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Hackathons for Heritage at Risk: Participatory and Transformative Potential in Higher Education

Sara Fiorentino *, Anna Casarotto and Mariangela Vandini

Department of Cultural Heritage, University of Bologna, via degli Ariani 1, 48121 Ravenna, Italy; anna.casarotto3@unibo.it (A.C.); mariangela.vandini@unibo.it (M.V.)
* Correspondence: sara.fiorentino2@unibo.it

Abstract

Higher education increasingly requires educational approaches capable of engaging students with complex sustainability challenges through interdisciplinary, participatory, and context-sensitive learning. Although hackathons have gained attention in higher education as intensive collaborative and challenge-based formats, their educational use remains predominantly associated with technological and solution-oriented contexts, while their adaptation to cultural heritage and its relationship with Education for Sustainable Development remain comparatively underexplored. This study investigates how the hackathon format can be critically adapted to cultural heritage higher education and examines the educational processes, opportunities, and limitations emerging from its application to heritage-risk challenges. Drawing on an exploratory case study involving 25 university students in Ravenna (Italy), the initiative combined Project-Based Learning and design thinking within an intensive, collaborative format focused on cultural heritage at risk. Rather than directly transferring a prototype-driven model from technological contexts, the activity emphasized interpretation, communication, audience awareness, and community engagement. Findings indicate high levels of student engagement and interdisciplinary collaboration, while the proposals developed during the activity framed heritage risk as a challenge involving not only conservation and scientific understanding, but also communication, accessibility, and civic engagement. Participants' responses further highlighted processes of critical reflection, collaborative meaning-making, and shared responsibility consistent with sustainability-oriented learning. The study suggests that heritage-focused hackathons can provide structured spaces for engaging students with complex and socially situated sustainability challenges, while also highlighting the need for caution in interpreting short-term, self-reported outcomes as evidence of sustained learning or competence development.

Keywords: Education for Sustainable Development; higher education; project-based learning; design thinking; active learning; civic engagement; risk awareness

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1. Introduction

Higher education is increasingly challenged to prepare students to engage with complex social, cultural, and environmental issues characterized by uncertainty, interconnected forms of knowledge, and multiple stakeholders [1–4]. Within Education for Sustainable Development (ESD), this challenge has increased attention to active and participatory pedagogies capable of connecting academic knowledge with complex, real-world

problems while fostering collaboration, critical reflection, and shared responsibility [2–4]. Approaches such as Project-Based Learning, challenge-based learning, and experiential pedagogies are particularly relevant in this respect because they support collaborative and problem-oriented learning through authentic educational experiences [5–9].

Although these methodologies have been widely explored within STEM disciplines, their application to cultural heritage studies remains comparatively limited [10,11]. This gap reflects not only disciplinary traditions, but also deeper epistemological differences. While STEM-oriented educational models frequently emphasize solution-oriented logics, optimization processes, and technological prototyping, cultural heritage involves interpretative complexity, contested meanings, emotional dimensions, and socially embedded decision-making processes that cannot be reduced to purely technical solutions.

At the same time, the conception of cultural heritage itself has undergone a profound transformation over recent decades. International frameworks such as the Faro Convention [12] and UNESCO conventions increasingly frame heritage not simply as an object to be safeguarded, but as a participatory and socially constructed process shaped through interpretation, negotiation, and shared responsibility [13,14]. From this perspective, heritage education becomes more than the transmission of disciplinary knowledge: it emerges as a space for fostering participation, communication, critical awareness, and civic engagement, while encouraging learners to negotiate different perspectives and assume responsibility toward shared cultural resources and their future.

These issues acquire additional relevance within the framework of the United Nations' 2030 Agenda for Sustainable Development [15]. Although culture is not formally recognized as one of the traditional pillars of sustainability, it is embedded across several Sustainable Development Goals, particularly Goal 4 (Quality Education), Goal 11 (Sustainable Cities and Communities, target 11.4), and Goal 13 (Climate Action). From an ESD perspective, this intersection positions heritage education as a potentially significant setting for developing sustainability-oriented competences through engagement with real-world problems that combine environmental, social, cultural, and civic dimensions. Heritage education therefore represents a strategic space where sustainability, resilience, community participation, and democratic citizenship intersect. At the same time, contemporary approaches to heritage risk management increasingly recognize that scientific knowledge concerning degradation processes, vulnerability assessment, and preventive conservation must be complemented by effective communication and public engagement strategies capable of supporting long-term resilience. The interdisciplinary nature of cultural heritage at risk further reinforces the need for educational approaches capable of integrating diverse forms of knowledge. Understanding and managing heritage risk requires the combination of scientific and technical perspectives—such as degradation processes, vulnerability assessment, and preventive conservation—with social, cultural, and communicative dimensions related to public awareness, stakeholder engagement, and community resilience. As a result, heritage education provides a particularly valuable context in which to experiment with collaborative and challenge-based pedagogies designed to address complex societal and sustainability issues through multiple and interconnected perspectives.

Within this broader pedagogical and societal context, challenge-based and collaborative educational formats such as hackathons have attracted growing interest across higher education as intensive learning environments supporting collaboration, interdisciplinary engagement, creativity, and problem-oriented learning [16–18].

A notable example of co-design practice was the nocturnal hackathon organized through a collaboration between the CRRI—Research Centre of the Castello di Rivoli (Turin, Italy) and the Scuola Holden of Turin, aimed at developing narrative formats for the exhibition pathways of the Museum of Contemporary Art. Under the guidance of structured encounters, brainstorming sessions, and performative events, students were

encouraged to elaborate diverse narrative proposals for the museum's collections and spaces. The resulting projects were subsequently submitted to a jury composed of representatives from the Castello di Rivoli and faculty members of the Scuola Holden, who evaluated and selected the most compelling contributions [19].

