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Learning About Archaeology and Prehistoric Life The Effects of Two Workshops in Primary Education



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Abstract

This article is about an intervention introducing prehistoric life in primary education. Its objectives were to foster openness and interest for prehistory and archaeology, as well as content knowledge and conceptual learning with a focus on four main facets: basic knowledge about prehistoric life; conceptual learning/change regarding prehistory; learning about archaeologists and archaeology as a scientific discipline; and learning about interactions of archaeology and other disciplines (interdisciplinarity). Students participated in two workshops about the creation of a prehistoric object, highlighting the close interaction between the natural sciences and humanities within archaeology. The workshop emphasised dialogue between students, teachers and researchers, as well as active participation by the students. The educational effects of the workshops were studied using a pre-post design (N = 439, ages 8– 10 years). Results show that the workshops had sizeable positive effects on both affective and cognitive variables. The appreciation of the workshops ranged from ≈ 70 to 90% (of maximum value) for interest, perceived educational value and further aspects. We also found a positive impact of the intervention on cognitive variables, e.g. for several elements of key knowledge about prehistory (such as where prehistoric people lived and with what resources; medium to large effect sizes: d > 0.9 and d = 0.46, respectively). Regarding conceptual learning, we found improved understanding of the link between climate change and long-term changes in wildlife in a given area (medium to large effect sizes, d = 0.5 - 0.8). A positive impact was also found for the understanding of archaeology encompassing both humanities and the natural sciences (e.g. understanding of climate change as inferred from archaeological knowledge, d = 0.3-0.5). No differences of the various outcomes were found between girls and boys; the workshops appear suitable for both genders. We conclude with a discussion of the interpretation of our findings, of some limitations and possible improvements, and of future perspectives, in particular for further classroom implementation.

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1 Introduction

This contribution is about a project entitled "Valentina and Leo: everyday life in prehistoric times" (V&L, for short) which was conducted between 2013 and 2015 among primary school students in the canton of Geneva (French-speaking part of Switzerland). The purpose of the project (an intervention in the form of workshops, and an evaluation of its impact) was to introduce prehistoric life and archaeology as a discipline in primary education, following a series of learning goals explained in detail below. Two workshops of 90 to 120 minutes in length were developed and carried out with 12 classes of the 3rd and 4th grade of primary school (international classification: ISCED code 1, UNESCO 2011; Swiss classification: HARMOS 5P, 6P, EDK/CDIP 2015; age group 8–10 years old). In each workshop, students were invited to actively participate in the creation of a prehistoric-style object, by using techniques and materials that would have been available at that period. Valentina and Leo were conceived as fictional characters participating in all of the project's activities, giving their name to the whole project.

Archaeological studies of prehistory are a field that offers interesting links between the natural, the human, and the social sciences. Consider, for example, a lithic arrowhead. Its shape tells us about the social group that created it and its raw material (the type of flint used) gives us indications about its origins and the economic networks of exchange it might have travelled through (Affolter 2002). The same holds for the fragments of fauna found in archaeological sites, and studied through archaeozoology. An animal's species informs the researcher about the environment (climate, biotope, type of terrain, etc.), and one can detect e.g. climatic changes occurring at different points during prehistory, which would in turn have led to technical innovations and modifications of human societies (Marinval-Vigne and Vigne 1985). Faunal determination also allows us to identify the social and economic functioning of these societies, e.g. by looking at the proportion of domesticated vs. hunted animals (Chaix and Méniel 2001; Horard-Herbin and Vigne 2006).

The educational objectives of this project lay at the intersection of three perspectives, based on the local study program (CIIP 2010–2016), and the expertise of the participating prehistory researchers, complemented by research in science education and educational science (e.g. about conceptual learning). These objectives included both affective (attitudes, interest) and cognitive (learning and understanding) aspects, described as follows:

- Fostering openness and interest of students to learn about prehistory and archaeology: The current understanding of general and scientific literacy, on both international and national levels (OECD 2006; EDK/CDIP 2015), emphasises affective aspects such as attitudes and interest beyond purely cognitive ones. A first objective was thus to foster interest in prehistory and archaeology, and a willingness to actively engage in learning and thinking about it.
- Knowledge of prehistory, of chronology, and of the importance of chronological landmarks: During the two workshops, we presented the scale of prehistoric time, which is often difficult to understand, particularly for children. The workshops also drew students' attention to several key aspects of prehistory: the hunting economy, art, circulation and exchange of raw materials, domestication of animals and plants, settlements, metallurgy, everyday life, social structures and power. The students also reflected on the evolution of techniques and objects over the course of time according to environmental, economic, demographic and cultural pressures. Knowing how to place objects and events within a

timeline is a fundamental aspect of an archaeologist's work. The V&L project aimed to raise students' awareness of the various prehistoric eras and the principal stages of human evolution.

- Learning about archaeologists and archaeology as a scientific discipline: This project was also an opportunity to discuss the scientific reasoning of archaeologists, who aim to reconstruct the history of human societies through the study of the materials they left behind. It is important to note that the researcher is like a detective, taking into account all available evidence at a given time in order to reconstruct the human past, while remembering that this knowledge always remains open to development. Archaeologists observe archaeological facts (artefacts, traces, structures), analyse them and interpret them to propose scenarios of the human past. All data, even when quite incomplete, are useful to reconstitute past lifestyles. Like all scientists, the archaeologist goes through steps of observation and questioning to build her reflexion on the matter. She must select and organise data, observe and describe facts, use equipment and measurements during analyses, imagine research and experimentation strategies, formulate hypotheses and confront them to experiment results, and confront his or her observations, analyses and experiments to their original hypotheses. Science observes, questions and investigates in order to propose interpretations of the world and on the functioning of prehistoric societies. Archaeology is a science based on evolving knowledge, and it has its limitations and uncertainties (we cannot be certain of some things, some hypotheses are conflicting, some interpretations are questionable, etc.). The archaeologist can require practical investigations in order to test and validate some hypotheses. Indeed, sometimes she uses the same raw materials and recreate the same actions as prehistoric men and women, in order to better understand their lifestyle. By comparing various sources of evidence, the archaeologist can then conclude that one hypothesis is preferable to another. In this respect, the creation of a prehistoric object by the children during these workshops is a direct parallel to the work of archaeologists.1
- Conceptual learning about prehistory and archaeology: One of the aims was to teach some key concepts (such as chronology), in order to correct existing stereotypes about archaeology and prehistory, some of which are deeply anchored in children and adults. Examples include archaeologists as treasure hunters or prehistoric humans being brutish and stupid.
- Learning about interactions of archaeology and other disciplines (interdisciplinarity): As
 emphasised above, archaeology is a domain that offers the possibility to establish links
 between different fields related to the natural sciences, as well as social and human
 sciences. Archaeologists consult many specialists during different stages of their analyses:
 geologists, archaeozoologists, archaeobotanists, palaeoanthropologists, ethnologists,
 draftspeople, conservator-restorers, etc. The workshops were therefore an opportunity to
 show students that one must often build bridges between different disciplines in order to
 understand a topic.
- Active participation of learners: The workshops required the active participation of students in order to create a "prehistoric-style" object, using techniques and materials that would have been available at the time. This participative approach allowed for playful

¹ Although the topic of nature of science was not explicitly addressed in the workshops, the above considerations are connected to it, and we will come back to this at the end of this contribution

learning of some important steps and themes of prehistory, materialised as a particular object.

 Link with regular curriculum/teaching: One of the objectives of the local study plan is to "identify the way Humankind has organised its collective life through time, here and elsewhere...", and to cover topics such as "changes and permanence in lifestyle, everyday life and social organisation", "myths and reality" and "traces and memories" (Plan d'Etudes Romand, CIIP 2010–2016). We adapted our project to these objectives.

From a larger perspective, the project and its objectives were guided by the idea of scientific literacy, in its own right and as an integral component of general literacy. First, conceptual learning (in particular related to conceptual difficulties) is a core issue of the current understanding of scientific literacy (AAAS 1990; Bybee 1997; Impey 2010; Roberts 2007). Second, beyond the knowledge *of* science, providing a reliable image *about* science, scientific thought and scientific work is a defining element of scientific literacy (OECD 2006). This is therefore another important objective of the project, as exemplified by the discipline of archaeology. Third, another main objective of the workshops was to point out the interdisciplinary nature of archaeological research, and the importance of linking the natural sciences to the humanities and cultural studies that are involved, in terms of both methods and results. Important links of this kind are of fundamental philosophical interest. They create links with anthropology (our image of the Humane; Kaeser 2008; Patou-Mathis 2011) or with astronomy (our worldviews, and their historical development; see Fucili (2005) for an interesting example of such an interdisciplinary approach including archaeology in astronomy education).

