# Experience, Explicitation, Evolution: Processes of learning in a free-choice science museum activity for children up to 6 years of age

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**Abstract**

*Using a qualitative methodology and based on the observations of children in a free-choice activity in a science museum, this research focuses on determining which learning processes take place during these sessions. The learning processes of the activities were analysed based on three phases: Experience, Explicitation and Evolution.*

*The results obtained indicate that the value of the scientific learning of the activity is found in providing children with direct experience with the material. This also favours the explicitation of their ideas and provides abundant stimuli that can generate the evolution of ideas. However, this evolution requires co-operation from other contexts, and greater continuity.*

**Keywords:** science education, early childhood education, science museums, free-choice learning, natural sciences

## Introduction

In January 2011, the Natural Science Museum of Barcelona opened its new building, with a view to offering content for the youngest age groups, thus an exclusive space was reserved for children up to six years of age. The *Niu de ciència* (*Science Nest*) was conceived to offer young children access to the natural assets of the museum based on the child's personal initiative and free exploration.

The activity researched for this article, *Puc tocar?* (*Can I touch?)* is made up of various independent and differentiated proposals that bring children closer to natural materials and instruments

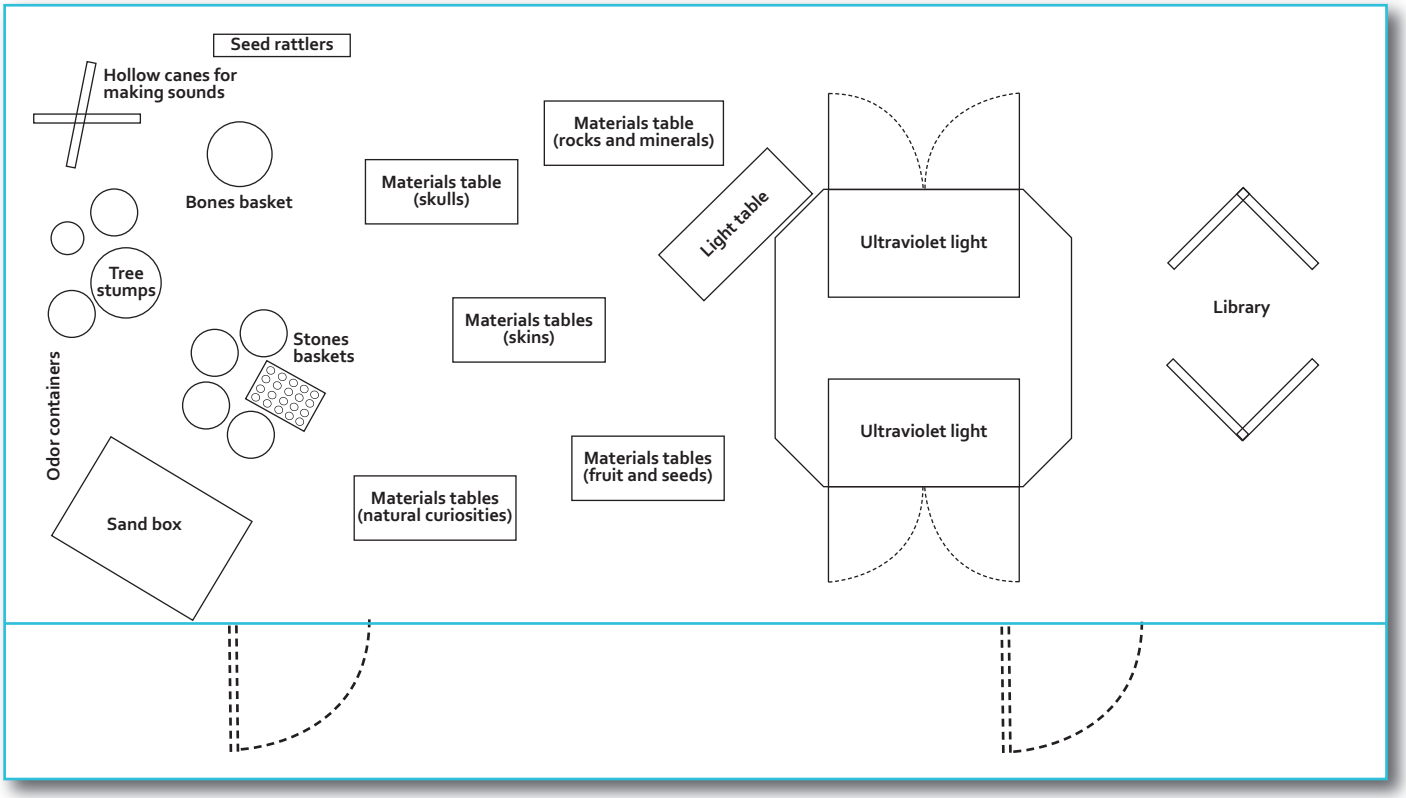



**Figure 1:** Distribution of the space and materials for the activity *Can I Touch?* (Source: Alba Carbonell, *Niu de ciència).*

inherent to scientific work (magnifying glasses, binocular magnifying glasses, tweezers, etc.). Some of these proposals are X-rays of animals exhibited in a light table; minerals that change colour under ultraviolet light; seeds to be classified using tweezers; collections of natural material (skins, skulls, antlers, shells, stones and minerals, seeds, etc.); seed rings (diversity of colours, sizes, forms, sounds, etc.); a collection of objects from the natural world to be looked at through the binocular magnifier; a large container with sand and remains of animals from the marine environment; and a library with books and tales of science, amongst others. All materials are distributed as shown in Figure 1 on the previous page.