However, their application within cultural heritage studies remains underexplored, particularly in relation to contexts characterized by ambiguity, plural interpretations, and socially negotiated forms of knowledge. Their potential contribution to ESD is also particularly relevant in this context, as hackathon-based learning can create spaces in which students confront open-ended problems, integrate different forms of knowledge, negotiate alternative perspectives, and collectively develop responses to complex sustainability challenges.

This article examines one such experiment: a university hackathon on cultural heritage at risk, organized in Ravenna (Italy) within the broader framework of the SIRIUS—Strategies for the Management of Cultural Heritage at Risk [20] and RESTART—Resilience and Territorial Development: Heritage at Risk and Protection [21] projects. Ravenna, internationally recognized for its UNESCO World Heritage monuments yet increasingly exposed to environmental threats such as flooding and climate-related risks, provides a particularly relevant context in which to situate the initiative. Twenty-five students from different academic backgrounds engaged with real-world challenges concerning heritage risk communication, public awareness, and participatory approaches to heritage protection through collaborative and project-oriented activities.

The purpose of this article is threefold. First, it investigates how hackathon methodologies originally rooted in STEM education can be critically adapted to cultural heritage within higher education. Second, it explores the educational processes and learning outcomes generated through the experience, with particular attention to sustainability-oriented and civic competences, collaborative dynamics, communication literacy, and reflexive forms of learning. Third, it reflects on the opportunities and limitations emerging from the transfer of challenge-based pedagogies into studies characterized by complexity, uncertainty, and social embeddedness, considering their contribution to Education for Sustainable Development as well as their potential to support stakeholder engagement and preventive conservation strategies in heritage risk management. Building on these three interconnected aims, the study addresses the following overarching research question: How can the hackathon format be critically adapted to cultural heritage higher education, and what educational processes, opportunities, and limitations emerge from its application to a complex and socially situated heritage-risk challenge?

2. Theoretical Framework

2.1. Hackathons as Active and Challenge-Based Learning Environments

Hackathons are increasingly explored within higher education as active and experiential learning environments capable of fostering collaboration, creativity, and problem-oriented engagement [8,22]. Rooted in constructivist, experiential, and project-based pedagogies, they encourage students to engage directly with real-world challenges through iterative processes of inquiry, ideation, reflection, and collective problem-solving [5,6,23]. Their educational value lies not only in the production of outputs, but also in the collaborative, situated, and reflexive nature of the learning process itself.

Within educational research, hackathons have progressively evolved from purely technological events into broader pedagogical formats capable of supporting interdisciplinary collaboration, peer learning, creativity, and challenge-based learning experiences [10,11]. Their increasing diffusion reflects wider transformations in higher education, where active participation and authentic problem engagement are increasingly considered essential for preparing students to confront complex societal challenges.

2.2. Hackathons and Education for Sustainable Development

These characteristics also establish a potential connection with Education for Sustainable Development (ESD), which emphasizes educational processes that enable learners to engage with complexity, uncertainty, interconnected forms of knowledge, and collective responsibility [3,4]. This connection has begun to emerge more explicitly in sustainability-oriented higher education, where hackathons have been used to engage students with Sustainable Development Goals and real-world sustainability challenges through intensive, interdisciplinary, and collaborative learning experiences. Existing studies suggest that sustainability-focused hackathons can support interdisciplinary collaboration, sustainability awareness, and the development of academic, professional, and transversal skills, while providing opportunities to translate sustainability concepts into situated forms of problem engagement [24,25]. These developments position hackathons as a potentially relevant pedagogical format for ESD. However, the existing literature has largely examined hackathons in relation to sustainability challenges through problem-solving, innovation, entrepreneurship, or solution-development frameworks. Comparatively less attention has been devoted to how the hackathon format itself may need to be pedagogically reconfigured when sustainability challenges involve interpretative ambiguity, cultural values, public communication, and socially negotiated forms of knowledge rather than primarily technological or entrepreneurial solutions. This question is particularly relevant to cultural heritage education, where sustainability involves not only technical responses to risk but also processes of interpretation, participation, communication, and shared responsibility.

2.3. Adapting Hackathons to Cultural Heritage Education

This distinction is particularly relevant to cultural heritage at risk, where decision-making requires balancing scientific and technical knowledge with cultural values, community perceptions, institutional priorities, and sustainability concerns. Adapting the hackathon to this context therefore involves reorienting its conventional emphasis on technological prototyping and solution optimization toward a participatory and process-oriented environment in which interpretation, communication, and negotiation become central learning dimensions. This perspective aligns with the broader theoretical shift in heritage studies from heritage as object to heritage as process. Critical heritage scholarship emphasizes that cultural heritage is not a fixed entity to be passively conserved, but a dynamic and socially constructed process continuously shaped through participation, interpretation, and negotiation [13,26]. Within this framework, communication and participation are not secondary activities added to conservation practices, but constitutive dimensions of heritage itself, closely connected to democratic citizenship, shared responsibility, and community engagement [12].