These interdisciplinary links might also be of societal and political interest, just like environmental and climate studies (begin of introduction). PISA (OECD 2006) has a nice example of a test item related to archaeology at the intersection of scientific and general literacy (in fact, an item in the reading assessment part), requiring students to infer a connection between the changes to the water level of Lake Chad over time and to the wildlife in its surrounding from prehistoric rock art and other sources of information. Museums (Masciangioli 2011), media (Jarman and McClune 2007) and travels (Packer 2015) provide several kinds of real-life situations where the close interaction between the natural sciences and humanities within archaeology can be frequently encountered, with little consideration of the traditional boundaries between disciplines, and the educated citizen should be able to make sense of these encounters.

Again, this is very much in the spirit of science literacy: emphasising links from the natural sciences to other disciplines and areas of human activity (Matthews 2014), emphasising science as a part of culture (Galili 2012), and scientific literacy as part of general literacy (Norris and Phillips 2003; Yore et al. 2007). Finally, as stated above, one of the project's objective was to foster interest in prehistory and archaeology, and the willingness to actively engage in learning and thinking about it. This is equally in line with the inclusion of interest and other affective aspects into the current understanding of scientific literacy (OECD 2006). The ROSE study (Relevance in Science Education) states that archaeology is one of the research areas mentioned by young people as sparking interest, due to the sense of mystery and unsolved questions that it generates (Schreiner 2006).

The project represents a close collaboration between prehistoric archaeologists, teaching specialists for primary school, science educators and school authorities. Moreover, the preparation of the workshops, of the project documentation and of the demonstration objects required close collaboration between prehistoric archaeologists and technicians. With the

approval of the school authorities, 12 classes were chosen to participate in the project. The discussions with the education experts resulted in the design of two prehistoric workshops, including the evaluation of the impact of the project.

2 Research Background

Beyond the guiding idea of scientific literacy as part of general literacy, the Valentina and Leo workshop intervention is mainly based on three strands of research, namely the educational impact of (i) manipulatives and hands-on activities, (ii) out-of-school learning offers, and (iii) conceptual difficulties and conceptual learning. Each of these we will review in turn.

2.1 Manipulatives and Hands-on Activities

Hands-on and manipulative activities are considered by many practitioners as strongly motivating for learners; Brunsell and Fleming (2014) describe them as one way to provide joy in a learning context. For science learning, a large-sample study has indeed shown that they are the type of learning activities generating the highest degree of interest (Häussler et al. 1998; Wentzel and Wigfield 2009). A recent study (Swarat et al. 2012) has confirmed that hands-on activities can be strong predictors of science interest in school.

As for cognitive effects, the RAND corporation has conducted another thorough study about the impact of hands-on learning on science achievement of 8th graders (age group 13-14 years old) on a large sample, which yielded very strong results on science achievement; moreover, no strong influences of learner ability were found in this study (Ruby 2001). These effects concerning general science learning are consistent with those for various specific science topics: seasons, lunar motion, lunar phases and other topics of elementary astronomy (Brazell and Espinoza 2009); proportional reasoning as applied to mixing/concentration problems (Fujimura 2001); or molecular models in organic chemistry (Stull et al. 2012). Furthermore, these findings from individual studies are confirmed by meta-analytic results on the effects of manipulatives on science learning (Schroeder et al. 2007; Wise and Okey 1983). Comparable effects have been found for several outcomes in mathematics education (effect sizes for simple application, problem solving, justification/explanation; Carbonneau et al. 2013). Indeed, these effects are partially lower than those for science learning (and also less consistent; Calove and Gomila 2009), a fact discussed in terms of the difficulty of learners to link or transfer from a concrete manipulation to an abstract concept and its symbolic representation (Dörfler 2000; Carbonneau et al. 2013).

The theoretical background behind hands-on-activities and manipulatives as educational approaches is manifold, and the idea has a long tradition in the history of education and educational science. A historical account can be found in Furinghetti et al. (2013) and Robert et al. (2013), starting with early ideas by Fröbel to Montessori and other proponents of progressive pedagogy. These ideas were taken up by developmental psychology (Bruner 1960; Piaget 1952), investigating and establishing empirically how students can benefit from learning various subject areas through manipulatives (see e.g. Carbonneau et al. 2013 for a more detailed description of this strand of research for mathematics learning). Most influential among these schools of thought are probably (neo-)Piagetian theories of learning, according to which active manipulation is an essential basis for acquiring concepts and for learning. This is stated throughout the work of Piaget, e.g. "the fundamental fact that all knowledge is linked to

action" (Piaget 1967) or the "primacy of action" (1977, and is well-known to be a central tenet of his theory of cognitive development (Müller et al. 2009b). This important fact becomes most apparent in the concrete-operational stage of cognitive development, where learners develop more and more complex concepts and cognitive procedures, but still closely related to concrete, material instances and not yet available as abstract and formal ideas and rules (Inhelder and Piaget 1959; Piaget 1954; Singer 2008). This stage was initially associated with the age group 7/8–11/12 years old (Inhelder and Piaget 1959), but it must be emphasised that Piaget himself, as well as later researchers, stated that a given person's stage of cognitive development is strongly context-dependent. In many cases, adults remain concrete-operational thinkers (Piaget 1966; Singer 2008). Within our project, our target age group is consistent with the concrete-operational stage and the rationale for the use of manipulatives applies well.

We may summarise with Vosniadou and Vamvakoussi (2006) that "[t]he use of manipulatives, models, and cultural artefacts is considered a significant component of powerful learning environments". However, as they also noted, and as the results show, the mere presence of such tools is not a guarantee for successful learning. One is thus well advised to take into account two strong factors that moderate the learning effects of manipulatives, as inferred from a recent meta-analysis of their use in mathematics education, and consistent with the current understanding in educational science in general. First is the age/developmental status, i.e. the support for learners in the concrete-operational stage is stronger, very much consistent with the developmental theory as just discussed. Second, instructional guidance was found to influence the efficacy of manipulatives (Carbonneau et al. 2013). A similar result concerning advantages of interventions with vs. without (teacher) guidance has been found, for example in a metaanalysis for inquiry-based learning (Furtak et al. 2012).

2.2 Out-of-School Learning Opportunities

We now turn to the research background for another main educational component of the Valentina and Leo project: out-of-school learning opportunities (OSLeOs). In terms of terminology, these include on the one hand field trips of learners to an out-of-school location (e.g. museums and science centres) and on the other hand visits of researchers or other experts to schools from the outside (e.g. from universities or from various other professional domains) (Jones and Stapleton 2017; National Research Council 2009). The latter are special in the sense that they are learning opportunities offered from outside the school, but taking place at school, often during regular classes. Examples of this format are various mobile laboratory or learning activity offered by non-school providers (often museums or research institutions), and expert/professional interventions at school, for example the project "Scientists and Mathematicians in Schools" (Rennie 2015; Rennie and Howitt 2009); the Valentina and Leo project is of the latter kind. Strong support for the educational value of OSLeOs of both kinds has been gathered for decades, and they are increasingly recognised as an integral part of science and technology education (Braund and Reiss 2006; Jones and Stapleton 2017; National Research Council 2009; UNESCO (Edt.) 1983). We discuss two of the main arguments in favour of an extensive use of OSLeOs, which are essential for the present contribution.

The first argument is that out-of-school learning can help to establish ongoing, lifelong attitudes and learning processes in the sense of scientific literacy (Lucas 1983; Rennie 2007), especially when coordinated with in-school (formal) learning (CAISE 2010; Stocklmayer et al. 2010). Braund and Reiss (2006) discuss the following ways in which out-of-classroom contexts can foster science learning (their formulations are given in italics):

- "Extended and authentic practical work" and "Access to rare material": This is very much in line with what was stated in the section about manipulatives and "hands-on" activities. In fact, V&L provides a unique learning experience showing authentic prehistoric objects, and providing material allowing for the reproduction of some of them.²
- "Attitudes to school science, stimulating further learning": This is very much in line with the other research just cited above and one of the positive OSLEO effects most consistently stated in the field. In the case of V&L, this concerns archaeology in particular and its specific status between the natural sciences and humanities (see above).
- "Improved development and integration of concepts": This is an important aspect of V&L, to which we return below.

For the sake of completeness, it should be mentioned that Braund and Reiss (2006) discuss *"collaborative work and responsibility for learning"* as a fifth way to foster science learning by out-of-classroom contexts, but this will not be considered in the present study.

A second argument is that the personal contact with researchers and the work they do provides opportunities to experience authentic ways of doing science (as opposed to the restricted or even artificial views of science as they may sometimes be presented in school). This contributes to overcome misconceptions and stereotypes related to researchers as people and research as a professional activity, and how it is done in a given area (Euler 2004; Stocklmayer et al. 2010). Moreover, the researcher may convey the experience of curiosity, excitement and satisfaction found in her work (Euler 2004; Stocklmayer et al. 2010). Tytler et al. (2017) argued that such encounters can make a valuable contribution to provide role models of adults interested in and committed to science and related areas. Affective outcomes of this kind are also one of the main objectives of V&L, and we will discuss the relevant research in more detail in the following section.

