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Weaving mathematics across contexts: a theoretical–methodological framework for researching classroom–museum continuity

Raffaele Casi[1a]

[a]Department of Philosophy and Education Sciences
University of Turin, Turin, Italy
raffaele.casi@unito.it

Abstract: Museums are increasingly recognised as relevant settings for mathematics education beyond school, but the relation between classroom and museum learning remains difficult to describe. This theoretical–methodological paper addresses classroom–museum continuity as a research problem: how can mathematical work remain recognisable and meaningful when it moves across contexts shaped by different objects, spaces, forms of mediation, institutional purposes, and ways of participating? To address this question, the paper develops a framework that brings together informal mathematics education, the museum experience as contextual configuration, double didactical continuity, and continuity across sociocultural difference. Organised through Falk and Dierking's Contextual model of learning, the framework shifts attention from the museum visit as an isolated event to the broader learning opportunity woven across classroom and museum. A worked example involving circumferences, spirals, bodily movement, and mathematical machines illustrates how the framework can support analysis. The paper closes by discussing methodological implications for studying continuity across contexts, including the need to follow mathematical meanings, mediations, and forms of work before, during, and after the museum visit.

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1. Introduction

Research in mathematics education has increasingly acknowledged that mathematical work exceeds the institutional boundaries of the classroom. Bakker et al. [1] identify the relation between mathematics education and other practices as one of the major directions for future research, and recent work on out–of–school mathematics education has begun to give sharper visibility to the environments in which such activity is organised beyond school [2]. This

[1]Corresponding author.

development leaves an important question open. Once mathematical work is recognised across multiple settings, how should mathematics education research describe the relations among those settings?

Museums make that question unusually demanding. Within informal mathematics education, they have emerged as environments in which mathematically rich activity can be intentionally designed beyond formal instruction [3]. At the same time, museum learning is shaped by a configuration of objects, spaces, mediations, and temporalities that has its own educational logic. Falk and Dierking [4] locate museum learning in the interplay of personal, sociocultural, and physical contexts, and thus place the visit within a wider process of meaning making. For mathematics education, this has an immediate consequence: what is at stake in museums cannot be described through a generic opposition between school and outside school. The museum enters the field as a distinctive context in which mathematical work takes form under conditions that differ from those of classroom practice.

The kind of continuity addressed in this paper can be illustrated through the mathematical work later discussed in the example. In that path, students move between classroom explorations of circumferences and a museum workshop on spirals, where distance from a centre, rotation, and variation of distance are encountered through architectural details, bodily movement, and mathematical machines such as the spiralograph and the helicograph. These examples show that what travels across classroom and museum is richer than a simple mathematical topic, providing a set of ways of seeing, moving, describing, conjecturing, and using artefacts mathematically.

Research on field trips, much of it developed in science education, has repeatedly shown that the educational significance of a visit depends on what prepares it and on what takes it up afterwards [5, 6]. Within museum learning, the same point has been developed through a temporal understanding of experience that exceeds the moment of the visit itself [4]. This body of work provides an important basis for studying school–museum relations, especially by making visible the role of preparation, mediation, and follow–up. However, a mathematics education perspective raises a more specific question: not only whether the visit is well integrated into a broader educational sequence, but how mathematical meanings, representations, gestures, artefacts, and forms of inquiry remain available when they move across contexts. In this sense, classroom–museum continuity concerns the intelligibility of mathematical work across different environments, whose materials, rhythms, mediations, and institutional purposes do not coincide. What a mathematics education perspective adds, then, is an analytic concern with the continuity of mathematical meanings and forms of mathematical work. The central question is whether the mathematical work developed in one setting remains intelligible in another, so that ideas explored during the visit can be taken up, reinterpreted, and further developed back in the classroom. This requires attention to how mathematical meaning is produced through objects, inscriptions, bodily movement, dialogue, and documentation, and to how resources become available again when the mathematics returns to the classroom.

Against this background, this theoretical–methodological paper treats classroom–museum continuity as a specific problem for mathematics education research. The focus is therefore on how mathematical meanings and forms of mathematical work remain available when they are reconfigured across classroom tasks, museum encounters, mediated interactions, and later classroom discussions. The paper is organised around three guiding questions:

1. In what terms can classroom–museum continuity be conceptualised as a distinct problem for mathematics education research?
2. Which analytical dimensions are needed to study the continuity of mathematical activity across classroom and museum as contexts shaped by different material, institutional, and sociocultural conditions?

3. What does the proposed framework make visible in an integrated classroom–museum path?

The contribution of the paper does not lie simply in bringing together adjacent literatures on informal mathematics education, museum learning, and continuity across settings. Rather, it lies in coordinating these perspectives into a single theoretical–methodological framework that makes classroom–museum continuity more precisely researchable as a mathematics education problem. More specifically, the paper shifts attention from the visit as an isolated event to the *distributed learning environment* woven across classroom and museum, and from the simple recurrence of mathematical topics to the ways mathematical work is sustained, reformulated, or weakened across contexts. In these terms, continuity becomes analytically visible without collapsing classroom and museum into a single pedagogical logic. A related implication concerns outdoor mathematics education: rather than classifying museums as outdoor settings, the paper shows the analytic value of an outdoor lens for foregrounding place, materiality, movement, mediation, and contextual difference. This paper is conceived as a conceptual and theoretical-methodological contribution rather than as a report of a new empirical study. It first develops the conceptual bases of the proposal, then illustrates the framework through a worked example, and finally draws out its methodological implications for research on continuity across contexts.