From this perspective, educational activities focused on heritage communication acquire transformative potential. By engaging students with real-world heritage challenges, participatory methodologies can foster not only disciplinary learning, but also reflexive thinking, civic awareness, and socially situated forms of responsibility. This dimension resonates with theories of transformative learning, which emphasize how educational experiences can generate shifts in perspectives through critical reflection and collaborative meaning-making processes [27]. In the context of short-term educational interventions, however, the presence of critical reflection, perspective negotiation, and collaborative meaning-making should not be interpreted as evidence of sustained transformative learning. Rather, these processes may indicate a transformative potential by creating conditions in which learners are encouraged to question established assumptions and explore alternative ways of framing complex problems.

It also intersects with ESD approaches that move beyond the acquisition of knowledge toward the development of competences enabling learners to understand and respond to

complex sustainability challenges [3,4]. From this perspective, competences such as collaborative problem-solving, critical and systems thinking, the capacity to negotiate different perspectives, and the ability to act under conditions of uncertainty are particularly relevant.

Rather than being treated as predetermined learning outcomes to be measured in isolation, these competences can emerge through situated educational experiences in which students are required to interpret problems, negotiate meanings, and collectively develop possible responses.

In this study, the term "hackathon" refers to the overall educational format rather than to a specific ideation technique. The format retains several defining characteristics of conventional hackathons: an intensive and time-bounded structure, collaborative work in small teams, engagement with a shared real-world challenge, rapid cycles of idea generation and refinement, and the development and public presentation of a final proposal. Design thinking, by contrast, provides the methodological process through which participants navigate this format, while Project-Based Learning provides the broader pedagogical rationale for learning through the collaborative development of a response to an authentic problem. The three concepts are therefore related but operate at different levels of the educational design. What distinguishes the heritage-oriented adaptation proposed here is the deliberate modification of the expected outcome and of the problem-solving logic typically associated with technology-oriented hackathons. Rather than requiring participants to produce a functional technological prototype or converge rapidly on a technically optimized solution, the activity emphasized interpretation, communication, audience awareness, stakeholder engagement, and the contextual feasibility of proposed interventions. The final outputs were therefore conceived as project concepts and communication or engagement strategies rather than as fully developed prototypes. In this adaptation, the time-bounded, collaborative, and challenge-driven structure of the hackathon is retained, while its conventional emphasis on technological production is replaced by a process centred on situated interpretation, participatory meaning-making, and socially oriented responses to heritage risk. In this form, heritage-oriented hackathons can be understood as temporary learning communities in which students negotiate meanings, confront uncertainty, and engage collaboratively with socially relevant issues. Communication- and participation-oriented activities may further foreground audience awareness, stakeholder engagement, and civic responsibility, connecting disciplinary knowledge with broader sustainability and heritage-risk concerns [28].

3. Methodology

3.1. Study Context and Participants

The initiative involved 25 students enrolled in undergraduate and graduate programmes offered by the Department of Cultural Heritage at the University of Bologna. Participants came from different heritage-related educational backgrounds,—archaeology, art history, conservation—reflecting the interdisciplinary nature of cultural heritage studies and allowing the activation of heterogeneous perspectives during collaborative activities. The group included both male and female students, with a predominance of female participants. Although the post-event questionnaire collected participants' age range, only aggregate results from the original questionnaire analysis were available at the time of revision; consequently, a detailed demographic distribution by age cannot be retrospectively reported.

The hackathon took place over two afternoon sessions of four hours each within a broader two-day workshop entitled "Managing Cultural Heritage at Risk", organized at the MAR—Museo d'Arte della città di Ravenna on 19–20 February 2025 [29]. The workshop aimed to provide conceptual and operational tools for understanding heritage

degradation processes, assessing vulnerability, and promoting sustainable approaches to risk prevention and resilience in cultural heritage management.

The morning sessions consisted of lectures and discussions involving researchers, institutional representatives, and professionals working in pre-emergency, emergency, and post-emergency heritage risk management contexts. Through real-world case studies and operational experiences, participants were exposed to interdisciplinary perspectives on degradation processes, vulnerability assessment, preventive conservation strategies, and resilience-oriented intervention models. Within this broader educational framework, the afternoon hackathon sessions functioned as collaborative and challenge-based learning environments where students were invited to reinterpret and operationalize the issues discussed during the workshop through locally situated and participatory activities. Rather than focusing on technological prototyping, the hackathon was intentionally structured around communication, interpretation, and civic engagement, coherently with the assumption that heritage-related challenges require socially embedded and relational approaches rather than exclusively technical solutions. This structure enabled students to engage with heritage risk as a complex, real-world challenge involving interconnected scientific, environmental, cultural, and social dimensions.

3.2. Hackathon Design and Facilitation

The conceptualization of the hackathon format was itself developed through an interdisciplinary collaboration involving researchers from the SIRIUS and RESTART projects with backgrounds in conservation, applied sciences to cultural heritage, archaeology, art history, and digital heritage. Prior to the activity, the research team participated in a four-hour facilitator training session coordinated by Sprintaly [30], an organization working with participatory co-design and collaborative methodologies. The session introduced the methodological structure of the hackathon and the design-thinking tools that would subsequently be used with the students. Particular attention was devoted to the role of the facilitator, including how to interact with participants, support group dynamics, guide the different phases of the process, and encourage participation without directing groups toward predefined solutions. The training session also provided an opportunity for the research team and Sprintaly facilitators to jointly define the challenge proposed to the students. The challenge was developed collaboratively by considering the objectives of the SIRIUS and RESTART projects, the educational aims of the workshop, and the need to translate heritage-risk issues into a suitable open-ended task for collaborative work. Sprintaly therefore contributed both to the methodological design of the initiative and to the adaptation of the hackathon format to the specific context of cultural heritage education.