Children had free access to the materials for over half an hour, accompanied by two museum educators who took an active, but not directing, role (Bulunuz, 2013; Kallery & Psillos, 2002). In the *Can I Touch?* activity, the child is the protagonist and the adults must be very careful to consider the relevance of their intervention. They are adults who do not make interventions aimed at the whole group, so that the attention of all the children is not distracted from what they are doing; instead, they directly address children or small groups of children in a discrete voice using the right volume to reach the interlocutors.

Two basic areas of intervention are identified for the adults. On the one hand, educators are an important reference in maintaining a sense of security and as a guarantee of wellbeing for the whole group participating in the visit. On the other, they should be aware to ensure that learning opportunities are provided that do not *'overtake or swamp the ideas of the children but sensitively engage with them as they explore their questions'* (Sands, Carr & Lee, 2012, p.558). In this regard, the role of the educator is not easy.

From the beginning, *Can I Touch?* has been extremely popular among teachers and children, as shown by the evaluations gathered by the museum and the steady increase in demand for the activity from pre-schools. In a prior study, it was found that free choice among high quality natural materials promotes an atmosphere that is both relaxed and stimulating, and propitious for learning (Pedreira & Márquez, 2017). This article focuses on highlighting the learning processes related to science that take place in a free-choice scenario with limited time, such as the one described.

## Learning science at the youngest ages

Recent literature (Ferrés, Marbà & Sanmartí, 2015; Minner, Levy & Century, 2010) points to an idea widely shared in science education research that the process most aligned with scientific knowledge, and most interesting from the learning standpoint, is what is called inquiry-based focus (or foci, given the variability). It is a focus that the Natural Science Education Standards (National Academy of Sciences, 1996) define as a process that includes asking oneself questions, planning and carrying out research using instruments and techniques for data gathering, thinking critically and logically about the relationships between evidence and explanations, building and analysing alternative explanations and communicating scientific reasoning. This idea has been qualified in recent publications to put scientific practice at the centre of teaching and learning (Garrido & Simarro, 2014; Monteira & Jiménez-Aleixandre, 2015; Osborne, 2014), so that a transition is made from the concept of teaching science as 'inquiry' to one of teaching it as 'practice'. This scientific practice includes the processes of inquiry, reasoning and explanation based on models (Osborne, 2014).

A review of different authors from several research traditions from different countries on how scientific learning takes place makes it possible to identify regularities or phases with a certain homogeneity that can be observed by reading the vertical axis of the table (Table 1 overleaf).

The first phase focuses on the acquisition of direct experience with reality. Physical contact activities, direct action over the natural world, investigating into the tangible world...different names to highlight the importance of the experience lived out, of contact with reality as a source of primary information, as a base from which to ask oneself questions or launch investigations.

A second phase focuses on the value of language as an individual's expression of the ways of thinking. Certain authors place greater emphasis on pre-existing ideas that will be the basis for the construction of new ideas, while others underscore the communicative process itself.

**Table 1:** Phases of the science learning process according to various authors.

| | | | |
|---|---|---|---|
| **Osborne** (2014) | Researching the tangible world: observing, measuring, gathering data, etc. | Generating hypotheses: developing explanations based on what's been observed. | Evaluating: based on the evidence, data, theories and models. |
| **Harlen** (2010) | Direct physical action on objects and materials. | Language as a basis for building abstract ideas. | From specific ideas to the 'big ideas' on science and the construction of scientific knowledge. |
| **Pujol** (2003) **Sanmarti** (2006) | Doing: perceiving, observing, handling, monitoring the phenomenon... | Communicating: putting it into words, describing, finding explanations, reasoning. | Thinking: asking oneself questions, imagining solutions, predicting, portraying, modelling, evaluating. |
| **Arcà & Mazzoli** (1990) | Experience: doing, working with one's hands, sensibility, perception. | Language: speaking, specifying what experience and perception have made accessible. | Knowledge: the ongoing exchange between language and experience builds individual knowledge that in turn feeds off socialised 'culture'. |
| **Saçkes** (2014) | Physical contact activities. | Starting from pre-existing ideas. | Reaching shared discussions to give meaning to the facts. |

The third phase focuses on high-level cognitive skills: reviewing, evaluating, building 'big ideas', modelling, predicting, portraying, etc. These are processes whose purpose is to achieve a reasoned change in individuals' ways of thinking – in other words, to achieve learning.

This reiterated organisation in three phases suggests the possibility that the analysis in the *Can I Touch?* activity can be carried out based on a parallel approach, although certain specific aspects should be considered.

## Specific aspects of *Can I Touch?*

An initial condition is the age of the subjects, from two to six years of age. They are in development, with limited mastery of language and pre-operational thought (Piaget & Inhelder, 1969).

Another condition is time. The approximate duration of a session, around half an hour, is a significant limiting factor. It must be remembered that participating in *Can I Touch?* can promote other learning opportunities beyond the museum, but the research presented is solely focused on specific aspects that occurred during the visits.

Lastly, it seems relevant to emphasise that the type of materials in *Can I Touch?* are fixed in a natural science museum; this does not allow for experimentation, understood as the direct intervention in materials to intentionally modify them (Pedreira, 2006; Poddiakov, 2011; Sanmartí, Márquez & García, 2002), as this possibility is not offered. Attempts to answer the questions that emerge during the sessions can only be made *in situ* through a process of searching for explanations by interacting with others and/or consulting books or visiting the adult museum.