2. Informal Mathematics Education as a Conceptual Entry Point

A conceptual challenge arises from the expression *outside school*. Taken on its own, it names a location more readily than an educational form. Eshach [7] showed the limits of such spatial shorthand in distinguishing formal, non–formal, and informal education through differences of structure, mediation, participation, and intentionality rather than through place alone. Indeed, museum does not enter this argument merely as what lies beyond the classroom, but as part of a field of educational activity whose relation to school mathematics requires a more exact vocabulary.

Informal mathematics education (IME) can provide that vocabulary. Nemirovsky et al. [3] use the term for mathematically intentional environments organised beyond formal instruction and marked by forms of participation that are not governed by the ordinary logics of curriculum, compulsion, and assessment. This stance makes thinkable the connection between school mathematics and museum mathematics by creating an educational context through deliberate design in which the activities remain open to exploratory movement, shifting disciplinary boundaries, and forms of participation usually unavailable in routine classroom settings.

Its contribution becomes sharper once it is placed alongside research on mathematics in everyday practices. Nunes, Schliemann, and Carraher [8] established that sophisticated mathematics may arise outside school while remaining embedded in the goals and representations of specific practices. Pattison, Rubin, and Wright [9] later gave this distinction a useful formulation by separating everyday mathematics from designed informal learning environments. Museums belong to the latter configuration: their mathematical activity is intentionally arranged, institutionally framed, and educationally mediated. This places them in a position that is neither that of school mathematics nor that of mathematics embedded in ordinary practice.

This intermediate position also helps clarify what distinguishes museum mathematics from school mathematics. The difference lies in the conditions under which mathematical meaning is produced. Mathematical objects such as spirals, symmetries, measures, or spatial relations remain central, but they are encountered and explored through forms of activity that are characteristic of the museum setting. In school, mathematical work is usually organised through structured curricular sequences and opportunities for collective discussion and written representation, together with the possibility of returning to the same ideas over time. In museums, mathematical work is more strongly shaped by spatial exploration and encounters with objects, often within brief interactions and culturally mediated experiences, that begin from noticing, questioning, and interpreting what is materially present. Participation is therefore organised differently: students or visitors may engage mathematically by looking, moving, gesturing, comparing, following a guide's prompt, manipulating an artefact, or connecting a form to the cultural setting in which it appears. For this reason, classroom–museum continuity cannot be understood as the simple transfer of school tasks into a different venue, but requires attention to how mathematical meanings are reconfigured through museum–specific forms of participation and mediation.

This distinction gives the present paper its starting point. The problem of continuity arises between school mathematics and another form of mathematically intentional work, one organised through different modes of participation, materials, mediations, temporalities, and expectations. IME opens that space conceptually; it does not yet explain the museum as such. The next step, therefore, concerns the museum's own specificity as an educational and cultural configuration for mathematics education.

3. Museums as Specific Contexts for Mathematics Education

Museum specificity begins at an institutional level. According to the International Council of Museums [10], a museum is a not–for–profit, permanent institution in the service of society that researches, collects, conserves, interprets, and exhibits tangible and intangible heritage, offering experiences of education, enjoyment, reflection, and knowledge sharing. As Walz [11] argues, the museum definition functions less as a description exhausted by any single institution than as a collective norm for a heterogeneous field. A museum is therefore never just a site in which educational activity happens to take place. Curatorial decisions, architectural organisation, public mission, and interpretive regimes already shape the forms of attention, movement, and mediation available within it. Mathematical work, when it takes place in museums, is formed within these conditions rather than simply placed inside them. For example, a spiral encountered in a staircase, a shell–shaped decoration, or an architectural detail does not first appear as an already isolated mathematical object. It becomes mathematically available through the way students are invited to look at it, move around it, compare it with other forms, describe its variation, and relate it to ideas such as rotation, distance from a centre, or movement in space.

Falk and Dierking [4] give this specificity its most productive articulation. Their contextual model locates museum learning in the interplay of personal, sociocultural, and physical contexts, and in the temporal relations that extend beyond the visit itself. Thus, mathematics in museums does not unfold in an abstract setting; it takes shape within a context that distributes attention, organises encounters, and gives force to what may later be recalled, resumed, or reinterpreted. The museum therefore belongs to the activity under study, conditioning what can be noticed, how it can be talked about, and under what forms it may continue.

This becomes clearer once objects and artefacts are brought into focus. The object–centred perspective developed in the work collected by Paris [12] shifts attention away from exhibits as carriers of preformed content and towards the interpretive work through which objects become meaningful in relation to narrative, inquiry, and use. De Kluis et al. [13] sharpen the point further in showing that the educational force of museum objects depends on context, presentation, and opportunities for interaction. For mathematics education, the decisive issue can be the mediation: artefacts become mathematically productive through the signs and shared meanings that emerge in activity, as Bartolini Bussi and Mariotti [14] have shown in their work on semiotic mediation. Gesture enters the same field as a semiotic resource rather than as a marginal accompaniment to speech [15]. In museum settings, then, objects, spaces, and bodily movement participate directly in the formation of mathematical work.