During the sessions, five trained facilitators worked alongside the Sprintaly team to support group dynamics, reflection processes, and collaborative interactions. Their role was not to provide predefined solutions, but rather to scaffold participation, encourage critical reflection, and facilitate collective meaning-making throughout the different phases of the process.

The hackathon design followed a progressive sequence intended to move participants from problem interpretation toward collaborative proposal development (Figure 1). Operationally, the hackathon provided the time-bounded, challenge-driven, and collaborative structure of the activity, while design-thinking tools were used to guide participants through successive phases of problem framing, ideation, audience definition, proposal development, and presentation. The expected outcome was not a functional prototype, but a contextually grounded project concept addressing heritage risk through communication, education, or community engagement.

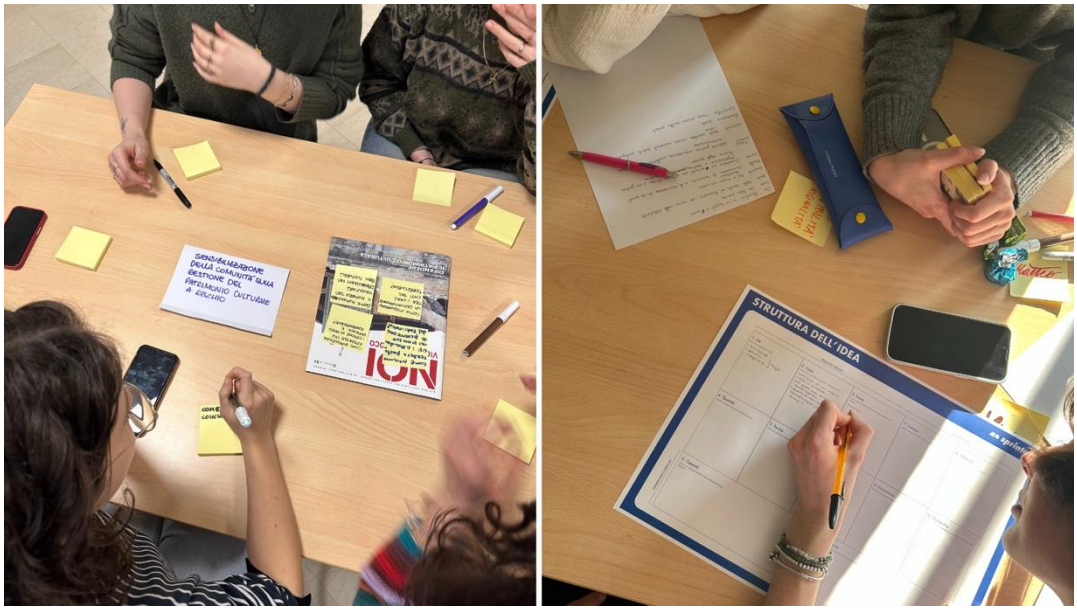


Figure 1. Students engaged in collaborative ideation and design-thinking activities.

First, students engaged in a problem reframing activity using the "How Might We" (HMW) method [31], transforming heritage-risk issues into open-ended and action-oriented questions. This phase encouraged participants to interpret risks not only as technical problems, but also as social and communicative challenges connected to local contexts and community awareness.

The second phase focused on ideation and benchmarking. Participants used the "Crazy 8" technique [32,33] to rapidly generate multiple proposals within limited timeframes, encouraging divergent thinking, experimentation, and creative exploration. This process was complemented by benchmarking activities involving the analysis of communication campaigns, participatory initiatives, and awareness strategies developed in other contexts.

Subsequently, students developed personas representing hypothetical community members potentially involved in or affected by heritage-risk scenarios [34]. This exercise aimed to strengthen empathy and audience awareness, encouraging students to reflect on how different social groups perceive, interpret, and engage with cultural heritage.

In the final design phase, proposals were refined through the 5W + H framework [35], which supported participants in structuring objectives, audiences, resources, implementation strategies, and expected impacts. Each group then presented its proposal through a ten-minute public pitch evaluated by a panel composed of academics, facilitators, and professionals working in cultural heritage and communication. Evaluation criteria included thematic relevance, originality, feasibility, and potential community impact.

Immediately after the workshop, all 25 participants individually completed a post-event questionnaire developed ad hoc by the interdisciplinary research team responsible for the design and organization of the initiative (response rate = 100%). The complete questionnaire is provided in Appendix A. The questionnaire was conceived as an exploratory feedback instrument rather than as a standardized psychometric scale for measuring learning outcomes or sustainability competences. Its purpose was to collect participants' perceptions of the workshop and hackathon experience in relation to the educational objectives of the activity. As the instrument was designed for exploratory and descriptive purposes rather than for the measurement of a latent construct, no formal psychometric validation or reliability testing was conducted. It combined rating-scale items, multiple-choice questions, and open-ended questions. The quantitative rating-scale items asked participants to assess: (i) the extent to which the workshop stimulated reflection on the impact of heritage-related risks; (ii) the extent to which the workshop affected their

perspective on cultural heritage conservation; (iii) the perceived usefulness of the experience for developing competences and future professional perspectives; and (iv) their overall satisfaction with the workshop. These items were rated on a 1–10 scale. Additional multiple-choice items explored participants' perceptions of the impact of heritage-related risks on communities, the aspects of the hackathon they appreciated most, and their willingness to recommend the experience.