OSLeOs are very often conceived to promote positive effects on the affective level, such as an enjoyable science experience, curiosity and interest for particular contents, or science in general (Braund and Reiss 2006; Euler 2005; NRC 2009; Stocklmayer et al. 2010). Developers and researchers emphasise the importance of affective outcomes as an aspect of scientific literacy (attitudes of future citizens, interest in learning about science, etc.). As Rennie (1994) put it, "an enjoyable and successful visit experience is an important outcome because it can predispose the learner to engage in further cognitive learning. Motivation and willingness to engage in further instruction are most likely to be the important affective outcomes of a visit." A considerable body of research indeed supports positive affective outcomes of various kinds (Rennie 2007; Tal 2012). For instance, a series of studies on more than 10 sites have shown quite positive results for enjoyment/general appreciation of various out-of-school science learning opportunities (70–90% of maximal value), consistently across several countries (France, Germany, Switzerland), age groups (primary to secondary level II), various settings (single and multiple visits, degree of guidance) and disciplines (biology, chemistry, physics), and across more than a decade (Müller 2017). Moreover, it appears that the positive effects of out-of-school learning particularly apply to girls. Pawek (2009) has found a considerable decrease of the "gender gap" (tendency of girls to be less interested in Science, Technology, Engineering and Mathematics than boys). A similar effect was found for the self-concept of girls (Euler 2007).

² Braund and Reiss (2006) mention also "access to big science", which is of course not applicable to the project presented here.

This is also in line with the encouraging impact of encounters with role models as mentioned above, for girls in particular with female scientists (Tytler et al. 2017). Even OSLeOs taking place as a single event (typically during half a day) can provide a situation with a decreased gender gap for interest and self-concept. The same holds true for the interest gap in general: the difference in general physics interest between a highly and weakly interested group of students (median split) decreases from d = -2.33 before to d = -0.49 after an out-of-school lab visit (Pawek 2009).

It is furthermore useful to locate V&L within existing research on out-of-school learning opportunities. Falk et al. (2008) have proposed a simple classification model along two dimensions of the formal/informal learning "landscape", as they called it. These two dimensions are the degree to which understanding in some area of science (or related disciplines) is a goal of the various learning settings (from weakly to strongly present), the other the degree of informality (from highly to weakly informal, Fig. 1). Cooperative expert/professional interventions at schools like Valentina and Leo or "Scientists in School" (Rennie 2015; Rennie and Howitt 2009) can be integrated in this landscape in a natural way, as they are characterised by a high value placed on the "understanding" dimension, and a medium value on the "informal/ formal" dimension (integrating an informal, external offer in the formal classroom setting). Existing research provides evidence that such a type of scientist-school cooperation is capable of "bringing authentic science into schools" (Cripps Clark et al. 2014), and of providing "opportunities to experience scientists as real people, and as role models/mentors", increased knowledge, and last but not least an enjoyable experience (Marginson et al. 2013; Rennie 2015; Rennie and Howitt 2009).



Fig. 1 The formal/informal education landscape proposed by Falk et al. (2008) for science and related areas (STEM = science, technology, engineering, mathematics). Within this framework, experts/professional interventions in schools (EPIS) like Valentina and Leo are characterised by a high value placed on the "understanding" dimension, and a medium value on the "informal/formal" dimension

2.3 Conceptual Difficulties and Conceptual Learning

We now address conceptual learning and conceptual change as a third area of research background important for the present study. As stated above, Braund and Reiss (2006) considered "improved development and integration of concepts" as one of the main ways in which out-of-classroom settings can foster science learning. Conceptual change, in particular, is related to a situation where existing concepts originating either from previous instruction or, more often, from sources outside school (everyday life, popular culture, etc.) are markedly different from the scientific concepts in a given area (Chi and Roscoe 2002; Scott et al. 2007). In the latter case, these are often described as "conceptual obstacles" (or intuitive conceptions, preconceptions, misconceptions, to name but a few other terms). In the context of the V&L workshops, we consider the following topics of conceptual learning:

- Kinds ("species") of animals represented in prehistoric paintings: This implies not only reliable factual knowledge (naming and recognising the species in question), but also an understanding of (at least) two important conceptual aspects, which are essential for meaningful representation and interpretation of this factual knowledge (National Research Council 2000). First, understanding that there were profound *changes* in the species present in a given geographical area at different times (with species present in former times one would nowadays associate to very different geographical regions), and second of the *reasons* of these changes (in particular, climate change).
- Dinosaur misconception: The idea that "cavemen" lived at the same time as dinosaurs is a classic misconception (in fact, it is a special case of the topic of "represented animals"), well studied for more than two decades. Research has shown a considerable prevalence among children and even adult university students (Catley and Novick 2009; Schoon 1993).
- "Brute caveman" stereotype: Another stereotype is that of prehistoric man as an ape-like brute, typically depicted hirsute, with a chimpanzee-like skull, armed with a club, and with an overall dull and aggressive appearance. This "brute caveman" stereotype is discussed with respect to conceptual understanding of prehistory and archaeology (Feder 2008; Patou-Mathis 2011). It is quite current in popular culture (van Riper 2002), in part based on early representations of Neanderthals and Hominids, and it can be found in older academic work (see Gamble 1994; Moser and Gamble 1997, for an account on how this stereotype has developed and changed during the development of our view of prehistoric human beings).
- Archaeology/archaeologist stereotypes: One of the objectives of the project was to convey
 a reliable image about archaeologists and their work, their object of study and the scientific
 approach in the discipline. In Anglo-Saxon countries, the "Indiana Jones" stereotype is
 widespread, preventing the formation of a reliable image: discovery of precious objects
 inside a forgotten tomb and use of a treasure map by a male adventurer fighting criminal
 adversaries and ferocious beasts (Gotshalk-Stine 2011; Scantlebury et al. 2007). Yet, it is
 not the pecuniary value of an archaeological object that makes its scientific value: modest
 and broken objects and even "garbage" can be of great value in this respect (see below),
 and archaeological research is done very often in unspectacular field sites, laboratories and
 libraries.
- Garbage: A further aspect of specific interest was the understanding of the well-known scientific value of garbage in archaeology (Rathje and Murphy 2001), nicely formulated as

follows: "99 percent or more of what most archaeologists dig up, record, and analyse in obsessive detail is what past peoples threw away as worthless—broken ceramics, broken or dulled stone tools, tool-making debitage, food-making debris, food waste, broken glass, rusted metal, on and on." (Shanks et al. 2004). This is not an easy paradox to understand, and there could be a strong misconception here for two reasons: first, the notions of garbage and value in everyday experience are by definition opposite to each other. Second, there is the "precious object" idea strongly linked to the "Indiana Jones" stereotype.

2.4 Research Questions

In line with the research background outlined in the preceding sections, our research questions were as follows:

- Research question 1: What is the perception of the workshops by the students on the affective level, in particular regarding overall appreciation/enjoyment, activation/engagement, educational value, as well as practical aspects (organisation)?
- Research question 2: What are the effects of the workshops on the cognitive level, in particular for the following aspects:
- learning about prehistoric life
- conceptual learning related to prehistory and archaeology
- familiarisation with archaeology as a discipline and work (what an archaeologist does)
- understanding of the interdisciplinarity of archaeology, its interactions (as a discipline between human and natural sciences) and other disciplines (such as ecology and climate studies).

3 Educational Scenario of the Workshops

As mentioned previously, Valentina and Leo were conceived as fictional characters participating in all of the project's activities, and giving the project its name. A logo was designed and included on all project documents to allow the students to identify with these characters (Fig. 2).



Fig. 2 Valentina and Leo project's logo (by Eva Gutscher, University of Geneva)

Two workshops were presented to each class (see Table 1 for an overview). Each of the workshops (total length 90–120 minutes) consisted of three phases. During the first phase, the archaeologist, using a PowerPoint presentation, introduced the topic with numerous images, photos and reconstitutions. During 20 to 30 minutes, she discussed the work of archaeologist, humans' way of life at the end of the Palaeolithic, their settlements, and the animals present and/or hunted during that period. The idea of time and how prehistory actually refers to different well-defined periods, as well as how each of these periods represents changes in lifestyle, was extensively discussed.

For the painting workshop, the archaeologist showed several examples of painted or engraved cave-art and explained painting techniques. During the bone awl workshop, she explained archaeozoology, which enables the determination of the species to which the bone belonged, the use of bone material as a tool or a medium for art, and details of the method of the awl's creation. During the presentation, the archaeologist regularly asked the students questions, allowing them to express what they know or think (e.g. What kind of climate would there have been 20,000 years ago? Which animals could humans hunt at that time?).