## Specification of the research problem

The research discussed in this article aims to determine which scientific learning processes are promoted in a visit to *Can I Touch?*

To answer this question, two goals are addressed:

- Goal 1: To define the type of analysis needed to evaluate the scientific learning processes; and
- Goal 2: To identify evidence of the scientific learning processes in *Can I Touch?*

## Methodology

This research is based on a qualitative methodology, as what is intended is in-depth understanding of educational phenomena, transformation of practice, and decision-making (Sandín, 2003), as well as emphasising the meaning that individuals give their own realities, which provides the phenomena with depth and interpretative richness (Sabariego, 2004). It was decided to conduct a case study, as what was intended was a systematic, in-depth examination of a unique phenomenon or educational entity (Bisquerra, 2004).

An essentially inductive research strategy has been used, in which work is done based on flexible, open guidelines that are adapted depending on what occurs over the course of the research.

Lastly, analysis within the natural context was decided. Despite the drawback of impeding the isolation or control of variables, this has the advantage that comes with the richness and complexity of real situations.

The data in this research were gathered from the observation of three school sessions in the *Can I Touch?* activity, participated in by three different schools from Barcelona province, and covering the range of ages to which the activity is geared (Table 2)

For the analysis of the data, units have been established based on the logical sequence of action, understood as that set of acts that follow a single line of logic, a narrative unit that takes place with certain players, intentionality, and with a beginning and an end.

To complete the data, a focus group was held with the teachers responsible for the participating groups, and a survey conducted among the museum educators responsible for the activity.

To address ethical issues related to the research, a consent form and an information sheet were provided to responsible adults, with the commitment to make no further use outside of academia. Pseudonyms replaced the name of participants.

## Results and discussion

***Goal 1: To define the type of analysis to evaluate the scientific learning processes***

Considering the contributions from research, specificities discussed and based on the observation of the children's behaviour in the sessions established an analysis of the learning processes that might take place in the *Can I Touch?* activities. This is based on a three-phase organisation, parallel to that presented in Table 1.

| Age | Date | Duration | Number of children | Number of sequences identified |
|---|---|---|---|---|
| 2 year-olds | February 27, 2014 | 42 minutes | 22 | 60 |
| 4 year-olds | September 27, 2013 | 27 minutes | 13 | 59 |
| 3, 4 and 5 year-olds | April 4, 2014 | 30 minutes | 12 | 143 |

**Table 2:** Basic data on observations made, ordered by age of the children.

The three phases are entitled *Experience, Explicitation* and *Evolution.* Their justification follows:

## ❒ Experience

If the subjects are children of the youngest ages, apprentices to the world, it seems logical to attach more relevance to an initial phase, experience, which is based on gathering information from contact with reality. The observation of the sessions made evident three different types of actions focused on gaining experience:

- *Use of the senses:* this is an especially relevant aspect of the *Can I Touch?* activities given the sensory wealth in colours, shapes, textures, weights, sounds, smells, etc. of the natural material, but also because early childhood is a stage in which sensory information is recognised as being very important by authors of classical pedagogy (Montessori, 1972), by the science museum realm (Dierking, 1991; Falk & Dierking, 2000) and by the contributions from neuroscience (Mora, 2013). Therefore, in the analysis of the activity, situations are sought in which it is identified that the senses are being used in an intentional way.
- *Exploratory actions:* understood as *'action sequences that respond to the interests of the child, who organizes and structures them autonomously, the result of which is the attainment of information on the object or phenomenon'* (Weissmann, 2014, p.31). Authors such as Poddiakov (2011), who appreciate natural objects as activators of the development of exploratory activity, also refer to the importance of children's activities to actively understand the world based on their own actions. Other such authors include Sands, Carr and Lee (2012) who state that one of the ways in which research is developed in children is through dialogue between them and the objects, often without spoken language as a mediator and only through direct action.
- *Use of instruments:* the importance of instruments as cultural mediators and the need for them to build scientific facts is addressed by several authors (Falk & Dierking, 2000; Izquierdo, 2006; Sanmartí *et al,* 2002). In *Can I Touch*?, children are given access to magnifying glasses, binocular magnifying glasses, strainers or tweezers. Within the research process, the occasions when the children made exploratory use of these were observed. In other words, observations took place when it was clear that the children intended to make scientific use of the instrument, either correctly (for example, keeping the right distance between the magnifying glass and the eye) or, if they were just trying it out, trying to find the right way to use it.

## ❒ Explicitation

The second phase emphasises the showing of children's pre-existing ideas, which must be used for the construction of new ideas. To do so, we rely on the one hand on communicative processes, because when something is given a name, when it is defined or explained, this is done based on the existing theories about the world (Gómez, 1998), but also with the operations related to the formation of concepts (Jorba, 1998; Kamii & DeVries, 1978; Piaget, 1964), such as comparing or classifying, as basic cognitive skills through which information is structured. Most of the material in *Can I Touch?* are collections (of stones, skins, skulls, antlers, etc.) that are presented, grouped with the idea of helping children 'group the things that go together', identifying the qualities that are shared among all the elements of the collection while also pointing out what sets them apart. Arcà, Guidoni and Mazzoli (1990) stress the importance of underscoring similarities and differences as a gateway to conceptualisation.