Open-ended questions invited participants to identify critical aspects and suggest improvements to future activities. Closed-ended questionnaire responses were collected individually from all 25 participants and analysed descriptively; the quantitative results reported in the study represent aggregate scores derived from these individual student responses. The quantitative results available for the present study consist of aggregate mean scores derived from the original questionnaire analysis. Individual-level response data were not available at the time of revision; consequently, measures of variability, such as standard deviations or response distributions, could not be retrospectively calculated. For the same reason, it was not possible to retrospectively examine differences in questionnaire responses according to participants' field of study or degree programme.

Open-ended responses were examined qualitatively by the research team to identify recurrent topics and shared patterns across participants' accounts. No formal coding framework was applied; rather, the analysis involved a collective review and comparison of the written responses, through which recurrent aspects of the educational experience were identified and discussed by the research team. Given the exploratory and descriptive nature of this analysis, these recurring patterns are interpreted as contextual insights into participants' experiences rather than as the outcome of a formal thematic analysis. No formal ethics approval was sought for this study. Before completing the post-event questionnaire, participants were orally informed that participation was voluntary and that their responses would be used for research purposes. Participation in the questionnaire had no consequences for participation in the workshop. Oral informed consent was obtained before questionnaire completion. The questionnaire did not collect names, email addresses, or other direct personal identifiers, and responses were analysed and reported at the aggregate level. Open-ended responses were likewise examined without information directly identifying individual participants.

The relationship between these recurrent patterns and sustainability-oriented competences was considered only at the interpretative stage, by comparing these descriptive observations with the competence dimensions discussed in the theoretical framework. These competences were therefore not used as predefined analytical categories or measured outcomes.

4. Results

4.1. Student Project Outputs

The hackathon generated a diverse range of proposals aimed at enhancing public awareness of cultural heritage at risk and promoting participatory approaches to heritage protection within the local community. Rather than converging toward purely technological solutions, the projects demonstrated a marked orientation toward communication, educational mediation, and community engagement. Although the proposals primarily focused on communication and public engagement, they were grounded in scientific contents related to heritage degradation, vulnerability, and risk management that had been introduced during the workshop sessions. The proposals included educational tools for children, participatory territorial events, collaborative discussion formats involving local stakeholders, and emotionally driven visual campaigns aimed at raising public awareness. Although differing significantly in format, target audience, and communication strategy, all projects shared a common emphasis on public engagement, accessibility, and community-oriented approaches to heritage protection.

Particularly significant was the initial "How Might We" (HMW) phase, which encouraged students to formulate heritage-risk issues through open-ended and action-oriented questions. The HMW questions developed by the groups reflected perspectives centred on accessibility, public awareness, and civic involvement. These outputs provide evidence of how participants framed the heritage-risk challenge during the activity, but, in the absence of a pre-workshop assessment, they cannot establish whether or to what extent individual students' understanding changed as a result of the activity. Benchmarking and ideation activities further expanded the range of perspectives considered by exposing participants to communication campaigns and participatory initiatives developed in other contexts.

The persona-development phase also emerged as especially relevant. Rather than addressing an abstract "general public," students were encouraged to identify differentiated audiences characterized by specific needs, expectations, and behaviors. This exercise fostered stronger audience awareness and empathy-oriented approaches, encouraging participants to critically reflect on how different social groups perceive and engage with cultural heritage (Figure 2).



Figure 2. Examples of collaborative design-thinking during the workshop activities.

4.2. Project Evaluation

An important aspect of the activity concerned the evaluative framework adopted throughout the hackathon. Table 1 reports the evaluation of the four project proposals developed by the student groups. These scores refer exclusively to the characteristics of the proposed projects and should not be interpreted as measures of individual or group learning outcomes. Each proposal was assessed according to four criteria—thematic relevance, originality, feasibility, and potential community impact—using a five-point scale for each criterion (1 = insufficient; 2 = sufficient; 3 = good; 4 = very good; 5 = excellent). Two sets of scores were assigned to each proposal: the first was jointly determined by the academic team and Sprintaly facilitators, while the second was assigned by the Sprintaly facilitation team. The two sets of scores were then summed, resulting in a maximum overall score of 40 points per project.

Table 1. Overview of student proposals and evaluation outcomes.

Group	Proposal	Communication Approach	Total Score (/40)	Strengths	Critical Aspects
Group 1	Interactive pop-up book for children about heritage risk	Educational storytelling and tactile interaction	35	Strong thematic relevance, creativity, educational impact, audience-oriented communication	Need to better distinguish between end users and institutional stakeholders
Group 2	Series of public events and local festivals focused on lesser-known heritage sites at risk	Community engagement through territorial events	30	High community relevance and public outreach potential	High organizational costs, unclear implementation structure and target stakeholders
Group 3	Discussion tables among local institutions and stakeholders	Institutional dialogue and collaborative governance	29	Strong relevance and concrete collaborative perspective	Weak methodological structure and unclear operational framework
Group 4	"Apocalyptic" visual campaign portraying monuments in post-disaster scenarios	Emotional and visual impact communication	27	High originality and strong visual impact	Limited feasibility, risk of sensationalism and lack of specific target audience

The winning proposal consisted of an interactive pop-up book for children designed to communicate concepts related to heritage risk, emergency response, and restoration practices through visual storytelling and tactile interaction. The evaluation panel particularly appreciated the project's educational potential and its capacity to translate complex heritage-related issues into accessible narratives capable of fostering emotional engagement and early awareness among younger generations.