The second phase, of about 20 minutes, was a moment of exchange and free conversation around a table on which archaeological objects were presented (Fig. 3). The objects were either real archaeological artefacts or replicas: animal hides, bones, flint, bone and antler tools, pigments. For both workshops, there were different objects linked to the activities proposed. The archaeologist presented each object, some of which were more enigmatic (ligament, hammerstone, polished stone axe, etc.), and tried to make the students guess their function. Sometimes, she demonstrated their use directly. The students had ample opportunity to discuss, ask questions and to touch the archaeological objects. They tended to be very active and impressed during this phase, due to rarely having the occasion to be in contact with real archaeological material (they often asked if the objects were real, their age, etc.). This phase was a special moment of exchange between the students, the archaeologist and the teacher, and allowed the students to dig deep into the past. The archaeologist fostered and participated in a dialogue to make students think and formulate hypotheses on objects' functions, the material used and the method employed to make them, just like researchers do. Students asked many questions about the everyday activities of prehistoric humans, such as what they ate, about their clothes, whether they had shoes, etc. They realised that the most beautiful or "better finished" objects were not necessarily the most recent ones. They discussed the differences between artefacts from the Palaeolithic and the Neolithic, since they corresponded not only to different human needs, but to environmental changes as well.

The third and main phase was the manual activity during which the students tried to emulate prehistoric man by using similar techniques and materials to create an object. First, the archaeologist showed students how to proceed and what material they should use. The students then carried out the activity and the archaeologist stayed among them to answer

Workshop title	Key content	Period
Prehistoric painting Bone awl	 Archaeology, end of Palaeolithic, ice age, animals, hunting, settlements, caves, painting techniques, flint, pigments Archaeology, archeozoology, animals, hunting, craft, abrading, engraving, bone, weapons, flint tools, antler tools, 	December 2013 to February 2014 March to May 2014

Table 1 Characteristics of the two workshops (common educational objectives are described in the text)



Fig. 3 a, b Pictures of the students during the presentation and manipulation of objects (Livrons school, April 2014)

questions and to help them, if necessary. This phase lasted 30 to 40 minutes, including preparation and clean-up. We now turn to some specific details of the workshops.

As stated in the introduction, an important overall objective of the project was to maintain a close link with the regular curriculum/teaching. In this regard, the project was based on the areas entitled "Mathematics and natural sciences" (MSN) and "Human and social sciences" (SHS) from the local study plan called the *Plan d'Etudes Romand* (PER; CIIP 2010–2016), with particular emphasis on the following learning objective (the translations from the original documents in French are our own; the acronyms in parentheses give the relevant chapter of the PER):

- "to identify the ways in which humankind organised their lives in groups through time, here and elsewhere" (SHS 22, central to both workshops);
- "to self-appropriate relevant tools in real-world situation to understand questions in human and social sciences"; "to explore natural and technological phenomena using procedures typical of experimental sciences" (SHS23 and MSN 26, respectively; focus of the objective "Learning about archaeologists and archaeology as scientific discipline" of the project);
- "to determine characteristics of life and of various environments, drawing conclusions about the sustainability of life" (MSN 28; central to the core content "changes of climate" and of wildlife in a given area).

The project took into account further chapters of the local study plan, such as "Creative and manual activities" (A 23 AC&M: "Experiment with various plastic and artisan techniques" or A 24 AC&M: "To have deep encounters with various artistic fields and cultures") or certain areas of general skills (teamwork, communication, learning strategies, creative thought and procedures for reflection).

3.1 Workshop 1: Prehistoric Painting

In the course of the Upper Palaeolithic, many caves, mainly located in Southern France and Spain, were adorned by a large number of rock paintings and engravings. Most of them depict animals (aurochs, horses, reindeers, mammoths, bison, etc.) and geometric designs. Humans are rarely represented. Cave art, some dating back about 30,000 years in the Chauvet Cave (Vallon-Pont-d'Arc, Ardèche; Clottes 2001) and even earlier in Northern Spain (Hellstrom 2012; Pike et al. 2012), was made during nearly 20,000 years. Current research on cave art aims at developing our understanding of various aspects: determining the chronology of artistic expression and its dating, reconstructing the drawing techniques, analysing the pigments used, understanding the meaning of the pictorial representations. This workshop allowed students to discover the masterpieces of the first prehistoric painters by creating a painting in the same manner with Palaeolithic artists, i.e. by using their fingers and organic pigments on a canvas resembling a cave wall (Fig. 4). The students were instructed to paint what humankind could have represented 20,000 years ago, with photos of real cave art made available as inspiration. During this exercise, they realised the mastery of the artistic productions of these prehistoric people and were generally impressed by this.

3.2 Workshop 2: Manufacturing a Bone Awl

At the end of the Palaeolithic period, humans started using reindeer antlers, bones and other materials cut from hunted animals to manufacture various objects such as weapons, tools or



Fig. 4 a, b Pictures of the students during the prehistoric painting workshop (Ami-Argand school, January 2014)



Fig. 5 a, b Pictures of students during the bone awl workshop

ornaments. The study of bone artefacts is related to archaeozoology, yielding information on the faunal species used, and using shape and wear analysis to determine the function of these objects. The archaeologist refers to collections stemming from experimentation (animal skeletons, use wear types). Each child in the workshop reproduced the actions of these ancient people by abrading a bone on a block of sandstone in order to obtain an awl that could be decorated with a flint tool (Fig. 5).

This workshop required strength and patience in order to obtain a useful awl; at first some students were discouraged as they found the process to be long, but they eventually found the right technique and ended up comparing the efficacy of their creation to those of other students.

4 Methods

The impact of the workshops was studied from two perspectives, affective (appreciation/ enjoyment, engagement³) and cognitive (learning and understanding), in close alignment with the objectives of the project.

³ Following PISA (OECD 2009), we use "engagement" as an umbrella term comprising in particular interest, effort investment and active participation.

Participants were from 12 classes at three primary schools in the canton of Geneva, in 3rd and 4th grade classes (international classification: ISCED code 1, UNESCO 2011; Swiss classification: HARMOS 5P, 6P, EDK/CDIP 2015; see 4.2 for selection of these classes). There were five classes 5P, four classes 6P, two classes 5P-6P, and one special needs class. The sample sizes were N = 217 ("prehistoric paintings" workshop, PP) and N = 222 ("bone awl" workshop, BA), with 52% girls and 48% boys, mean age 9 years (SD = 1 year). The language used in teaching in this area of Switzerland is French.

Student data were collected in the classes at four measurement points (PP pre/post, BA pre/post), with a test administration time of about 30 minutes (judged as acceptable by the primary teaching experts in the project group, as well as by the participating teachers). There were N = 374 participants from whom we could gather the questionnaire from both workshops. Teacher data were also collected and will be reported elsewhere.

4.2 Framework of the Intervention

The project was supported by the Swiss National Foundation within the framework of the Agora science communication program. Total funding amounted to approx. 300 Swiss Francs per student, with 20% allocated for evaluation. In order to ensure coherence between the intended content and the educational approach of the workshops, the curriculum, the interests and abilities of the students, and the evaluation, a steering group of experts was formed. It was composed of prehistoric archaeologists, teaching experts and school authority for primary schools, as well as science education researchers.

Authorization by the school authorities was obtained, taking into account educational adequacy and interest, and ensuring anonymity. The 12 classes from three schools were selected by the responsible coordinator taking into account the temporal constraints of both the lesson plan and the project schedule, and after having obtained the approval of school principals and teachers. All schools were within the canton of Geneva (Champs-Fréchets and Livron school in Meyrin, Ami-Argand school in Versoix).

The prehistoric painting workshop was tested in two pilot classes in November 2013, and some details were changed. The remaining classes did the workshop between December 2013 and February 2014. The second workshop (bone awl) took place between March and May 2014. The interventions lasted about two hours and were conducted by an archaeologist.

4.3 Instruments and Data Analysis

4.3.1 Methodological Choices

The Valentina and Leo team opted for a primarily quantitative approach based on questionnaires, for several reasons. First, it is well suited for the specific educational objectives of the project. In the domain of specific engagement and appreciation, one is not in a new area requiring an exploratory approach, since there is a rather considerable body of research (Kind et al. 2007; OECD 2013; Rheinberg 2004) and of validated methods justifying a quantitative approach, in particular relating to two essential aspects of the project namely extra-curricular learning opportunities in general (Orion et al. 1997; Rennie 1994) and science learning in particular (Hoffmann et al. 1997; Rheinberg and Wendland 2003). Second, to assess specific, well-defined learning aspects, a quantitative approach is also justified (OECD 2013); in fact, this is the foundation of the entire development of evidence-based research (Hattie 2009). This true not only for factual, but also conceptual knowledge (Liu 2012). Third, a quantitative approach allows to probe for *changes* of both affective and cognitive variables, when combined with pre- and post-testing (see Section 4.1).

It is certainly true that interesting aspects of the project, such as prevalent ideas and stereotypes about archaeologists (see 5.2.3), could be investigated in a more complete manner by including qualitative methods (e.g. interviews). It has to be kept in mind, however, that research approaches taking qualitative methods fully into account invariably require full-time work for years, very often within the framework of a stand-alone project (Gotshalk-Stine 2011). The investigation of the educational effects of Valentina and Leo, however, is not such a research project, but an adjunct evaluation that had to be carried out in a very limited amount of time (a 20% FTE, i.e. one day per week). In this time, the evaluation had to be developed, tested, administrated more than 400 times, and the data entered and analysed. Moreover, the results gathered in this very tight framework were expected to allow useful conclusions to be drawn about the future development of the workshops, and further offers based on them to be developed. To carry out this work program was a non-trivial achievement even for a quantitative approach restricted to a limited set of well-defined questions.