The museum specificity at stake is also cultural. Museum encounters are organised through historical, artistic, scientific, and civic meanings that remain active in the activity itself. Kéfi et al. [16] describe mediation in museums as the production of relations among participants, cultural objects, and institutional structures. From this point of view, it is necessary to prevent mathematics from losing its connection with the museum environment in which it occurs. By way of example, which will be discussed later, a spiral encountered in a museum is not only a geometrical form: it belongs simultaneously to material display, cultural interpretation, and mathematical inquiry. Research on continuity therefore cannot treat the museum as a backdrop against which mathematical work takes place. It must recognise the museum as one of the conditions through which that work acquires its form. The next section considers what research gains when this specificity is approached through an outdoor lens.

4. Museums and the Analytic Gain of an Outdoor Lens

For the purposes of this paper, it appears appropriate to adopt the analytical framework of outdoor education to examine specifically the continuity in mathematics between the classroom and the museum. This approach, as noted above, is not intended to be classificatory; rather, it brings into focus dimensions of experience that outdoor education has taught research to treat with greater precision: place, movement, materiality, mediation, and the pedagogical consequences of contextual difference. In Priest's [17] classic formulation, outdoor education is structured through relations rather than through a simple change of venue. More recent work has given that intuition a sharper shape. Lloyd, Truong, and Gray [18] describe place–based outdoor learning as an integrated, place–responsive approach that interconnects place, curriculum, and learners; Zanato Orlandini [19] similarly treats outdoor education through the conjunction of place, mediation, intentionality, and reflective planning. In this light, the outdoor lens provides a perspective for examining continuity by directing attention to how environments participate in the formation of educational activity.

Applied to museums, this lens makes contextual specificity more analytically productive. The museum appears as a place in which mathematics is shaped by routes of movement, perceptual orientation, spatial density, object encounters, and culturally sedimented forms of mediation. Students looking for spirals across a staircase, a ceiling decoration, or the movement generated by a spiralograph are not simply applying a classroom definition in a new place; they are learning to coordinate perception, movement, artefacts, and mathematical language under conditions that the museum itself helps to organise. Although these dimensions have already been partially introduced in the previous section regarding Falk and Dierking's contextual model, this section proposes a shift in focus through the outdoor lens. They no longer belong only to a description of museum experience; they become part of the explanation of how mathematical work is configured within the museum. Place–responsive outdoor research asks what the environment contributes to the activity that unfolds within it. The same question becomes decisive here, pointing out that mathematical noticing in a museum is inseparable from the way bodies move through rooms, from how objects arrest attention, from the relation between visual search and interpretive framing, and from the rhythms through which the institution organises encounter. Casi and Sabena [20] bring this point directly into mathematics education by extending outdoor mathematics beyond nature–based environments and towards culturally mediated settings such as museums.

A second gain concerns continuity itself. An outdoor lens foregrounds the fact that continuity unfolds across environments whose affordances are not interchangeable. Research on classroom–museum continuity therefore becomes more sensitive to the ways in which mathematics is sustained, transformed, or interrupted under altered conditions of place, movement, mediation, and perception. The question is no longer exhausted by whether classroom work and museum activity can be connected. It extends to how mathematical meanings remain recoverable across settings that reorganise attention and participation differently. The outdoor lens strengthens the research focus, supporting a more precise formulation of the distributed learning environment constituted through the weaving together of classroom and museum. The next section develops continuity itself as a research problem internal to that distributed environment.

5. Continuity as a Research Problem

Continuity becomes a research problem at the point where mathematics can no longer be in a single setting. Museum experience may be mathematically rich, perceptually intense, and educationally memorable, yet remain detached from the longer movement of classroom work. Casi [21] names this fragility through the *parenthesis effect*: the visit acquires local significance without entering a broader didactical trajectory. Continuity becomes visible precisely where mathematical meanings are required to survive a change in setting.

Casi et al. [22] propose *double didactical continuity* to account for a more demanding form of persistence across settings. Continuity depends on the passage of mathematical content together with the didactical forms through which that content becomes thinkable, discussable, and workable. The point resonates with broader discussions of pedagogical continuity, where common subject matter may coexist with marked discontinuities in forms of activity, expectations, and participation [23]. In the present argument, continuity concerns the continued recognisability of mathematical work across contexts, not only the reappearance of mathematical themes.

The problem deepens further once classroom and museum are treated as distinct sociocultural practices. Akkerman and Bakker [24] show that boundaries do not simply separate domains; they make visible differences in action, interaction, and participation. Continuity therefore takes shape within difference rather than beyond it. The museum contributes its own materials, rhythms, mediations, and forms of attention; the classroom contributes others. Relations between them are neither automatic nor neutral: they must be educationally sustained. This is also why the problem of continuity cannot be resolved simply through pedagogical equivalence. Continuity is sustained when mathematics remains recoverable across differentiated conditions, when it can be resumed without erasing the difference that gave each context its educational force.

These concepts help in adding precision to the object of inquiry: the parenthesis effect names a recurrent vulnerability, the double didactical continuity specifies what must persist, and the sociocultural difference defines the condition under which continuity becomes educationally demanding.