Harlen (2010) states that experience gradually brings about the construction of abstract ideas, and that grouping and classifying by different criteria lead to the development of concepts. Zohar (2006) advocates the value of actions such as comparing or classifying, which she defines as activities of a higher order, given the fact that the formation of concepts is an act not only of perception but also one that is intimately related to the use of a theoretical reference model.

Recognising 'what goes together' can be done with or without words and, given the age of the subjects of this research, especially in the case of the youngest children, it makes sense to take into account and evaluate the actions by which children specify what they think, while also considering the linguistic skills that make it possible to share their thoughts. With a view to integrating both processes, the cognitive and communicative, which

are so intimately linked, the suggestion of Inan, Trundle and Kantor (2010) was followed. They emphasised the value of labelling information with a name that has a meaning shared with others (naming), indicating similarities and differences (comparing), organising the information into significant units based on comparison (classifying) and sharing this information with others (communicating). In the latter category, based on the contributions of several authors (Jorba, Gómez & Prats, 1998; Naylor, Keogh & Downing, 2007) and taking into account the observations recorded, two specific cognitive-linguistic skills have been considered: describing and reasoning. Regarding the latter, it should be noted that, at such young ages, it is not meant to find complete reasoning with the need for acceptability, belonging, completeness and precision, but that the cases in which the child contributes some explanation on the object or phenomenon are identified.

### ❒ Evolution

Understanding learning as change (Pozo, 2008) means attributing value to the evolution of children's ideas, which is manifested in two ways in *Can I Touch?*

- *Emergence of questions:* this is determined by all authors to be a fundamental step to approach any problem, and a significant first step to consider the possibility of changing ways of thinking. Mora (2013) states that anything that is different and stands out from its surroundings sparks excitement and, with that, the windows of attention are opened in a focus necessary for the creation of knowledge.

  Csikszentmihalyi and Hermanson (2009) propose a learning paradigm in museums that begins with the need to attract the subject's attention (the 'hook') and is based on curiosity (probability of investing mental energy in a new stimulus) to reach the interest (probability of investing mental energy in one stimuli more than others). It is the same idea that Wagensberg postulates (2008, p.24), when he highlights the importance of the '*stimulus, that is useful to go from one mood – in which an individual is not especially interested in knowing anything specific – to another, in which they do seek to know something, even with urgency'.*

  Considering the age of the children, not only their specific questions but also the statements or actions to which adults can give the value of a hypothesis have been considered to help question ideas and facilitate the possibility of change.

- *Introduction of new knowledge:* understanding learning as change means attaching value to the entry of new ideas as a basic factor to achieve a change in pre-existing ideas. Situations in which children's ideas are reconsidered, as related to the contribution of new information, are taken into account. Three ways of introducing new ideas were identified: by direct contributions from the adult; triggering the contrast of ideas among peers; and also the consultation of books.

Table 3 on page 25 sums up the categories of analysis identified based on the alignment between the existing literature on science learning at the youngest ages and the observations made in *Can I Touch*?

***Goal 2: Identify evidence of scientific learning processes in Can I Touch?***

After finishing the definition of the categories, their application in the observed sessions was necessary. To do so, all appearances of each category in each sequence were tallied up. To compare the data from session to session, the number of appearances was divided by the total of sequences in each session, resulting in a frequency of around 1.

An example of the identification of each of the categories in the sequences is shown in Table 4 on page 26.

### ❒ Experience

Figure 2 on page 27 shows the comparison among frequencies of appearance of each experience phase categories in the different sessions, corresponding to different ages.

The frequency of opportunities to acquire direct experience with reality through the three highlighted categories is clearly high – 1.68 overall. This is proof of one of the values of the activity.

**Table 3:** Analysis categories of the science learning process in *Can I Touch*?

| | | |
|---|---|---|
| **EXPERIENCE with reality** | Use of the senses | Looking<br>Touching<br>Listening<br>Smelling |
| | Exploratory actions | Picking up, putting down<br>Shaking<br>Filling-emptying<br>Tapping<br>Fitting into<br>Passing on<br>Building towers |
| | Exploratory use of instruments | Hand-held magnifying glass<br>Binocular magnifying glasses<br>Strainers<br>Tweezers |
| **EXPLICITATION of children's ideas** | Cognitive-linguistic | Naming<br>Comparing<br>Classifying<br>Describing<br>Reasoning |
| **EVOLUTION of children's ideas** | Emergence of questions | As questions<br>As statements<br>As actions |
| | Introduction of new knowledge | Contributions from the adult<br>Contrasting of ideas between peers<br>Consulting books |

The results are irregularly distributed within each category. Looking and touching are by far the two most used 'sense actions'. Shaking, fitting into and passing on are the most recurrent exploratory actions. Hand-held magnifying glasses are the instruments that generate the most interest and activity.