4.3.2 Student Questionnaires

The questionnaire for the affective part of the study was based on existing instruments (Kuhn 2010; Kuhn and Müller 2014, in turn based on Rheinberg and Wendland 2003; Rennie 1994; Orion et al. 1997). The format was a 15-item five-point rating scale questionnaire, from 1 (very bad) to 5 (very good), concerning the student's perception of the following aspects of the workshops (for the exact item wording see Fig. 6):

- organisation
- educational value
- engagement
- general appreciation/enjoyment.

These aspects are in line with the research background for the setting and the potential of hands-on OSLeOs (Section 2.2), and the existing research about the assessment of their presumed positive effects. The first group of items ("organisation") concerns the fact that learners should be enabled to understand the purpose and activities of an OSLeO. Items were taken from Rennie (1994), with an additional item from Orion et al. (1997). The second group of items is about whether the educational potential offered by a hands-on OSLeO (see 2.1 and 2.2) is also perceived by the *students*, as the perception of one's own learning and increased competence is a strongly motivating and cognitively activating factor. Items are again from Rennie (1994) and Orion et al. (1997), with a supplementary item specific for Valentina and Leo. The third group of items asks an analogous question for how well the engagement potential of the intervention (see 2.1 and 2.2) was perceived. Items were taken from an established and validated instrument, from a broad research program on context-based science learning (Müller et al. 2009a; Kuhn 2010; Kuhn and Müller 2014; Vogt 2010; Weiss and Müller 2015; $N \approx 1700$; $\alpha_{\rm C}$ in these studies from 0.86 to 0.94), in turn based on a large-sample physics interest study



Fig. 6 Workshop appreciation by students (in % of maximal value)

(Hoffmann et al. 1997; $N \approx 10,000$). The last aspect, "general appreciation", completed by a "school grade" (in the grading system familiar to the students, 1 = lowest, 6 = highest grade), was included to complement the evaluation by some simple and overall questions, in order to have an additional validation of the more differentiated, individual rating scale items. To this was added one further question concerning the length of the workshop (with 1 = too long, 2 = adequate, 3 = too short).

The cognitive part of the study had focused on the following aspects, in line with the project objectives and the research background:

- learning about prehistoric life (common and specific to both workshops)
- conceptual learning related to prehistory and archaeology
- familiarisation with archaeology as a discipline and work (what an archaeologist does)
- understanding of the interdisciplinarity of archaeology, its interactions (as a discipline between human and natural sciences) and other disciplines (such as ecology and climate studies).

The evaluation in this domain consisted of a questionnaire with about a dozen items ("prehistoric paintings": 12, "bone awl": 13), which were identical for the pre- and postquestionnaires in order to probe for *changes* in students' knowledge and understanding. Postquestionnaires had a few additional items in order to probe for factual learning content about prehistoric life specific to both workshops (the first learning component mentioned above). Item formats varied, often with a visual element (mostly multiple true false, MTF, and rating scale multiple choice with four options, MC4 (+ no answer option)). For the four central learning aspects of the project, the expert team developed specific items, in line with the general objectives of the project. Much care was taken in order to work with item formats accessible for the target age group, with a strong visual character and avoiding a purely textual multiple choice format as much as possible. Moreover, the item formulations were checked for comprehensibility by the primary school teaching experts in the team, and by a pilot administration in two classes (N=32).

4.3.3 Analysis

Statistical significance was analysed by t tests (dependant samples, for pre-post comparisons) (SPSS, IBM Corp. 2013). Effect sizes, as a measure of practical relevance (Hattie 2009; Wilkinson 1999), were computed as Cohen d (Cooper et al. 2009, ch. 15). While our analysis is mainly quantitative, there are various qualitative data available which are used to further the discussion.

5 Results

5.1 Affective Domain and Appreciation /Enjoyment

The four different aspects of both activities were generally well rated by students, with averages (for both workshops together) between 80 and 90% of the maximal value (organisation: 85%; educational value: 81%; engagement: 84%; general appreciation: 94%; see Fig. 6). This is confirmed by the "school grade" of 5.5 for the workshop (max. 6), and by replicating the finding (e.g. general appreciation: pilot test, 96%; PP workshop, 94%; BA workshop, 94%). The length of the intervention was judged as adequate (2.2; scale: 1 = too long, 2 = adequate, 3 = too short). Finally, no differences in these outcomes were found between girls and boys.

With respect to the educational value, the following individual results are relevant to the central objectives of the V&L project: *The workshop allowed me to better understand how prehistoric people lived* (86%); and *The workshop helped me understand how archaeologists work* (84%). With respect to engagement, students' perception was strongly positive regarding concentration (in the sense of on-task behaviour), active participation (*I was focused during the workshop*, 88%; *I actively participated in the workshop*, 93%), the interest raised by the activities (*the activities were interesting for me*, 91%), and even to some extent the increased investment of effort (*I invested more effort into the workshop than in regular lessons*, 73%). Finally, the results indicated some impact going beyond the workshops: not only did the students consider the workshops as useful for their regular learning (*the workshop helped me understand the contents of regular lessons*, 74%), but they would like to extend their learning at home (*at home, I'd like to look up in books, internet, etc. to know more about the topics of the workshop*, 73%).

5.2 Cognitive Domain

In this section, the findings for each of the four aspects of the cognitive part of the study are presented (learning about prehistoric life—specific to each workshop; conceptual learning/ change; archaeology as a discipline and work, understanding of the interdisciplinarity of archaeology).

5.2.1 Knowledge About Prehistoric Life

A first item group concerning the "prehistoric painting" workshop was related to one of the central research objectives of archaeology, namely to learn about the way of life of prehistoric people. Specifically, this item was about where they lived, and with what resources (see Fig. 7a). As is shown, there is a considerable increase in correct knowledge, more specifically that people lived in tents and in the entrances of caves, but not at their far ends (p < 0.001, d = 1.1, 0.94, 0.91, respectively), and that they lived on hunting, fishing and gathering (p < 0.001, d = 0.46). It is noteworthy that for the question whether the place of living was at the entrance or the far end of the caves, there is a clear sign of "unlearning" an incorrect idea, and replacing it with the correct one; the majority changed from slightly favouring (56%) the (incorrect) "far end" option before the workshop (possibly because of thinking that it is the safer place, but this remains to be validated) to strongly favouring the (correct) entrance option afterwards (82%). This can be considered a case of "conceptual change", a kind of learning impact of the workshops to which we will return in 5.2.2. Some incorrect ideas were already low in presence before the workshops (<20%), which did not significantly increase them. Moreover, very few students did not have an opinion about the question (<10%).

Another item group about an essential knowledge element of the other workshop concerned the function of the awl (such as the one created by students of the second workshop; see example in Fig. 8). Again, there was a considerable increase in correct knowledge, for all functions in which an awl had been used in prehistoric life, piercing hides and bark, and as s sewing aid (Fig. 8b; p < 0.001, d = 0.58, 0.60, 0.80, respectively). There was no significant change regarding the function "decorating objects", for which students had already answered correctly before the workshop (no; > 80%).



Fig. 7 a Item on lifestyle of prehistoric people. b Results (% of yes answers; pre-test (left) and post-test (right)

A third item group was about which kind of different materials would be preserved through time. Here, a highly significant and practically relevant improvement was found for sewing thread, where initially only a minority of students gave the correct answer (yes; change from 40 to 60%, p < 0.01, d = 0.39). For other materials (skin, bone, flint), there was a high level of correct knowledge prior to the workshop ($\approx 65–90\%$), which did not further improve with the activities.

Finally, regarding the understanding of chronology, a strong majority of students achieved an acceptable understanding. This was measured through an item asking students to arrange four scenes (middle Palaeolithic, upper Palaeolithic, Bronze Age, Roman times) in the right chronological order (correct/incorrect/no answer = 56/21/23% after the second workshop; this item was not included in the pre-questionnaire in order to limit total test time). Other items regarding the passage of time (and the important changes it might provoke) concerned materials preserved through time (or not), the kind of animals represented in cave paintings, the changes compared to today, and climate change.