The evaluation process also provided complementary perspectives on the project proposals. The first set of scores was jointly determined by the academic team and Sprintaly facilitators, integrating educational, thematic, and methodological considerations, while the second assessment by the Sprintaly facilitation team provided an additional evaluation of the proposals according to the same criteria. These evaluations were used to assess the project outputs generated during the hackathon and were not intended as measures of student learning. In particular, they highlighted the importance of distinguishing between end users (children interacting with the book) and actual stakeholders or institutional actors responsible for adopting and distributing the educational tool, such as schools, families, or cultural organizations. This evaluative discussion proved particularly significant from an educational perspective, encouraging students to move beyond idea generation and reflect more critically on governance dynamics, communication strategies, and implementation processes. In this sense, evaluation itself became part of the learning experience.

4.3. Participants' Perceptions of the Educational Experience

Descriptive questionnaire results indicated a generally positive perception of the educational experience among participants. The available aggregate results suggested positive evaluations of the workshop and hackathon experience across the dimensions explored by the questionnaire. Given that only aggregate results from the original questionnaire analysis were available at the time of revision, and that individual-level response data could not be retrospectively accessed, the findings are reported here qualitatively rather than through numerical scores whose calculation could not be independently

reconstructed. They should therefore be interpreted exclusively as descriptive indicators of participants' self-reported perceptions and not as direct measures of educational effectiveness or learning outcomes. The descriptive review of the open-ended responses provided additional contextual insights into participants' experiences. Recurring observations in participants' written responses concerned: the effectiveness of the progressive structure of activities in supporting unfamiliar methodologies such as design thinking; the collaborative dimension of the experience, perceived as an opportunity to integrate different disciplinary perspectives; and the role of rapid ideation techniques in stimulating creativity and experimentation.

At the same time, several participants highlighted challenges and critical aspects. Some students initially experienced uncertainty and disorientation due to the openness of the methodology and the absence of predefined "correct" solutions, particularly in comparison with more traditional educational settings. Others emphasized the need for preliminary training sessions specifically dedicated to participatory design methodologies, suggesting that such approaches may initially feel unfamiliar within heritage-oriented curricula. Time constraints also emerged as a recurrent limitation, especially regarding opportunities for inter-group exchange and deeper refinement of ideas.

Beyond the production of concrete outputs, participants' written responses also provided insights into how they perceived the relationship between heritage protection, communication, and collective responsibility. The post-event questionnaire explicitly invited participants to reflect retrospectively on whether their perception of cultural heritage conservation had changed following the workshop. These responses are interpreted here as self-reported perceptions of change rather than as evidence of measured change, since no pre-workshop baseline assessment was conducted.

The collaborative intensity of the experience also emerged from participants' written responses as a relevant aspect of the activity, particularly in relation to motivation and emotional engagement. Taken together, these descriptive observations suggest that participants perceived the educational experience as extending beyond disciplinary knowledge acquisition to include relational, affective, collaborative, and civic dimensions.

5. Discussion

5.1. Reconfiguring the Hackathon for Cultural Heritage Education

The Ravenna case provides a basis for examining how the hackathon format changes when applied to cultural heritage education. The findings suggest that its transfer from STEM-oriented contexts cannot occur through simple methodological replication, but requires a reconfiguration of the model from an emphasis on rapid solution development and technological innovation toward more participatory, reflexive, and process-based forms of learning.

Unlike many STEM hackathons, where educational value is frequently linked to rapid prototyping and technological problem solving, the present experience generated learning primarily through interpretation, communication, negotiation, and collaborative meaning-making. Heritage-related challenges proved less reducible to definitive "solutions" and more connected to ambiguity, plural perspectives, and socially negotiated forms of knowledge. This distinction is consistent with recent developments in educational hackathon research, which increasingly conceptualize hackathons not simply as innovation events but as deliberately designed learning environments whose structure should be aligned with specific educational objectives and disciplinary contexts [17,18]. The Ravenna case extends this perspective by showing how the defining features of the educational hackathon—its intensive, time-bounded, collaborative, and challenge-driven structure—can be retained while its methodological emphasis shifts from technological prototyping and solution optimization toward interpretation, communication, audience awareness, and collaborative meaning-making. In this sense, adapting active learning

methodologies to heritage education requires attention to its epistemological characteristics rather than their uncritical transfer across contexts. In the Ravenna experience, the hackathon emerged from an interdisciplinary learning environment grounded in scientific and technical perspectives on heritage risk, vulnerability, and preventive conservation, while simultaneously engaging students with the social, cultural, and communicative dimensions of heritage management.

One of the most significant findings concerns the nature of the proposals developed by participants. Rather than focusing predominantly on technological devices or technical management systems, students consistently produced communication-oriented and community-based proposals, including educational tools, narrative formats, participatory initiatives, and awareness campaigns. This tendency suggests that, when cultural heritage is approached as a relational and socially constructed process, problem-solving can shift toward forms of mediation, accessibility, empathy, and civic participation that complement technical and scientific approaches to heritage protection.

The children-oriented pop-up book provides a particularly clear example of this orientation toward communication, accessibility, and public engagement. Rather than addressing heritage risk primarily through a technological or technical intervention, the proposal translated concepts related to heritage risk, emergency response, and restoration into an interactive educational format based on visual storytelling and tactile interaction. By targeting children, the project emphasized accessibility, emotional engagement, and early awareness, illustrating how heritage-risk preparedness can also be approached as a communicative and educational process.

The evaluation process added a further educational dimension by requiring participants to consider thematic relevance, originality, community impact, and feasibility alongside the distinction between end users and institutional stakeholders. This encouraged students to move beyond idea generation and consider implementation, governance, stakeholder involvement, and contextual constraints, exposing them to the multiple considerations involved in developing heritage initiatives within professional and institutional contexts.