6. Toward a Theoretical–Methodological Framework for Researching Classroom–Museum Continuity

Recent work on mathematics beyond the classroom has widened the range of settings treated as relevant for mathematics education without producing, in parallel, an equally robust language for relating them. As noted by Memiş and Özkale [25], this gap is especially visible in the case of museums, where the relations among museum education, mathematics education, and informal education remain only partially theorised. The framework proposed here is intended as more than a synthetic overview of relevant concepts. Its specific contribution is to provide an analytic structure for describing classroom–museum continuity with greater precision within mathematics education research. The contribution of the framework lies in its focus on the continuity of mathematical meaning across contexts. The framework is designed to follow how mathematical objects and relations are developed and taken up again across settings. In doing so, it extends museum–learning concerns with experience, mediation, and follow–up toward the analysis of mathematical intelligibility: how something encountered in the museum can become part of a continuing mathematical trajectory rather than remaining an isolated experiential episode. By coordinating four lenses that are often mobilised separately, the framework makes it possible to examine not only whether classroom and museum are connected, but how mathematical work is carried forward, reworked, or interrupted across them. In this sense, its value lies in turning continuity into an object that can be analysed through trajectories, mediations, forms of mathematical work, and relations across distinct educational practices, rather than through a generic appeal to connection, transfer, or coherence. The framework coordinates four intertwined lenses, already introduced in the previous sections: IME, museum experience as a contextual configuration, double didactical continuity, and continuity across sociocultural difference. The articulation of these four lenses is organised through Falk and Dierking's [4] Contextual model of learning, whose personal, sociocultural, and physical contexts, together with its temporal dimensions, provide the framework's operative architecture. Table 1 summarises the analytic contribution of the four lenses.

Analytical lens	**What it foregrounds**	**Analytic contribution to researching classroom–museum continuity**
Informal mathematics education	Mathematically intentional activity beyond formal instruction	Identifies the museum as an educational environment in which mathematical activity is deliberately organised under conditions different from those of ordinary classroom instruction
Museum experience as a contextual configuration	Objects, spaces, mediations, temporalities, institutional and cultural framing	Makes visible the museum's specificity as part of the mathematical activity itself, rather than as a neutral venue in which that activity happens
Double didactical continuity	Mathematical content together with didactical forms	Allows continuity to be analysed through the joint persistence of conceptual nuclei and recognisable forms of mathematical work across contexts
Continuity across sociocultural difference	Relations across distinct educational practices	Frames continuity as an educational relation sustained through difference rather than through equivalence, alignment, or transfer
Note. The four lenses do not function as sequential stages or independent layers. Their articulation is organised through Falk and Dierking's [4] Contextual model of learning.		

Table 1. The four intertwined lenses of the framework and their analytic contribution

In what follows, I present an example of how the framework can be used. To do so, I draw on an integrated learning path already discussed in Casi et al. [22], with the aim of showing how the framework can operate at different levels of analysis. The example is therefore used in an illustrative, heuristic sense, rather than as the object of a fresh empirical re–analysis. The learning path was implemented with two sixth–grade classes in lower secondary schools in Turin, and involved their classroom teachers, who also acted as teacher–researchers. It centred on a mathematically coherent but contextually differentiated trajectory linking classroom work and a visit–workshop at Palazzo Madama around the themes of circumferences and spirals. The path took shape in response to a difficulty that had already emerged in earlier museum–based mathematics experiences: the visit was often positively evaluated, yet it did not continue within the educational life of the class, thereby producing the very parenthesis effect the project sought to avoid. The integrated path was designed precisely to address that fragility, embedding the museum visit–workshop into a series of activities that begin in the classroom, move on to the museum, and then return to the classroom.

The museum visit–workshop at the centre of the path was *Swirls of Ideas*, developed at Palazzo Madama in Turin, a museum whose architectural and decorative forms offered a particularly rich environment for work on spirals. In the Juvarrian staircase and elsewhere in the building, students could encounter spirals as ornamental motifs, shell–shaped decorations, staircases, and curvilinear forms distributed across the museum space. From a mathematical point of view, the workshop treated spirals as kinetic objects, generated through the combined movement of rotation around a centre and displacement toward or away from that centre. The workshop unfolded through three connected activities: first, (1) a perceptual–motor choreography in which students physically enacted a spiral by walking a path of gradually changing distance from a centre; then an exploration of two mathematical machines, (2) a spiralograph, which generated spirals on the plane through coordinated rotation and translation; and (3) a helicograph, which generates three–dimensional helices by coordinating rotation and translation on orthogonal planes. The museum phase of the integrated path therefore organised mathematical work through bodily movement, guided observation, and interaction with specifically designed mathematical machines in relation to a culturally dense environment.

The classroom work before and after the visit was designed to hold that museum phase within a broader trajectory. Before the visit, students worked on circumferences through exploratory activities aimed at making distance from a point, constancy and variation of distance, and rotational movement mathematically available. These activities included work with standard and non–standard tools and with a rotating plane designed to connect classroom exploration to the logic of the spiralograph later encountered in the museum. After the visit, the trajectory returned to the classroom and resumed the museum experience analytically. Students were invited to recall the guide's instructions for using the spiralograph, discuss why those instructions mattered, and conjecture what would happen if they were modified. In this way, the visit re–entered classroom mathematics as material for renewed discussion, reformulation, and conceptual work. A documentation booklet accompanied the whole path. Students used it across the different phases to record titles, drawings, observations, key words, and reflections. The booklet preserved traces of what had been noticed, selected, and reformulated from one context to the next, and made continuity more readable both pedagogically and analytically. Figure 1 gives an illustrative scheme of the integrated path.

