument that the final presentation stage is pivotal in converting hackathon participation into durable entrepreneurial attitudes, and with the strong correlation found between personal and professional development ($p = 0.791$; $p < 0.001$), which suggests that students experience these as inseparable dimensions of the same formative process — a view consistent with holistic models of entrepreneurship education such as EntreComp (European Commission, 2016).

5. Conclusion

This study provides empirical evidence that a structured, single-day hackathon can serve as an effective mechanism for developing entrepreneurial and technological competencies among non-STEAM higher education students — a population underrepresented in the existing hackathon literature. Drawing on pre- and post-event data from 137 students and 85 students at IPCA respectively, the findings demonstrate that participants evaluated the experience positively across all dimensions analysed, with the pitch-related components emerging as the primary drivers of overall satisfaction, accounting for over half of its variance.

Three principal contributions stand out. First, the pitch presentation experience — both the guidance received throughout the process and the act of presenting publicly — is the most decisive factor in shaping participants' holistic evaluation of the hackathon, with direct implications for event design: structured coaching and mentoring throughout the ideation-to-presentation pipeline should be treated as a non-negotiable feature of hackathon formats targeting non-STEAM students. Second, hackathon participation broadened participants' perceived entrepreneurial competencies, with a statistically significant improvement in the pitch experience and notable post-event increases in resilience, technological literacy and empathy — competencies explicitly aligned with the World Economic Forum's (2023) future-of-work priorities. Third, the strong integration between personal and professional development ($p = 0.791$) reinforces the value of holistic, experiential approaches to entrepreneurship education across all disciplinary contexts.

This study is subject to certain limitations. The sample is drawn from a single institution and a specific programme type, which constrains the generalisability of the findings. Outcomes are based on self-reported perceptions rather than objective skill assessment, and the absence of a longitudinal follow-up precludes conclusions about the durability of the observed effects over time. Future research should employ longitudinal designs, comparative samples across disciplines and institutions, and objective performance measures to further validate and extend these findings. Nonetheless, the evidence presented here supports the value of hackathons

as inclusive pedagogical tools capable of bridging the gap between non-STEAM education and the entrepreneurial and technological competency demands of a digitally transformed economy.

Ethics Declaration

This research adhered to all ethical standards required for studies involving human participants. Prior to the administration of the questionnaire, ethical clearance was sought and obtained from the relevant institutional ethics committee. Participants were fully informed about the nature and purpose of the study and provided their consent to participate voluntarily. Anonymity and confidentiality were ensured throughout the data collection and analysis process.

A formal reference to the ethical approval granted for this study is included as attached to this paper.

AI Declaration

Artificial Intelligence (AI) tools were used in the development of this paper to support language refinement and structural editing. Specifically, ChatGPT by OpenAI was employed to assist with the rephrasing of academic text, grammar correction, and improving the clarity and coherence of certain sections, such as the discussion and conclusion.

All substantive academic content, including research design, data analysis, interpretation of findings, and critical arguments, was developed by the authors. The outputs generated by the AI tool were carefully reviewed, edited, and integrated into the manuscript with full academic oversight to ensure accuracy, originality, and scholarly integrity.

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