Another relevant aspect concerns the role of uncertainty within the learning process. Several students initially experienced discomfort and disorientation due to the openness of the methodology and the absence of predefined "correct" solutions. Rather than representing only a limitation, however, participants' written responses suggest that uncertainty was perceived as a relevant component of the educational experience. The necessity to negotiate meanings collaboratively, confront ambiguity, and make decisions within uncertain contexts encouraged reflexive forms of learning that are often less accessible within traditional lecture-based educational settings. The emphasis on collaboration, experimentation, and learning through engagement with an open-ended challenge is consistent with recent reviews of educational hackathons, which identify collaborative and experiential learning as recurrent features of these environments while also highlighting considerable variation in how learning is conceptualized and assessed across studies [17]. These observations should not be interpreted as evidence of sustained transformative learning at the individual level. Rather, they point to learning processes with transformative potential, insofar as the activity created opportunities for students to question established assumptions, negotiate alternative perspectives, and reconsider how heritage-risk challenges may be approached. Assessing whether such processes resulted in lasting changes in students' perspectives would require longitudinal or pre/post investigation beyond the scope of the present study. From this perspective, the hackathon functioned not simply as an active learning format, but as a temporary learning community structured around experimentation, critical reflection, and collaborative knowledge production.

5.2. Learning Processes and Education for Sustainable Development

These findings acquire additional significance when interpreted through the perspective of Education for Sustainable Development. As discussed in the theoretical framework, the study did not seek to measure sustainability competences through a standardized assessment. Nevertheless, several learning processes emerging from the experience can be related to competences and dispositions considered relevant to sustainability-oriented education [3,4]. In particular, students were required to integrate knowledge from different disciplinary domains, engage with an open-ended real-world problem, negotiate alternative perspectives, identify and differentiate stakeholders, communicate complex issues to specific audiences, and develop collective responses under conditions of uncertainty. The educational relevance of the experience therefore lies not only in the proposals produced, but also in the processes through which students collaboratively engaged with complexity, interdependence, and shared responsibility.

From this perspective, the findings establish a connection between heritage-oriented challenge-based learning and transversal and socio-civic dimensions of sustainability education. This connection resonates with emerging applications of hackathon-based learning to sustainability challenges, which have highlighted the potential of intensive interdisciplinary collaboration to engage students with sustainability problems and to connect academic learning with real-world challenges [24,25]. The present case adds a cultural heritage perspective to this developing field: rather than centring primarily on innovation or solution development, it suggests that sustainability-oriented hackathons can also create spaces in which students negotiate cultural values, audiences, communication strategies, stakeholder relationships, and collective responsibility.

Collaborative problem interpretation and interdisciplinary negotiation can be associated with the capacity to approach complex problems from multiple perspectives: personal development and audience-oriented design foregrounded empathy and stakeholder awareness while the emphasis on public engagement and collective responsibility encouraged students to consider heritage protection beyond individual disciplinary or institutional boundaries. Importantly, these dimensions should not be interpreted as independently measured competence gains, but as learning processes and outcomes that are consistent with a sustainability-oriented educational framework.

Cultural heritage at risk is particularly productive in this respect because it makes the interconnected character of sustainability challenges visible. Heritage risk cannot be understood exclusively through environmental hazards or material vulnerability: it also involves cultural values, institutional capacities, community perceptions, communication practices, and decisions concerning what and how societies seek to protect. The Ravenna experience therefore suggests that cultural heritage can provide a situated context for ESD in which environmental, cultural, social, and civic dimensions are addressed through a shared real-world challenge. This perspective also broadens the role of heritage within sustainability education: rather than functioning only as an object to be preserved under SDG 11, heritage can become an educational medium through which students critically engage with resilience, participation, responsibility, and sustainable futures.

In this broader perspective, the experience intersects with SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action), positioning cultural heritage as a field through which universities can explore participatory and sustainability-oriented forms of learning. The connection among these goals is particularly relevant in contexts such as Ravenna, where heritage protection, environmental and climate-related risks, education, and community resilience intersect at the local level.

5.3. Limitations and Future Directions

At the same time, the study also revealed several limitations. The compressed timeframe typical of hackathon formats constrained opportunities for deeper reflection, iterative testing, and long-term implementation. Students' requests for preliminary methodological training further indicate that participatory and challenge-based approaches cannot be assumed as self-evident within cultural heritage curricula. Their effectiveness depends significantly on facilitation quality, methodological scaffolding, and the creation of supportive learning environments capable of balancing structure with creative autonomy. At the same time, the active role of facilitators represents a potential source of influence on group dynamics and project development, and should therefore be considered when interpreting the processes and outputs observed during the activity.

These observations also resonate with recent hackathon research emphasizing the importance of pedagogical design, facilitation, and integration with broader learning trajectories rather than treating hackathons as self-contained events [17,18]. The present findings similarly suggest that hackathons may achieve greater pedagogical value when integrated into broader educational ecosystems. Follow-up activities, opportunities for project continuation, partnerships with local institutions, and curricular integration could help transform temporary engagement into more sustained forms of participatory practice and civic involvement. From an ESD perspective, such continuity would also provide opportunities to move beyond short-term engagement and examine whether the learning processes observed during intensive challenge-based activities translate into longer-term competences, professional practices, or forms of civic participation.

More broadly, the case study highlights the potential role of universities in connecting disciplinary expertise with socially situated challenges through collaborative and participatory learning. Within heritage education, this approach can create opportunities for students to engage with the scientific, cultural, communicative, and civic dimensions of sustainability within a shared real-world context.