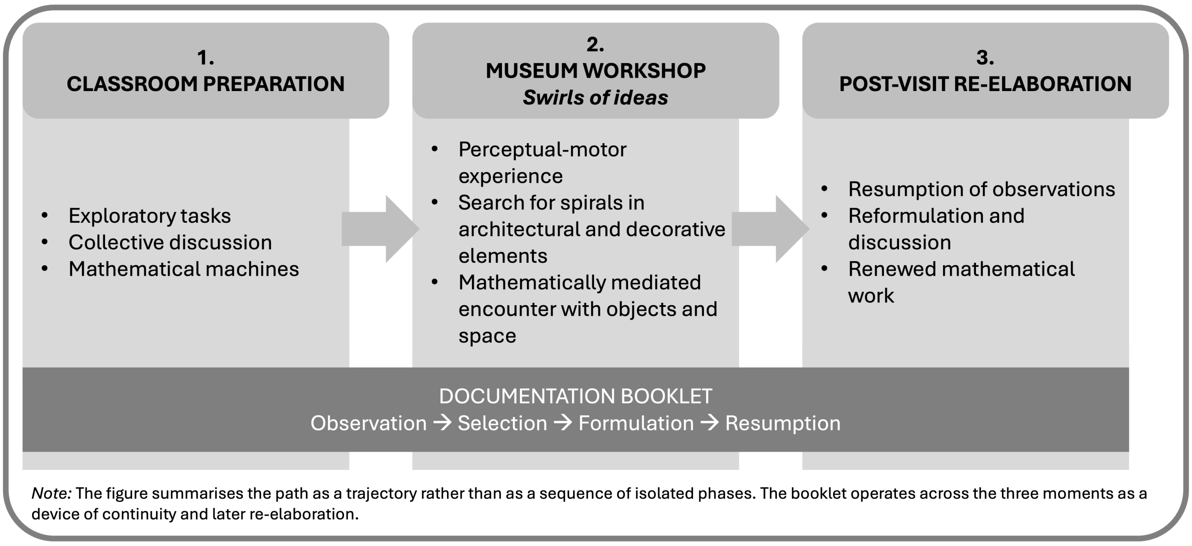

Figure 1. Structure of the integrated classroom–museum path discussed in Casi et al. [22]

Table 2 shows more explicitly how the proposed framework renders the integrated path analytically legible by specifying what each lens brings into view.

Through the framework, the integrated path becomes legible as more than a sequence of

Analytical lens	**What it brings into view**	**Concrete example(s) from the integrated path**	**Relevance for researching continuity**
Informal mathematics education	The museum phase as a form of mathematically intentional activity organised beyond ordinary classroom instruction	The visit–workshop *Swirls of Ideas* is not treated as a generic school trip, but as a designed mathematical experience in which students explore spirals through guided activity, bodily movement, and interaction with mathematical machines; the path also replaces traditional assessment with documentation and formative feedback	Clarifies that continuity is at stake between school mathematics and another form of mathematically intentional activity, rather than between school and a generic “outside”
Museum experience as a contextual configuration	The constitutive role of space, objects, movement, mediation, and cultural framing in shaping mathematical activity	At Palazzo Madama, students encounter spirals in the Juvarrian staircase, shell decorations, spiral staircases, and architectural details; they then experience spirals through a bodily choreography, the spiralograph, and the helicograph	Shows that continuity cannot be studied independently of the museum conditions through which mathematical activity takes form
Double didactical continuity	The persistence across phases of both mathematical content and forms of mathematical work	Before the visit, classroom activities on the rope, set square, everyday artefacts, and rotating plane make fixed distance, variable distance, and rotation mathematically available; after the visit, students recall the guide’s instructions for the spiralograph, discuss why they matter, and conjecture what changes if they are modified	Makes visible that continuity depends not only on the recurrence of conceptual nuclei, but also on the continued circulation of exploratory work, discussion, conjecturing, and reformulation across classroom and museum
Continuity across sociocultural difference	The educational work required to sustain mathematical intelligibility across contexts with different norms, temporalities, and forms of mediation	In the museum, the spiralograph activity is shaped by brief, guided, and relatively directive interaction; back in class, teachers reopen that experience through discussion and “what if...?” questions, allowing students to re-elaborate aspects that remained implicit or only partially explored during the visit	Frames continuity as an achievement across distinct educational practices, rather than as simple alignment, transfer, or equivalence

Table 2. Analytic visibility of the integrated classroom–museum path through the proposed framework

connected activities. It emerges instead as a trajectory in which mathematics is organised across classroom and museum under different but related conditions. In the present case, the museum contributes more than a setting: it shapes how spirals become mathematically available through architecture, movement, guided observation, and interaction with artefacts. Paris's [12] object–centred perspective clarifies how objects acquire educational force through interpretive work. Bartolini Bussi and Mariotti [14] show how this force becomes mathematically productive through semiotic mediation, while Arzarello et al. [15] make visible the role of gesture as a semiotic resource within that process. The classroom, in turn, prepares some of these conditions in advance and later re–elaborates the visit through discussion, conjecture, documentation, and reformulation. This becomes visible when the guide's instructions for using the spiralograph, initially encountered in the museum as situated prompts for action, are taken up again in the classroom as material for explanation, discussion, and "what if...?" conjecture. Continuity, then, lies not in simple topic alignment, but in the continued recoverability of mathematical work across contexts whose norms, rhythms, and mediations do not coincide.