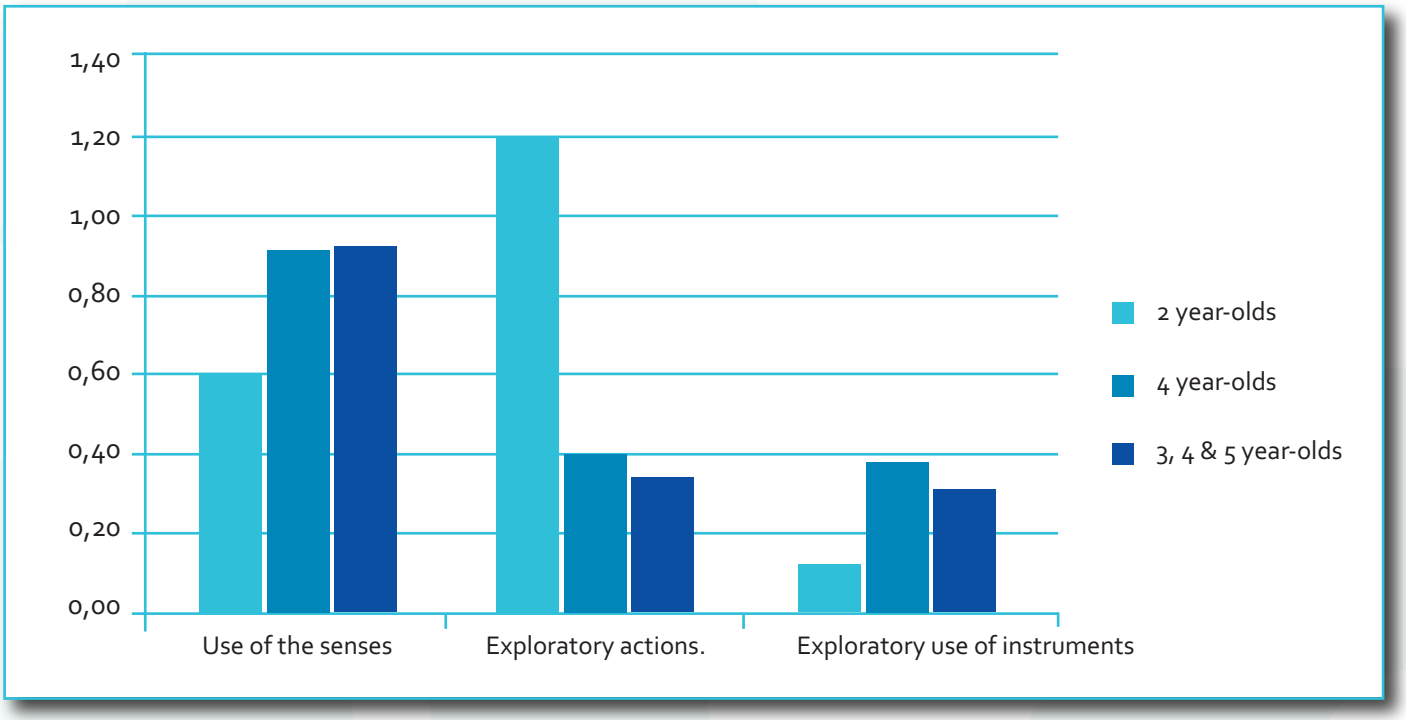
Some observations, such as the use of specific instruments like hand-held and binocular magnifying glasses as observation instruments appearing to increase the frequency of use of the senses, suggest the possibility of introducing modifications in the design and presentation of the materials to achieve results more in line with what is intended.

By ages, the high value of the exploratory actions in the case of the 2 year-olds studied is noteworthy. This coincides with the behaviour descriptions for this age made by various authors (Kamii & DeVries, 1978; Quintanilla, Orellana & Daza, 2011; Weissmann, 1999). Compared to older children, this age group shows little activity in the use of instruments.

**Table 4:** Sequences from each category for analysis of the science learning process in *Can I Touch?*

| | |
|---|---|
| **EXPERIENCE with reality** | |
| Use of the senses / Touching 2 year-olds | 31:26<br>(...)<br>The girl answers, **and lies down over the skins again and begins to touch two skins with both hands**. The adult leaves. **The girl touches the skins a little while longer.** Then she gets up and goes to the stones table, where there are several children.<br>31:50 |
| Exploratory actions / Shaking 2 year-olds | 14:27<br>Rattles are heard. **There is a boy next to the panels shaking a rattle with each hand. A girl approaches, takes one in each hand and shakes them.** They look at each other. The girl leaves both rattles on the floor and leaves.<br>(...)<br>14:50 |
| Exploratory use of instruments / hand-held magnifying glass 4 year-olds | 6:01<br>**A boy approaches the magnifying glass table and picks up the cylindrical magnifying glass. He brings it close to his eyes, backwards. He turns it, and looks again.** Then he puts it down and leaves.<br>6:15 |
| **EXPLICITATION of children's ideas** | |
| Cognitive-linguistic / reasoning 4 year-olds | 3:50<br>(...)<br>Teacher: Creatures, from where? She retraces the X-ray of the snake.<br>She stops and shrugs her shoulders as if to say, 'I don't know.' She looks at the camera.<br>Teacher: Are they all the same?<br>Child 14: No<br>Teacher: Oh? They aren't?<br>Child 14: **No, because this one is smaller and this one is bigger (comparing the two snake X-rays. He touches them with his hands). And these (the small snake and the lizard) look the same, but they aren't.**<br>(...)<br>4:47 |
| **EVOLUTION of children's ideas** | |
| Emergence of questions / As actions 4 year-olds | 0:00<br>(...)<br>The boy goes to pick up a skull. There are four children speaking while holding skulls in their hands.<br>**Another child goes to the horse skull, and opens and closes the jaw. He takes a tooth from the box and tries to fit it into the lower jaw**.<br>A boy picks up a skull and places it on his head.<br>**Boy: I put it on here!**<br>He puts the skull back in its place, picks up another one, and looks at it.<br>(...)<br>1:05 |
| Introduction of new knowledge / Contrasting of ideas among peers 3, 4 and 5 year-olds | 11:16<br>(...)<br>Educator 5: What do you think this is, [Boy 8]? Boy 8: Skin.<br>**Educator 5: [Girl 4] says that it is from a snake.**<br>Girl 4: And that it is skin, too.<br>Educator 5: It is snakeskin, says Girl 4.<br>The boy leaves. Girl 4 tries to open the cylinder.<br>Educator 5 takes it from her, apparently to open it for her. |

**Figure 2:** Frequency of appearance of each experience phase category over the various sessions.




## ❒ Explicitation

Figure 3 shows the frequencies of appearance of the explicitation phase categories.