There were several other cases, where the pre-post changes showed an increase in students' knowledge and understanding, but were statistically not significant, e.g. "Is it possible to know the life of prehistoric people", or "According to you, what kind of information can be inferred from prehistoric paintings: animal species/how people looked like/tools/weather/way of life/ beliefs and religion/nothing". In some of these cases, we have indications that individual items should be improved (see discussion, Section 6).

a <u>11. Awl function</u> <u>Circle</u> the correct/s answer/s. <u>According to you, what was the functions of the bone awl?</u> To pierce animal skins To decorate objects Help with sewing To pierce bark of wood <u>If you have another answer, write it here:</u>



Fig. 8 a Item on bone awl function. b Results (% of yes answers; pre and post-test)

5.2.2 Conceptual Learning About Prehistory

In view of the value of the intervention on the one hand, and its limited duration on the other hand, the Valentina and Leo team decided to focus on some conceptual aspects, considered to be particularly important:

(a) Kinds of animals represented, and their changes (PP workshop)

The main issue discussed here was whether students have an understanding that there can be long-term changes in the kinds of animals living in a given area, mainly due to climatic changes, and thus of the animals which can be known to and painted by humans in the same area. Changes, in particular, mean that the kinds of animals appearing in cave paintings can be quite different from the animals one finds nowadays in the same area. As Table 2 shows, there is a marked increase of correct answers by the students, including for animals which no longer live in our area (e.g. rhinoceros and penguin; for the latter, the largest increase occurs). These changes are highly statistically significant ($p < 10^{-3}$) and with effect sizes from medium to large (0.50 < d < 0.82). The change for ibex is less pronounced than for the other animals.

(b) Dinosaur misconception

The case of dinosaurs, however, represents a marked exception to the findings regarding the other animals. More than 50% of the students believe that prehistoric people could have painted dinosaurs, and this belief was not changed by the workshops.

(c) Brute caveman stereotype

Our findings show that this stereotype is also considerably present in our sample; 70–75% answer "rather yes" or "yes" (item averages 3.0–3.2. for the four measurement times, for which no significant differences were found), and few students do not have an opinion about the question (\leq 5% for all four measurement times). This is supported by the results of another item (see Fig. 9) according to which most students saw prehistoric man as ugly, dirty and violent (69, 69, 52%, respectively); on the other hand, most students also saw him as clever (52%; consistently, few as stupid: 29%), and again few students do not have an opinion about the question (6%). The preceding values are the averages over all the four measurement times, for which no significant differences were found.

Misconceptions about "garbage" and stereotypes about archaeologist stereotypes are treated in the next section.

Table 2 Proportions of positive answers to the item "Do you think that prehistoric people could have made thesepaintings? (x/- means that a given animal was shown in the workshop, or not)

% yes	Mammoth	Penguin	Rhinoceros	Steinbock (ibex)	Dinosaur	Owl
Workshop	х	x	х	X	_	x
Pre	0.77	0.51	0.65	0.67	0.54	0.62
Post	0.94	0.80	0.87	0.77	0.56	0.81
р	< 10 ⁻³	< 10 ⁻³	< 10 ⁻³	0.07	0.74	< 10 ⁻³
Cohen d	0.82	0.72	0.67	0.25	_	0.50

5.2.3 Learning About Archaeologists and Archaeology as a Scientific Discipline

The main objectives of the study include creating a reliable image of archaeologists and their work, the questions asked (and those not), the objects of study and the way scientific work is undertaken within the discipline. The V&L team had decided to probe for students' ideas about several of these aspects, but not directly about the "Indiana Jones stereotype", as the film series was deemed not to be sufficiently well-known among primary school students in Geneva. We report the results of this evaluation component in two formats: first, about the extent to which certain relevant ideas (including stereotyped ones) are present in the target



Stupid

I have no opinion on this subject

Fig. 9 a Typical illustration corresponding to the "brute caveman" stereotype (public domain, Wikimedia 2018) as used in the following item: *Does this picture correspond to how you imagine a prehistoric man*? b Another item probing for the mental representation of prehistoric Man: *Circle the adjectives that, according to you, describe prehistoric Man. You can also add other adjectives*

group (percentage values); second, about whether there were changes regarding these ideas induced by the workshops and the learning opportunity they offered (significance level and effect size values, as in the preceding sections).

A group of items asked for specific features of the "Indiana Jones" stereotype for an archaeologist (without mentioning the name or referring to the films). Indeed, such features were quite widespread among the students. They thought that archaeologists search for precious objects (74%), travel in faraway countries (68%), be described as adventurers (64%) and even fight with strange creatures (34%). They also thought, however, that they can just as well be a woman (as 46%) or a man (48%). These values did not show a significant change throughout the workshops (the values reported are the averages over all measuring times).

Another item group probed what students thought of as typical work for an archaeologist (Fig. 10) and whether this would change under the influence of the workshops. The following results are the post-test values of the PP workshops (there were no further appreciable changes in the BA workshop). (a) The component "scientific research" is well represented (87%). But two other components are under-represented in the students' perceptions, namely literature research (20%) and fieldwork (17%). Students did not strongly associate these aspects to the work of an archaeologist, even after the workshops, and very few did not have an opinion about this question ($\leq 10\%$ both workshops). (b) The contact with archaeology offered by the project produced significant changes towards a more complete vision (literature search: p = 0.009, d = 0.31; fieldwork: p = 0.04, d = 0.46; pre-post increases in first, PP workshop; no further appreciable changes in second workshop).

A third aspect of specific interest was the understanding of the well-known scientific value of garbage in archaeology (see Section 2.3). Our results show that, even before the workshop, there was a good understanding of the fact that garbage can help to understand how people lived in the past (54%), and even to some extent to know what they ate (32%); but almost as many students did not have an opinion (28%). The workshop then improved understanding about this, however only slightly (what prehistoric people ate: 40%, p = 0.06 (marginally significant), d = 0.20) and stabilised it (no opinion: 18%, p = 0.003, d = 0.30).

5.2.4 Learning About Interactions of Archaeology and Other Disciplines (Interdisciplinarity)

A first interaction of this kind (cave paintings informing about changes in animal diversity) was already presented above. Another example is the important link between archaeology and climate studies, with the following results (Fig. 11): A majority of students already knew that the climate 20,000–30,000 years ago was not similar to today, but were undecided about the type of change: colder, with glaciers (28%; correct) or warmer, with tropical weather (25%; incorrect). The workshop led to a reinforcement of correct statements (colder climate, glaciers, lower sea level; p < 0.001 in all cases, d = 0.83, 1.1, 0.69, respectively), and the reduction of incorrect ones (warmer, tropical climate, p < 0.001 in both cases; d = 0.63, 0.89, respectively). Moreover, the number of students believing that there was no change diminished (p = 0.04; d = 0.54), as well as the number of students who indicate having "no opinion" on the subject (p = 0.001, d = 0.43).





Fig. 10 a Question on archaeology as work. b Results (% of answers; pre and post-test)

6 Discussion

6.1 Affective Domain and Appreciation

Students' feedback regarding engagement, educational value and general appreciation/ enjoyment (research question 1) was positive to very positive throughout (in % of maximal value, 73 to 94% for individual items, ≈ 80 to 90% for averages). The value obtained for general appreciation (94%) confirms the high potential of OSLeOs for creating an enjoyable learning experience known from previous research (see 2.2).

As for organisation, the length of the intervention (90–120 minutes) was judged to be adequate, with a slight tendency in favour of longer workshops—a desirable result for the project. The only point to be improved appears to be the information provided before the workshop. The perception of this item is the only organisational aspect below 80% (*Before the workshop, we received sufficient information on what was going to happen*, 77%), and adequate preparation of an out-of-school learning offer is a core element of one of the leading educational theories in this area (novelty space theory, Orion 1993; Orion and Hofstein 1994).

As for educational value, two individual results are noteworthy in view of the central objectives of the V&L project: *The workshop allowed me to better understand how*

а

1. Climate

Circle the correct/s answer/s.

According to you what was the climate about 20,000 - 30,000 years ago when men were painting in caves?

It was colder

Glaciers covered part of Europe

The sea level was lower

It was warmer

It was hot and humid

The climate was the same as today



Fig. 11 a Question on climate. b Results (% of answers; pre- and post-tests)

prehistoric people lived (86%) and the workshop helped me understand how archaeologists work (84%). Note that the positive perception of the students about these aspects of the educational value is supported by considerable, closely related *learning effects* found in both domains (see Sections 5.2 and 5.3). Two more individual results open up an interesting perspective, which could be termed "effects beyond" (i.e. beyond the workshops). First, students would like to extend their learning at home (at home, I would like to look up in books, internet, etc. to know more about the topics of the workshop; 73%); second, they perceived the workshops as support for regular learning (the workshop helped me understand the contents of regular lessons, 74%).

The first finding is worth noting as an indication of active learning and the willingness to invest an effort, the latter being considered as a strong indicator of interest (Swarat et al. 2012), especially in the framework of models where when a cognitive evaluation of motivational aspects by the individual takes place (Boekaerts 2006; Rheinberg et al. 2000). The second finding is in line with existing research emphasising the link between out-of-school learning offers and regular classroom learning (Anderson and Zhang 2003; Fallik et al. 2013; Orion 1993; Orion and Hofstein 1994); in the case of the V&L project, we find evidence that such a link was successfully established.