Double didactical continuity becomes visible at another level. Circumferences and spirals recur across classroom and museum, and the coherence of the path also depends on recognisable forms of work: exploratory attention, mediated discussion, collective interpretation, documentation, and later reformulation. The activity moves forward because mathematical meanings and didactical forms remain in circulation across differently configured environments. The documentation booklet embodies the double didactical continuity in two ways: on the one hand, it records the students' mathematical work; on the other, it accompanies and follows the students throughout the whole process, functioning as a cross–context semiotic trace through which observations, words, drawings, and emerging mathematical meanings can be carried from one setting to the other. In this sense, it does not serve merely as a record of activity, but as a mediating artefact of continuity, supporting the reactivation and reformulation of museum experience in subsequent classroom work.

7. Methodological Implications

The framework proposed here redefines the object of inquiry for research on classroom–museum continuity. It cannot be organised around the visit as a self–contained event, because continuity becomes empirically legible only within a broader educational trajectory that is time sensitive. Falk and Dierking [4] already place museum learning within a temporal field that exceeds the physical and chronological bounds of the visit; Casi [21] sharpens the point for mathematics education through the parenthesis effect, which captures the contraction of mathematical meaning into the local intensity of the museum experience when later classroom uptake is weak or absent.

Evidence of continuity is temporally dispersed and unequally distributed across the trajectory. Preparatory classroom activity matters because it establishes tasks, vocabularies, expectations, and modes of attention through which the museum can later become mathematically legible. The visit matters because it concentrates encounters with objects, spaces, movement, and museum mediation under conditions unavailable elsewhere. Post–visit activity matters because continuity acquires empirical density only when observations, gestures, descriptions, or documents are resumed, reformulated, selected, or allowed to dissipate in subsequent classroom work. Tal and Steiner [26] make this especially clear by following school–museum relations across planning, visit, and wrap–up; Rennie and McClafferty [27] similarly treat before, during, and after as educationally consequential phases. A continuity–sensitive corpus therefore takes longitudinal form.

The same logic applies to mediation. Teachers prepare and later reactivate the museum mathematically; museum educators organise access to objects, spaces, and tasks; students appropriate, select, and transform what becomes available in activity; artefacts and documents stabilise some threads of the trajectory while allowing others to disappear. Fredricks [28] gives this point broader support in showing that engagement is shaped by relations with teachers or staff, by peers, by structure, and by task characteristics. Kelton [29] adds a crucial interactional refinement: continuity becomes visible in situated practices of naming, linking, and framing across school and museum. For these reasons, a suitable corpus of researchable data may combine preparatory classroom video, museum interaction data, student documentation, post–visit classroom discussion, teacher planning notes, and interviews with both teachers and museum educators. The point is not exhaustive coverage of the trajectory, but the possibility of reconstructing it analytically.

A further consequence concerns what counts as evidence. Continuity leaves its traces in uptake, reformulation, delayed reuse, and selective disappearance. It appears when museum-based observations re–enter classroom discourse, when perceptual noticing becomes mathematised description, when an artefact or a page of documentation is reused as a semiotic resource, and when recognisable forms of mathematical work persist under changed conditions. Some formulations remain local to the visit, some discoveries lose didactical future, and some links are never resumed. Continuity research therefore depends on a notion of evidence that includes persistence, transformation, and loss within the same analytic frame.

Documentation occupies a particularly strong place within this methodological design. In the integrated path discussed in Casi et al. [22], the booklet accompanied the movement between classroom and museum and supported later re–elaboration. More generally, documentation preserves transitions: what was noticed, selected, named, reformulated, or carried forward can be followed there with a precision that fleeting interaction rarely affords on its own. Krechevsky, Rivard, and Burton [30] treat documentation as a practice of observing, recording, interpreting, and sharing learning processes. Within the present framework, documentation becomes one of the sites in which continuity leaves a readable mark. Its methodological value lies in making longitudinal reconstruction possible. Continuity becomes researchable where transitions can be followed across documents, interactions, and later resumptions of activity.

8. Discussion and Conclusions

This paper has treated classroom–museum continuity as a research object internal to mathematics education across contexts. Bakker et al. [1] identify relations between mathematics education and other practices as a major direction for the field. The contribution developed here gives that direction a more precise form by focusing on the intelligibility of mathematical work across educational practices that do not share the same material, institutional, or sociocultural conditions. The proposed framework makes this problem analytically tractable, relocating inquiry at the level of the distributed learning environment constituted through the weaving together of classroom and museum, where mathematical meanings, didactical forms, and mediations may persist, weaken, or acquire new educational force. Framing continuity as a distributed relation has consequences for how research on mathematics beyond the classroom may be framed. If continuity is treated only as coherence between activities, the analysis risks privileging planned connections while overlooking how mathematical meaning is reconstituted across settings. The framework proposed here invites a different reading: continuity becomes visible in the relations among tasks, mediations, gestures, artefacts, documents, and later classroom uptake. It therefore directs attention to the work through which mathematical ideas are made available again after a change of context, and to the moments in which this work remains partial, fragile, or unsuccessful.

The rationale for bringing the four lenses together lies in the fact that none of them, taken alone, is sufficient to account for classroom–museum continuity as a mathematics education problem. IME identifies the museum as a deliberately designed environment for mathematical engagement beyond ordinary instruction, but it does not by itself specify how a classroom–

museum trajectory can be analysed. The museum–learning perspective, organised here through the Contextual model of learning, foregrounds the personal, sociocultural, physical, and temporal configuration of experience, but it needs to be connected to the specificity of mathematical meaning making. Double didactical continuity indicates what must remain in circulation across contexts: not only mathematical content, but also recognisable forms of mathematical work. Finally, the lens of sociocultural difference prevents continuity from being reduced to alignment or equivalence, by treating classroom and museum as distinct practices whose relation must be educationally sustained. Their combination therefore makes visible a level of analysis that would remain difficult to grasp otherwise: the way mathematical meanings are carried, transformed, stabilised, or lost across a distributed learning environment.