Once again, the distribution is shown to be very irregular. Some of the categories show high frequencies, such as 'naming' and 'describing', while 'comparing', 'classifying' and 'reasoning' appear on very few occasions. This is apparently attributable to the fact that, as Zohar (2006) states, they are demands of the highest cognitive level.

The data evidence a relationship between explicitation of children's ideas and their age.

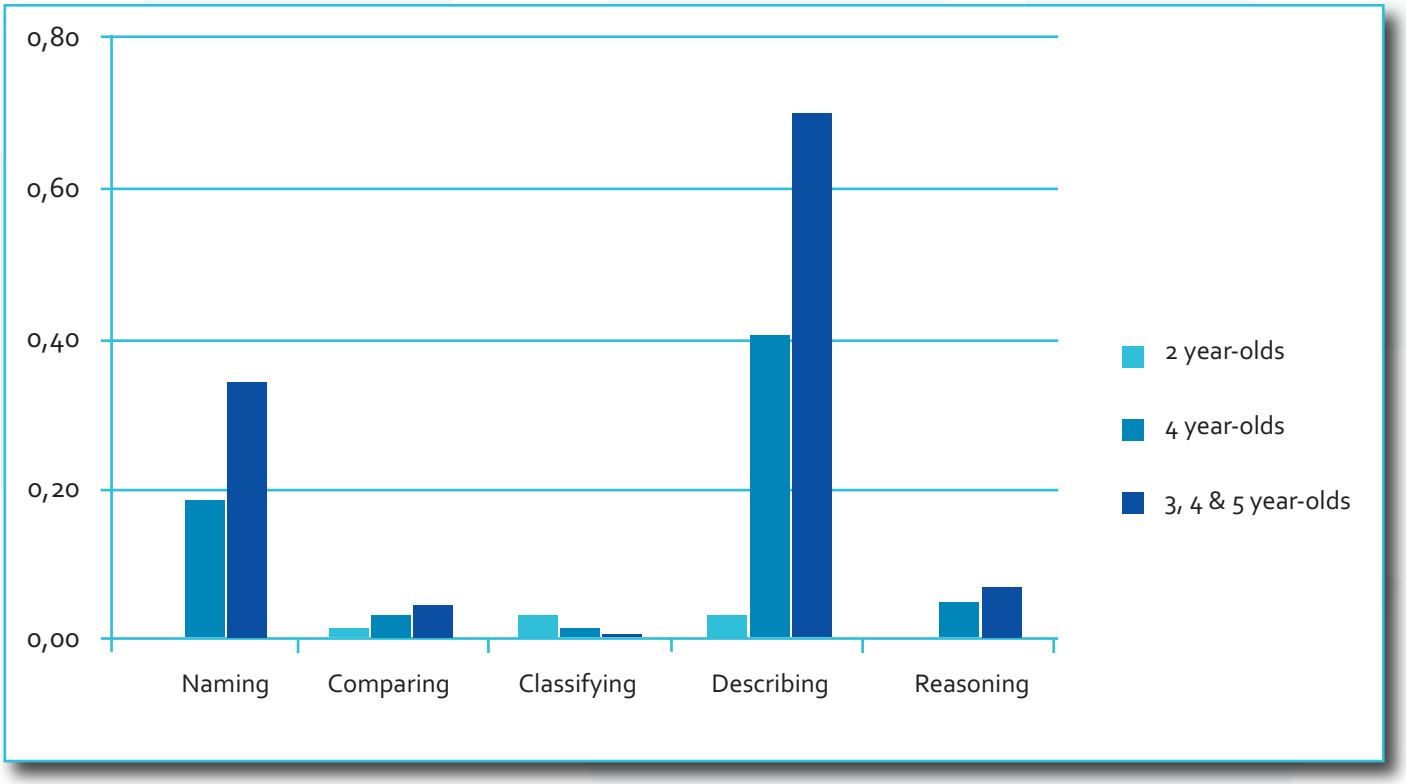



**Figure 3:** Frequency of appearance of each explicitation phase category over the various sessions.

As it is an area closely related to language, logically, the group of the youngest age has the lowest frequencies. This suggests the importance of finding ways to favour young children's ideas being made clearer through actions, not just language.

### ❒ Evolution

Figure 4 shows the frequencies of appearance of the evolution phase categories.

The graph shows a notable difference between the frequency with which questions emerge and the introduction of new ideas. This suggests that the visit to *Can I Touch?* favours starting points for the emergence of curiosity that can lead to inquiry itineraries, but does not promote the introduction of new ideas.

In an analysis by age, the idea of a revision phase seems out of reach for the youngest children. Although this seems logical, as it is related to a higher level of cognitive development, it must also be remembered that it is largely evaluated based on language. Although the research confirmed the possibility of identifying physical actions that have no spoken form as questions asked by children (for example, placing antlers over their heads, on their nose or backs as a reflection of their hypotheses), the difficulty of the adults in recognising them as such was also confirmed.

### ❒ Overall results of the three phases

The distribution of frequencies by phases and ages is reflected in the graph on the following page.