An additional factor of particular interest for the intervention presented here—dealing with prehistoric life and archaeology via with authentic objects, art (prehistoric painting) and a storytelling framework (Valentina and Leo)—could be that it helps to foster a "romantic

understanding" of science.⁴ This includes affective aspects like imagination, aesthetic experience, sense of wonder and personal involvement, completing conceptual and logical modes of thinking in science learning in an important way (Hadzigeorgiou 2005; Hampp and Schwan 2015). These aspects have been widely discussed in the context of science education, in particular for younger children (Girod and Wong 2002; Kokkotas and Rizaki 2011; Murmann and Avraamidou 2016), and even shown to be at work in secondary-level students (Hadzigeorgiou and Schulz 2017). While an investigation of this line of thought was not in the scope of the present study, we feel that it represents an important approach for further research and development of interventions like Valentina and Leo.

6.2 Cognitive Domain

In view of the four cognitive aspects of the project objectives (research question 2: learning about prehistoric life, conceptual learning/change related to prehistory and archaeology, familiarisation with archaeology as a discipline and work, understanding the interdisciplinarity of archaeology), there were findings supporting a positive impact of the intervention. Considerable effects where found regarding several elements of scientific literacy addressed in the workshops (e.g. where and with what resources prehistoric people lived; medium to large effect sizes: $d \approx 0.5$ and 0.9–1.1, respectively). Large gains were also found for another item group about the function of the awl as an essential knowledge element of the other workshop. Again, there was a considerable increase of correct knowledge, for all functions in which an awl had been used in prehistoric life ($d \approx 0.6$ –0.8).

As for conceptual learning, results showed a differentiated pattern, which we would like to discuss. Quite strong indications were found regarding improved understanding of the long-term changes on the kind of animals which live in a given area, mainly due to climatic changes. Effect sizes were medium to large for four out of five animals treated in the workshop and asked for in the test (owl, mammoth, rhinoceros, penguin; $d \approx 0.5-0.8$). Note that this voluntarily included animals which do not live in our area any longer, for which the largest changes occurred (rhinoceros, penguin). For the mammoth, there was the highest level of initial knowledge, which might be due to influences by popular culture (film series like "Ice Age", etc.). For the remaining animal (ibex), the effect was less pronounced (marginally significant), a result for which we do not have an explanation.

Dinosaurs are a special case, in the sense that the idea that "cavemen" lived at the same time as the dinosaurs is a classical misconception, well studied for more than two decades. Research (Schoon 1993) has shown a considerable prevalence among students (32% among 5th graders, USA) and even adult university students (20% pre-service, non-science teachers). Among the latter population (undergraduate non-science students), 25% of the time, the dinosaur extinction is thought of as occurring $\leq 600,000$ years ago, i.e. well within the existence of prehistoric human beings on Earth (Catley and Novick 2009). Our findings align well with this state of affairs, since more than 50% of the students (age group roughly comparable to that of the US study, Schoon 1993) believed that prehistoric people could have painted dinosaurs. This belief was not changed by the workshops, which is also consistent with the well-known persistence (stability) of preconceptions (Pine et al. 2001; Shtulman and Valcarcel 2012; Stavy and Tirosh 2015). This is particularly true in the case of interventions not specifically focussed on conceptual change (which in our workshops was not the case for the dinosaur misconception), leading to very little chances to achieve the desired learning progress. It should be noted, however, that the item in its present form does not directly ask about the co-existence of dinosaurs and prehistoric man. This is due to the decision to include many visual items for the target age group and to relate them to the content of the workshop. On the other hand, the association of the item answer with the co-existence conception is plausible, but not entirely unambiguous—a point to be improved in the future.

In a similar vein, our findings showed that the "brute caveman" stereotype is also notably present in our sample, (70–75% "rather yes" or "yes"), which is consistent with the findings of another item about some stereotypical features (Feder 2008) of this kind about prehistoric man (ugly, dirty and violent: 69, 69, 52%, respectively). Surprisingly, most students also saw prehistoric man as clever (52%). Children were quite decided about these points (no opinion \approx 5%), and their beliefs were not changed by the workshops, which had not addressed this stereotype explicitly (the preceding values are the averages over all four measurement times). Even though the students had learned about things like ingenuity (BA workshop) and even artistic expression (PP workshop) of prehistoric man, this alone was not sufficient to change an obviously deep-seated stereotype.

Note that the workshop did not address the dinosaur misconception and the brute caveman stereotype explicitly, nor did they aim to change them. The reason for including an item about these learning difficulties was to answer the question of whether one could replicate earlier findings (prevalence, persistence) for the target group of the study, and thus to know whether they should be included in future extensions of the workshops.

We now discuss the third of the cognitive objectives, learning about the archaeologist as a person and about the work they do (archaeology as a discipline). As for the *person* of an archaeologist, we again find the phenomenon of persistence (stability), for specific features of the "Indiana Jones" stereotype, i.e. that conceptual change without explicitly dedicated learning opportunities (and sometimes even with) is not probable: such stereotypical features were quite widespread, and did not significantly change throughout the workshops (association with a search for precious objects, travel in faraway countries and adventure were present for roughly 2/3 of the students, both before and after the workshops).

As for the *work*, the project was able to produce changes towards a more complete vision of archaeology. These improvements (effect sizes ≈ 0.3 and 0.5 for the components of literature research and fieldwork) are less pronounced than those for several instances of conceptual learning (compare with 5.2.2), but they concern a less tangible domain, less directly linked to the topics of the workshops, and therefore more difficult for students to grasp within the available time (≤ 120 minutes). In these circumstances, the observed changes appear encouraging.

Finally, for an understanding of the scientific value of garbage for archaeology (see Section 2.3), the project was also able to produce an improvement. Again, these improvements correspond to effect sizes (e.g. $d \approx 0.3$ of how many students did not have an opinion at all about this and $d \approx 0.2$ for how garbage can inform us about life in the past) smaller than those of learning about specific contents (5.2.1). But the (archaeological) value of garbage is not an obvious idea to understand, and there could be a strong misconception here for two reasons. First, the notions of garbage and value in everyday experience are by definition opposite to each other, and second, there is the "precious object" idea strongly linked to the "Indiana Jones" stereotype, as discussed above. Thus, while the effects found are not large, they concern conceptual learning, where considerable obstacles could be expected and occurred after the short 90–120-minute duration of the workshops. This is therefore to be interpreted as an encouraging result.

A comment about potential "gendered" perceptions is in order. When asking for different aspects of archaeology as work (Fig. 10), the "adventure" aspect became more present after the

workshops (p = 0.001; $d \approx 0.4$). It is worth noting that an increase could be induced by the contact with a true (female) archaeologist, a presentation of her work, and of course the workshop, instead of viewing an *Indiana Jones* movie. Moreover, even though we found several features of the "Indiana Jones" stereotype in the perceptions of the students, this was not associated with a stereotypical gender bias. An interesting question for future investigations could be to find out whether this is because a female archaeologist had held the workshops.

A fourth main objective of the workshops was to point out how archaeology encompasses the humanities, cultural studies and the natural sciences, and that there are important interactions between all three. One example is conclusions that can be drawn from cave paintings: as cultural objects, about animal diversity, as biological and ecological phenomena. The findings showed a considerable improvement of students' understanding of this aspect, as already discussed above. Another important example of this kind of interactions studied in the V&L project is the discussion regarding climate change and the necessity to know—as a comparison—about historical climates. In this case, archaeology becomes a source of essential information. The findings (reinforcement of correct knowledge, $d \approx 0.7$ –1.1; reduction of incorrect knowledge, $d \approx 0.5$ –0.9) showed a significant and practically relevant improvement on the understanding of this topic.

There is a close link of the facets of "archaeology as discipline" (e.g. its interdisciplinarity) to the topic of "Nature of Science" in science education (McComas 1998; Flick and Lederman 2006).). Even though not addressed explicitly in the present project, this could be a promising component of future development, in particular for aspects like the interplay of hypothesis and evidence (Martins and Silva 2001; Simonyi 2012; Heering and Höttecke 2014), the role of critical thinking and argumentation in view of the multi-faceted and sometimes conflicting nature of evidence (Achinstein 2001; Erduran and Jiménez-Aleixandre 2008; Hitchcock and Verheij 2010; Hodson 2014), and more.

6.3 General Discussion: Project Objectives and Research Questions

Summarising the above findings, one can conclude that the Valentina and Leo workshops had sizeable positive effects on both affective and cognitive variables of the students, in line with the project's objectives and the research questions formulated. Moreover, no difference was found between girls and boys; the workshops appeared suitable for both genders. Effect sizes range from small (for several kinds of conceptual obstacles) to large effects (knowledge about prehistoric life, conceptual learning). Table 3 summarises the results on affective and cognitive variables in view of the project objectives and related research questions. Together, the data support the conclusion that positive effects for most objectives of the project could be achieved.