Within this combined framework, the role of museums in mathematics education research can be stated more precisely. Museums are not simply the second setting in a classroom–museum trajectory; they intensify the problem of continuity because they configure mathematical work through objects, spaces, rhythms, and mediations that heighten contextual difference and make educational threading more demanding. The outdoor lens strengthens this analysis by foregrounding place, materiality, movement, and mediation as dimensions of mathematical work. Its contribution is analytic rather than classificatory: research becomes more capable of following how mathematical work travels across contexts while remaining shaped by the environments through which it passes.

This way of framing classroom–museum continuity also has methodological consequences. If mathematical work is distributed across settings and shaped by the environments through which it passes, the unit of inquiry can no longer be confined to the visit, nor can it be reduced to the teacher's planning intentions. Research requires trajectories, heterogeneous sources, and an evidentiary frame capable of following uptake, reformulation, delayed reuse, and loss. The integrated path discussed in this paper shows why these aspects matter. The same mathematical theme may appear before, during, and after the museum visit, but continuity becomes analytically convincing only when the researcher can show how meanings are prepared, transformed, documented, and reactivated across these moments. What becomes visible is neither a simple extension of classroom mathematics into the museum nor an isolated enrichment episode, but a distributed learning environment constituted through the weaving together of classroom and museum, whose mathematical coherence must be reconstructed through documents, interactions, mediations, and later resumptions of work.

The framework also has limitations that need to be made explicit. It has been developed from work on classroom–museum relations in culturally mediated museum settings and illustrated through a geometrical trajectory involving circumferences, spirals, bodily movement, and mathematical machines. For this reason, it should not be treated as a general model of all forms of mathematics education beyond the classroom. It is likely to be most productive in contexts where mathematical meanings are distributed across several phases, where material and spatial mediation play a strong role, and where researchers can follow how ideas, gestures, artefacts, and documents are taken up over time. Its applicability may be more limited in short, weakly documented visits, in museum experiences with little post-visit classroom elaboration, or in settings where mathematical work is only loosely connected to the institutional and material features of the place.

Further empirical work is therefore needed to test and refine the framework across different museum settings, mathematical domains, age groups, and forms of collaboration between teachers and museum educators. Comparative studies would be especially valuable: for instance, analyses of trajectories in which continuity is strongly sustained alongside trajectories in which the visit remains a parenthesis. Such comparisons could clarify which forms of preparation, mediation, documentation, and classroom re–elaboration support the persistence and transformation of mathematical meanings across contexts. They could also help examine how the framework operates beyond geometry, for example in relation to measurement, modelling, statistics, or algebraic thinking in museum and heritage environments.

At this stage, the paper offers a way of studying how mathematical work may continue across contexts without erasing the differences that make those contexts educationally productive. Its contribution is not to stabilise a general model of all classroom–museum relations, but to make such relations more open to analysis in mathematics education. The proposed framework helps distinguish between superficial connection and didactical continuity, between the recurrence of a topic and the reactivation of mathematical meanings, and between the museum as a venue and the museum as a condition of mathematical work. Its value lies in making the weave of continuity visible where research has too often seen only the visit.

Conflict of interest

The author declare that there are no conflicts of interest.

References

[1] A. Bakker, J. Cai, L. Zenger, Future themes of mathematics education research: An international survey before and during the pandemic, *Educational Studies in Mathematics*, **107**(1) (2021), 1–24, https://doi.org/10.1007/s10649-021-10049-w.

[2] M. Kuş, Conceptualization of out-of-school mathematics education, *Yaşadıkça Eğitim*, **38**(1) (2024), 245–257, https://doi.org/10.33308/26674874.2024381644.

[3] R. Nemirovsky, M. L. Kelton, M. Civil, Toward a vibrant and socially significant informal mathematics education, in J. Cai (Ed.), *Compendium for research in mathematics education*, National Council of Teachers of Mathematics, (2017), 977–1008.

[4] J. H. Falk, L. D. Dierking, *Learning from museums: Visitor experiences and the making of meaning*, AltaMira Press, 2000.

[5] N. Orion, A. Hofstein, Factors that influence learning during a scientific field trip in a natural environment, *Journal of Research in Science Teaching*, **31**(10) (1994), 1097–1119, https://doi.org/10.1002/tea.3660311005.

[6] M. Behrendt, T. Franklin, A review of research on school field trips and their value in education. *International Journal of Environmental and Science Education*, **9**(3) (2014), 235–245.

[7] H. Eshach, Bridging in-school and out-of-school learning: Formal, non-formal, and informal education, *Journal of Science Education and Technology*, **16**(2) (2007), 171–190, https://doi.org/10.1007/s10956-006-9027-1.

[8] T. Nunes, A. D. Schliemann, D. W. Carraher, *Street mathematics and school mathematics*, Cambridge University Press, 1993.

[9] S. A. Pattison, A. Rubin, T. Wright, Mathematics in informal learning environments: A summary of the literature (updated), TERC / Institute for Learning Innovation, (2017), http://www.informalscience.org/mathematics-informal-learning-environments-summary-literature.