Figure 5 shows that the essential strong point of *Can I Touch*? is made up of the possibilities provided by acquiring direct experience with reality at all ages, but most especially in the youngest children. The activity also facilitates, although to a lesser degree and mostly in children of three years of age, the explicitation of their ideas. As regards the evolution phase, points of curiosity are generated that can then give rise to a process of change in ways of thinking.

## Conclusions

***Goal 1: To define the type of analysis to evaluate the scientific learning processes***

Research into science learning for children of young ages and in the context of isolated sessions in a museum makes it necessary to adapt the type of research used with adults.

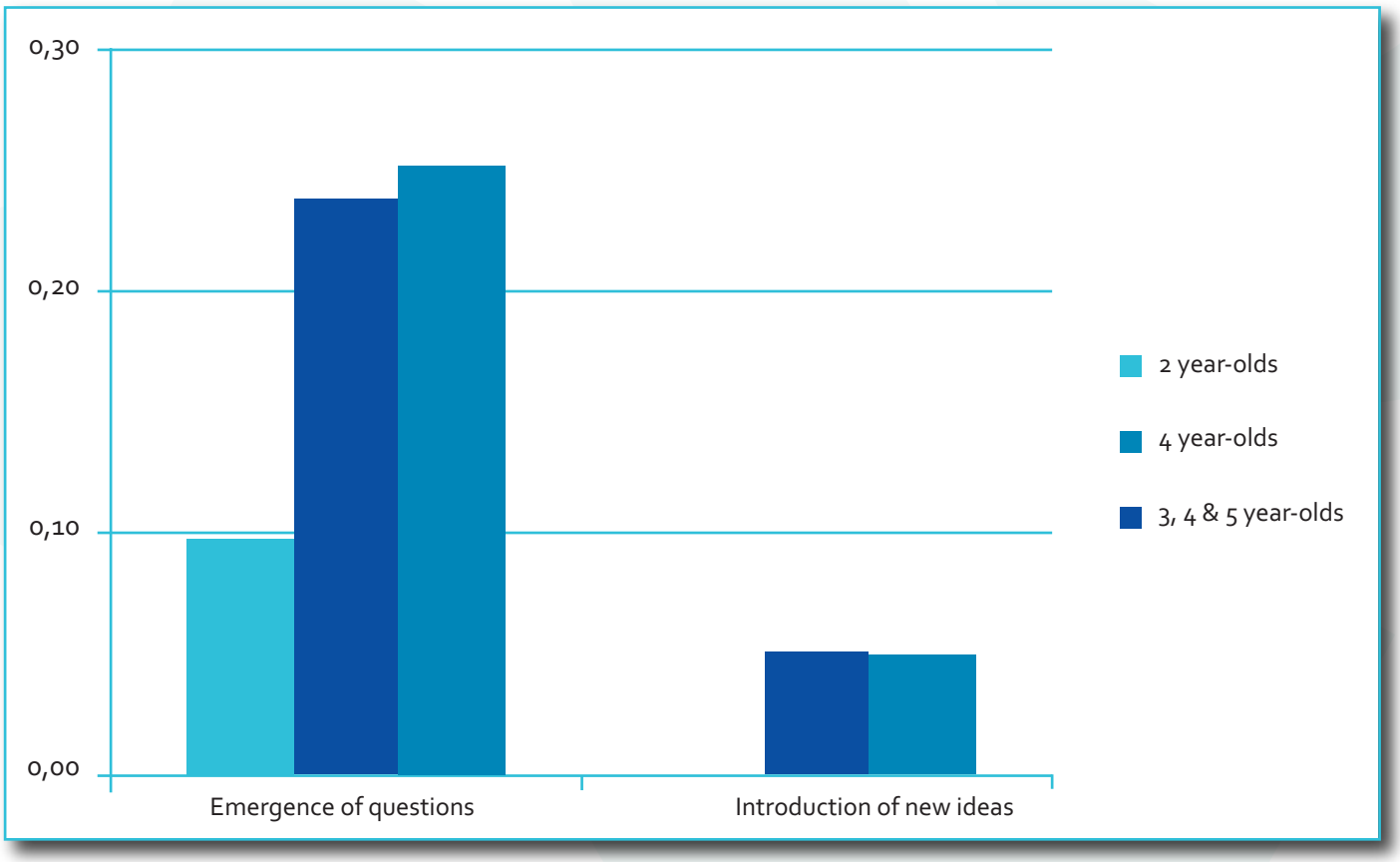
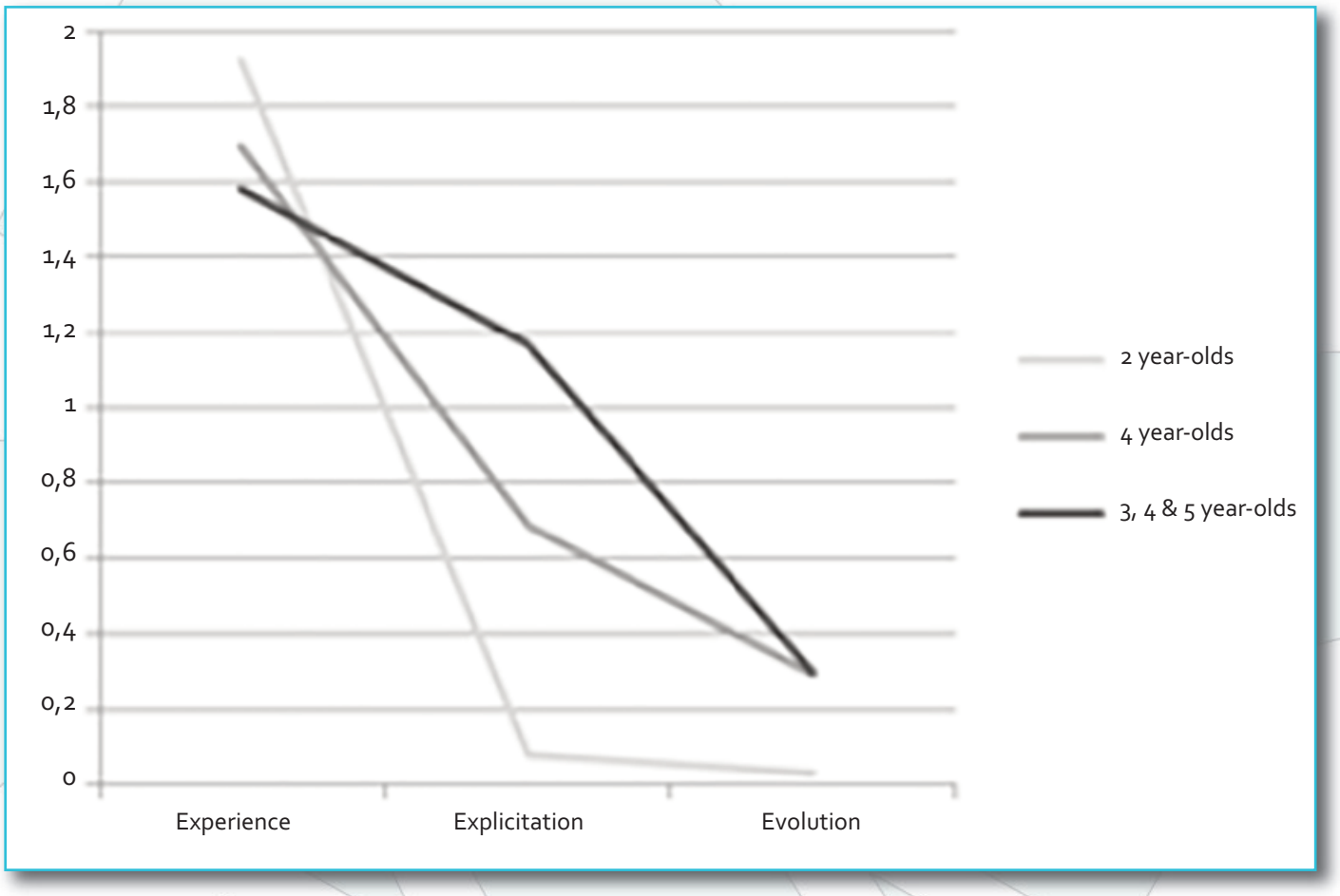