6. Conclusions

In response to the research question, the Ravenna case study suggests that the hackathon format can be adapted to cultural heritage higher education by retaining its intensive, time-bounded, collaborative, and challenge-driven structure while reorienting its methodological focus from technological prototyping and solution optimization toward interpretation, communication, audience awareness, stakeholder engagement, and collaborative meaning-making. This adaptation reflects the characteristics of heritage-related challenges, which involve not only technical knowledge but also cultural values, multiple perspectives, public communication, and socially negotiated forms of responsibility.

Within this exploratory case study, the activity was associated with high levels of student engagement and interdisciplinary collaboration and created opportunities for critical reflection, communication, negotiation, engagement with uncertainty, and shared responsibility. These observed processes are consistent with dimensions of sustainability-oriented education, but should not be interpreted as evidence of independently measured competence development or sustained transformative learning. The projects developed during the activity also framed heritage risk through communicative, social, and participatory dimensions alongside scientific and technical ones, suggesting that cultural heritage at risk can provide a situated context for engaging students with the interconnected environmental, scientific, cultural, social, and civic dimensions of sustainability. The contribution of this approach therefore lies not in replacing scientific and technical expertise, but in connecting it with participatory and communication-oriented forms of learning and engagement.

These findings should nevertheless be interpreted within the exploratory scope of the study. The small sample, short duration of the activity, absence of pre/post or control-group

comparisons, reliance on participants' self-reported perceptions, potential influence of facilitation, and availability of only aggregate questionnaire data prevent conclusions about sustained learning, competence development, individual change, or causal effects of the intervention. Future research should therefore examine heritage-oriented hackathons through longitudinal and comparative designs, investigate their integration into broader curricular pathways and stakeholder collaborations, and assess whether the learning processes identified here translate into longer-term educational, professional, or civic outcomes.

Overall, the Ravenna experience suggests that the educational potential of heritage-oriented hackathons lies less in reproducing the solution-driven logic of their technological origins than in creating structured spaces for collaboratively engaging with the interpretative, communicative, and socially situated dimensions of complex heritage challenges. In this form, the hackathon may provide a participatory learning environment through which students engage with the complexity, uncertainty, and shared responsibility that characterize both cultural heritage protection and Education for Sustainable Development.

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Institutional Review Board Statement: Ethical review and approval were not sought for this study. The activity was a non-clinical educational intervention involving a voluntary post-event questionnaire. According to the University of Bologna guidance on research data management, for non-clinical research projects involving the collection of personal data, the opinion of the University Bioethics Committee is not mandatory unless expressly requested, for example, by the funding body or the publisher.

Informed Consent Statement: Verbal informed consent was obtained from the participants. Verbal consent was obtained rather than written because the questionnaire was administered as a voluntary post-event feedback instrument within the educational activity and no separate written consent form had been prepared for its completion.

Data Availability Statement: The individual-level questionnaire response data are no longer available. The aggregate results available from the original analysis are reported in the manuscript. The questionnaire administered to participants is provided in English translation in Appendix A.

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Appendix A. Post-Event Questionnaire

The following questionnaire was administered to participants in Italian immediately after the workshop "Managing Cultural Heritage at Risk". The English version provided below

is a translation of the original instrument. The questionnaire was developed ad hoc by the interdisciplinary research team as an exploratory feedback instrument and was not intended as a standardized or validated measure of learning outcomes or sustainability competences.

1. Age

Single-choice question

18–24

25–34

35–44

45–54

55–64

65+

2. Which aspect of the workshop did you find particularly noteworthy?

Single-choice question

The topics and case studies presented during the sessions

The participation of different organizations and institutions with expertise in the field (Municipality, Superintendency, Regional Secretariat, Fire Brigade, museum curators, volunteer organizations)

The participatory activities carried out during the afternoon sessions

Other

3. To what extent do you think the workshop stimulated reflection on the impact of territorial risks on cultural and environmental heritage?

Rating scale: 1–10

4. In what ways do you think the activity could influence the community, including both the scientific community and the general public?

Multiple responses allowed

Increased awareness among professionals in the field (restorers, conservators, museum directors, museum staff, etc.)

Collaboration and exchange of expertise among organizations and institutions

Encouragement to develop courses or theoretical–practical training activities for the safeguarding of cultural heritage

Greater willingness to participate in volunteer activities

Increased awareness of a culture of risk prevention

Other

5. After participating in this workshop, to what extent did you modify your perception of cultural heritage conservation?

Rating scale: 1–10

6. After participating in this workshop, did your perception of cultural heritage conservation change?

Single-choice question

My perception of the protection and conservation of cultural heritage changed considerably

My perception of the protection and conservation of cultural heritage changed slightly

I was already aware of these issues, and the workshop reinforced my existing perspective

The workshop did not change my perception

7. How useful do you consider this workshop for your competences and future perspectives?

Rating scale: 1–10

8. Which aspect of the hackathon did you find particularly noteworthy?

Single-choice question

The proposed theme of raising community awareness of risks affecting cultural heritage

The participatory approach

The idea-generation method

The opportunity to develop a project that could potentially be translated into a concrete product

Other

9. What is your overall level of satisfaction with the activity?

Rating scale: 1–10

10. Would you recommend this activity to someone you know?

Single-choice question

Yes, absolutely

Yes, but I would suggest modifications to the proposed activities/sessions or to the organization of the two days

No

11. Do you have any suggestions for improving this type of activity?

Open-ended question

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