[10] International Council of Museums, *Museum definition*, (2022, August 24), https://icom.museum/en/resources/standards-guidelines/museum-definition/

[11] M. Walz, It is, it was, they are, we are: The museum definition as a norm and a collective framework, *ICOFOM Study Series*, **48**(2) (2020), 235–246, https://doi.org/10.4000/iss.2875.

[12] S. G. Paris (Ed.), *Perspectives on object-centered learning in museums*, Lawrence Erlbaum Associates, 2002, https://doi.org/10.4324/9781410604132.

[13] T. de Kluis, S. Romp, A. M. Land-Zandstra, Science museum educators' views on object-based learning: The perceived importance of authenticity and touch, *Public Understanding of Science*, **33**(3) (2024), 325–342, https://doi.org/10.1177/09636625231202617.

[14] M. G. Bartolini Bussi, M. A. Mariotti, Semiotic mediation in the mathematics classroom: Artifacts and signs after a Vygotskian perspective, in L. D. English, M. G. Bartolini Bussi, G. Jones, R. Lesh, D. Tirosh (Eds.), *Handbook of international research in mathematics education*, Lawrence Erlbaum Associates, (2008), 746–783.

[15] F. Arzarello, D. Paola, O. Robutti, C. Sabena, Gestures as semiotic resources in the mathematics classroom, *Educational Studies in Mathematics*, **70**(2) (2009), 97–109, https://doi.org/10.1007/s10649-008-9163-z.

[16] H. Kéfi, E. Besson, Y. Zhao, S. Farran, Toward museum transformation: From mediation to social mediation and fostering omni-visit experience, *Information & Management*, **61**(1) (2024), Article 103890, https://doi.org/10.1016/j.im.2023.103890.

[17] S. Priest, Redefining outdoor education: A matter of many relationships, *The Journal of Environmental Education*, **17**(3) (1986), 13–15, https://doi.org/10.1080/00958964.1986.9941413.

[18] A. Lloyd, S. Truong, T. Gray, Place-based outdoor learning: More than a drag and drop approach, *Journal of Outdoor and Environmental Education*, **21**(1) (2018), 45–60, https://doi.org/10.1007/s42322-017-0002-5.

[19] O. Zanato Orlandini, Outdoor education. Riflessioni su alcuni paradigmi che la rappresentano, *Studium Educationis*, **24**(3) (2020), 1–13, https://doi.org/10.7346/SE-012020-02.

[20] R. Casi, C. Sabena, Educazione matematica informale: prospettive didattiche ed esperienze nei musei, in C. Giorda, M. Leone (Eds.), *La scuola all'aria aperta*, Mondadori, (2026), 69–84.

[21] R. Casi, *Informal mathematics education in museums: An exploratory study on teacher education*, Doctoral dissertation, Politecnico di Torino, Torino, 2024, https://tesidottorato.depositolegale.it/handle/20.500.14242/157530.

[22] R. Casi, M. Borsero, C. Pizzarelli, C. Sabena, Circonferenze e spirali in un percorso di educazione matematica informale tra scuola e museo, *Didattica della matematica. Dalla ricerca alle pratiche d'aula*, **14** (2023), 30–58, https://doi.org/10.33683/ddm.23.14.2.

[23] K. Due, M. Skoog, S. Areljung, C. Ottander, B. Sundberg, Teachers' conceptualisations of science teaching – obstacles and opportunities for pedagogical continuity across early childhood school forms, *International Journal of Early Years Education*, **31**(3) (2023), 790–805, https://doi.org/10.1080/09669760.2022.2107492.

[24] S. F. Akkerman, A. Bakker, Boundary crossing and boundary objects, *Review of Educational Research*, **81**(2) (2011), 132–169, https://doi.org/10.3102/0034654311404435.

[25] Y. Memiş, A. Özkale, Exploring the role of museums in mathematics education: Perspectives and practices, in S. Alkan, G. Karaali, M. Taştepe (Eds.), *Mathematics beyond the classroom: A guide for expansive learning in out-of-school environments*, Springer, (2025), 193–213, https://doi.org/10.1007/978-3-032-05318-3_9.

[26] T. Tal, L. Steiner, Patterns of teacher-museum staff relationships: School visits to the educational centre of a science museum, *Canadian Journal of Science, Mathematics and Technology Education*, **6**(1) (2006), 25–46, https://doi.org/10.1080/14926150609556686.

[27] L. J. Rennie, T. P. McClafferty, Using visits to interactive science and technology centers, museums, aquaria, and zoos to promote learning in science, *Journal of Science Teacher Education*, **6**(4) (1995), 175–185, https://doi.org/10.1007/BF02614639.

[28] J. A. Fredricks, Engagement in school and out-of-school contexts: A multi-dimensional view of engagement, *Theory Into Practice*, **50**(4) (2011), 327–335, https://doi.org/10.1080/00405841.2011.607401.

[29] M. L. Kelton, Mathematics learning pathways on a school fieldtrip: Interactional practices linking school and museum settings, *Visitor Studies*, **24**(2) (2021), 181–204, https://doi.org/10.1080/10645578.2021.1939984.

[30] M. Krechevsky, M. Rivard, F. R. Burton, Accountability in three realms: Making learning visible inside and outside the classroom, *Theory Into Practice*, **49**(1) (2010), 64–71, https://doi.org/10.1080/00405840903435845.