**Figure 4:** Frequency of appearance of each evolution phase category over the various sessions.

**Figure 5:** Overall frequencies of the 3 phases by age groups.




The definition achieved in this study for the specific case of the educational activity *Can I Touch?* proposes phases that are parallel to those used with adults, but bearing in mind specificities: an activity aimed at children of the youngest ages, of limited duration over time and restricted to natural sciences.

The structure of the three phases, *Experience*, *Explicitation* and *Evolution*, is proposed as a groundwork to face the analysis of learning processes in a free-choice science learning activity, and for the youngest ages. The three phases are likewise divided into categories (see Table 3 for the case of *Can I Touch?*) that can be expanded or modified depending on the specific case in which the analysis is to be applied.

***Goal 2: To identify evidence of scientific learning processes in Can I Touch?***

Applying analysis based on the three phases, *Experience*, *Explicitation* and *Evolution*, as has been explained and justified throughout the text, defines *Can I Touch?* as an activity of great educational value. It is valuable because it provides direct experience of contact with natural material, it facilitates the explicitation of children's ideas, although irregularly, and it allows the emergence of curiosities that can be starting points for inquiry itineraries.

In research with adults, great emphasis is placed on the phase of greatest abstraction, incorporating processes such as modelling or evaluation, which have not been observed in the free-choice situation analysed. Considering that the children only had half-an-hour of autonomous exploration, it seems logical that no evolution is observed in their ideas, beyond momentary contributions. On another note, it seems that the activity offers important possibilities as a generator of stimuli (emergence of questions), which can be an important first step to initiate inquiry processes that will require continuity in other contexts. Given the fact that these are school visits, the most appropriate course of action should be the school itself, following the ideas of Kisiel (2005), Guisasola (2013) or Viladot (2015), who suggested integrating the visit to the museum as part of the class planning to obtain learning results that can involve aspects such as discussion about facts, modelling, or the evaluation of new ideas.

Like any research process, this one concludes by opening up new questions: would more evidence of the idea of evolution be generated in a free-choice school context in which, as opposed to the museum, children have sufficient time to take part in experiences with continuity? Can the environment be modified (inquiries, organisation, the role of the adult) to increase the occasions in which evidence of idea evolution is produced?

Lastly, it is relevant to note that two of the three schools participating in the research introduced changes in their classrooms following the visit to the museum, incorporating natural materials and various scientific instruments, and generating awareness about the value of getting questions to arise in children over teaching them the answers. This suggests the possibility of informal education being an element with which to streamline educational change in formal education. This shows the importance of reflection and pedagogical research set outside the classroom.

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