We now turn to the limitations and future improvements of the study. In some cases, results indicate that individual items should be improved. One item not well understood by the students was a question on animal parts (Fig. 12). It had been included in order to go beyond purely text-based, closed-answer formats, but students did not succeed well in giving answers in this form of graphical representation. These cases deserve further reflection for a future improvement of the methodology, which was not possible within the limitations of the project.

Another limitation is that no statements about long-term effects can be made based on the present study. As Rennie (1994) put it, in view of affective outcomes, a short intervention like the one presented here, "is more likely to raise students' awareness about science [and] scientists", and not so much "to result in a fundamental change of attitude". For cognitive outcomes, we found indeed indications of the "improved development and integration of concepts" stated by Braund and Reiss (2006) as one of the positive impacts of OSLeOs on

stereotypes, etc., given as $\%$ yes), effect sizes are Cohen d values for the pre-post comparisons	
1. Fostering active participation and engagement of students to learn about prehistory and archaeology	Result
I actively participated in the workshop	93%
The activities were interesting for me	91%
Would you like another workshop on prehistory?	%06
other findings:	
The workshop made me want to learn more about the archaeologist's work	83%
I was focused during the workshop	88%
I invested more effort into the workshop than in regular lessons	73%
At home. I'd like to look up in books, internet, etc. to know more about the topics of the workshop 2. Knowledge about prehistoric life	73%
Affective domain and appreciation	
The workshop allowed me to better understand how prehistoric people lived	86%
where/with what resources prehistoric people lived; strongly improved	$\geq 0.9/0.46$
usages of bone awl in prehistoric life (piercing hides and barksewing aid; strongly improved) 3. Conceptual learning about prehistory	$\approx 0.6/0.8$
kinds of represented animals: (owl. mammoth. rhinoceros. peneuin): medium to strongly improved	0.5 - 0.8
"dinosaur" misconcention: strongly present: not changed (but also not addressed in the workshon)	50-55%
"brute caveman" stereotype: strongly present; not changed (but also not addressed in the workshop)	70-75%
prehistoric man as ugly/dirty/violent: not changed (but also not addressed)	69/69/52%
understanding of the scientific value of garbage for archaeology, slightly improved	0.2 - 0.3
4. Learning about archaeologists and archaeology as scientific discipline	
Affective domain and appreciation: The workshop helped me understand how archaeologists work	84%
Cognitive domain:	
Indiana Jones -like stereotypes strongly present (precious objects) faraway countries/adventurery; not changed components of the work of the archaeologist:	/4/08/04%
"scientific research" well represented, literature research, fieldwork stronely under-represented	87/20/18%
literature research, fieldwork improved (in first, "painting", workshop; no further changes in second workshop)	0.31, 0.46
5. Learning about interactions of archaeology and other disciplines (interdisciplinarity)	
kinds of represented animals (cultural objects—animal diversity); strongly improved, see point 3. above	0.5 - 0.8
climate and its changes; strongly improved (enhancement of correct knowledge, reduction of incorrect knowledge)	0.4 - 0.8
6. Link with regular curriculum/teaching	
The workshop helped me to understand the contents of regular lessons	74%

16. Animal parts Make all the links possible between the two columns below

According to you, which parts of the animal could be used? What function each of these elements had?

	To feed themselves
Flesh	To make clothes
Bones	To make tools
Skin	To make jewellery
Tendon	To make blankets
Teeth	To cover tents
Antlers	To make ropes
	To make weapons

Fig. 12 An item which was not well understood by many students

scientific literacy. Whether these effects will lead to a long-term increase of knowledge and understanding remains an open question, in particular in view of the persistence and "resilience" of misconceptions, stereotypes and other non-scientific intuitions (Shtulman and Valcarcel 2012; Stavy and Tirosh 2015).

7 Conclusions and Perspectives

Even though this is *not* a research project in its own right (which would typically require a year or more of instrument development and validation, a pilot study, etc.), we would like to mention that there are interesting and useful perspectives for improvement on the methodological level. Examples are shortening or reformulating some aspects, probing deeper (e.g. for the dinosaur misconception, cf. 5.2.2) or extending others (e.g. an item about the pace of the workshops), or more items about historical, pre-historical and geological time scales, a topic of particular difficulty for students (Dodick and Orion 2006; Catley and Novick 2009). With respect to conceptual learning, a broader inclusion of qualitative methods appears as highly interesting (e.g. making students draw an archaeologist, as an analogy to existing studies about children's drawings of scientists; Painter et al. 2006), but we emphasise again that this was not possible within the objectives and constraints of the project. Second, and central to the project, is the feedback given by participants about Valentina and Leo. As discussed in the preceding section, appreciation and impact of the project on both affective and cognitive levels can be considered encouraging, and it is desirable for it to have a future. What can be concluded about this possible future from the available analysis?

In Fig. 13, we complement the discussion above with the reasons that teachers gave in favour of a generalisation of the Valentina and Leo offer to other classes

2. Directly linked to the school program

7. It is not often that practical activities are found in history (and of quality)

Fig. 13 Why a generalisation to other classes would be desirable (reasons given by teachers)

^{1.} It makes the life of these far-away men and women much more closer and concrete

^{3.} Practical aspect and active participation of the students + entertainment aspect

^{4.} It is concrete and illustrative for the kids

^{5.} Excellent idea. The workshops blend history, creative activities and relational aspects. Cantonal examinations have included this subject

^{6.} It was simply awesome. The teachers do not have the time, budget or material to organise that kind of workshops

(other teacher data will be reported elsewhere). Beyond the practical aspects of links to the curriculum (or official examinations) and the quality of an offer which would otherwise be impossible to carry out at school, teachers most often mention the playful, practical, concrete and "tactile" character of the activities. Moreover, teachers took up several central elements of the workshops in their suggestions for possible extensions, such as the use of tools for the production of jewellery or clothes (such as in the bone awl workshop), and settlements and diet as other essential aspects of the prehistoric life. Finally, there were even suggestions for an extension to other historical periods (e.g. ancient Egypt, medieval times).

In view of a repeated statement about the importance of links to the curriculum and concerning first the literature (Anderson and Zhang 2003; Eshach 2007), and, second, another group of statements about the value of "vision different from school learning" (and related statements about creativity, originality, etc.), one might wonder if these points of view are not contradictory. We see in the Valentina and Leo workshop an example that this is not necessarily the case. Showing creativity, originality, a "vision" for a given topic related to but going beyond the curriculum and regular school teaching is not only possible, but has very promising features, and potential to foster students' engagement and learning.

Even though it was not among the research questions of the project, it is obvious that these activities favour the dialogue between students and the specialist that answers their questions. These exchanges allow for a complementary viewpoint on the things learned in regular classes. The possibility to be active, to touch archaeological objects and to create similar ones allows for a constant and rich exchange between the student and the scientist. An underlying objective of this entire project was to bring the student to develop a critical mind, since this is a key component of the scientific method. It is important that students examine data, and discuss, compare and interpret it. In this way, they are able to question an interpretation if they can argue their point. Archaeology is therefore a discipline that can be used to illustrate scientific thinking in the sense that archaeologists observe facts and interpret them by formulating hypotheses on past lifestyles. The workshops demonstrate this methodology, since the students imitate the gestures and fabrication method of prehistoric man, while being provided with a reference framework of prehistoric knowledge. They are brought to think about and discuss the conclusions that can be then made about this prehistoric man. This experimental method is used in actual archaeological research; it has allowed for numerous subdisciplines to retain certain hypotheses as more plausible, and to understand some prehistoric lifestyles, whether concerning the creation of certain objects (Pétrequin and Pétrequin 2000), the learning processes implied or the transfer of techniques (Roux 2003).

To summarise, it appears that the Valentina and Leo workshops had considerable positive outcomes for enjoyment, engagement, perception of educational value and other affective aspects. It also improved cognitive aspects, such as conceptual learning/change related to prehistory and archaeology, and learning about archaeological research at the intersection of the natural sciences and humanities. These outcomes and the results discussed in the present paper provide a promising basis for further improvement and extension. They were obtained in the framework of a university-school cooperation of archaeology and science education experts and of teachers and school authorities, and of a limited financial support for development, delivery and evaluation of the workshops. As such, the project could serve as a useful example for similar externally funded, cooperative projects in other domains of science education. Acknowledgements The project was supported by Matteo Gios, technical assistant, Marisa Andosilla, secretary, and Eva Gutscher, graphic artist, at the Laboratory of Prehistoric Archaeology and Anthropology at the University of Geneva, and the teachers who hosted the project in their classes: Stefano Croci, Jean-Philippe Hulliger, Nelly Rautenstrauch, Marie-Armelle Dumitrescu, Cédric Schorno, Andrée Maret, Anne Metroz, from school De Livron; Virginie Hübschi-Ley, Eveline Langer, Sarah Pena, Isabelle Friedli, from school Champs-Fréchets; Antonella Pollo, Joëlle Allaman, Marc Rickenbacher, Séverine De Cocatrix, Sandra Cambi, Sylviane Hufschmid from school Ami-Argand.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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