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Inquiry in a Science Museum: Science Museum Educators' Views and Practices

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Abstract: Our study looks into science museum educators' views and their practices about inquiry in non-formal venues, such as NOESIS, Greece. On this ground, we developed an interview protocol to use as a basis in the semi-structured interviews conducted with four science museum educators to cast light on their views about inquiry. In addition, an observation protocol was modified in order to observe their practices when implementing educational programs for school groups. Data analysis showed that in regard to the museum educators' views, they all expressed a slightly different view about inquiry, which was either empirically or intuitively based. They all agreed that inquiry is easier adopted in non-formal settings and argued that students' main gain when they get engaged in inquiry-based activities is the actual involvement they experience. As regards the museum educators' practices, a repertoire of teaching approaches was observed, ranging from a traditional teacher-centered approach to open inquiry. Building on our data, we suggest the development and implementation of a professional development course that will enrich science museum educators' inquiry views and practices and empower them to integrate inquiry-based practices into their own.

Keywords: science museum educators; inquiry; views and practices

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1. Introduction

Current science curricula adopt inquiry as a basic component in their proposals, namely, as a prominent teaching–learning proposal, while at the same time, they place emphasis both on the non-formal aspect of education and on mixed education (a mixture of formal and non-formal education) [1]. The term inquiry refers both to the way scientists work and the activities through which students approach scientific concepts, procedures, and practices [1]. Inquiry in teaching and learning can be distinguished into two broad categories: (a) inquiry as means, namely, inquiry as a teaching approach; and (b) inquiry as ends, namely, inquiry as a series of expected learning outcomes [2]. In the first case, inquiry as a means of learning is realized through inquiry procedures that aim to solve a central problem [3]. In the second case, inquiry as ends, the focus point is on developing students' ability to engage in inquiry and understanding the nature of scientific inquiry [4,5].

Though respective literature highlights the multiple gains of inquiry-based activities, a number of studies point out that employing inquiry in class may be more demanding both for students and teachers and draw a distinctive line between theory and practice [6–8].

As research points out, difficulties in adopting inquiry in class are embedded both in external and internal factors. Bevins et al. [8] report that limited time allocated in teaching, together with curriculum demands and general restrictions applied in the school context, are common obstacles that teachers face at school. A general trend seems to be that inquiry in class is usually a teacher's choice in specific activities that may fit with the curriculum restrictions [8]. In terms of internal factors, the challenges teachers encounter are related both to their weak comprehension of inquiry as a concept and the way they encompass inquiry in their teaching practices. Alake-Tuenter et al. [6] carried out a literature review and verified that these factors actually apply to primary teachers.

Fitzgerald et al. [9] underscore that teachers' views are critical when they are expected to employ inquiry in their teaching practices together with their training on inquiry-based practices [10]. The role of teachers' views and their correlation with the adoption of specific teaching practices has been investigated both for formal [11] and non-formal education [12,13], and results have not always been congruent.

Non-formal learning environments, such as museums, science centers, environmental centers, etc., are challenged to move away from traditional teaching methods and move towards inquiry-based learning practices [14]. Research in the field underscores that it is easier for museums to implement innovative programs that draw on inquiry procedures due to the non-formal and non-evaluative character of education [15]. In these settings, science museum educators are the ones who have been assigned to the educational role of the museums, facilitating visitors' learning and their engagement in learning procedures together with the development of 21st-century skills [16]. They are those who design and implement educational programs and critically shape the museum experience offered to school groups [17,18], together with the teachers who accompany their students when visiting a non-formal education setting [19]. Museum educators' role is quite complex as they are expected to integrate the educational dimension with the special characteristics of non-formal settings [20], taking into consideration visitors' enjoyment, interests, and social interaction [21,22]. From this perspective, it is anything but easy for museum educators to employ all necessary knowledge drawing from current pedagogical, social, and teaching theories when they design and implement educational programs in non-formal learning environments without being properly prepared and supported [23].

Research in the field casts light on the context science museum educators are expected to act. According to Allen and Crowley [14], school trips rarely exploit the unique opportunities for science learning offered in non-formal learning settings, as the learning experiences offered in these places look more like formal learning. The researchers argue that this has to do, among other reasons, with the ways science museum educators conceive and employ models of learning, such as the knowledge transfer model, which usually reflects their own learning experiences at school when teacher-centered approaches were prevailing [24].

From another perspective, current science education approaches, such as inquiry, are not usually part of their training as educators, which usually occurs in the form of discussions with other members of the museum staff [24]. On their part, Anderson, De Cosson, and McIntosh [25] claim that discussions on theoretical perspectives in museum settings are rather confined due perhaps both to long working hours and somehow limited familiarity with theory-driven teaching approaches. On the same line, Patrick [1] asserts that museum educators may have the strong content knowledge and a rather weak theoretical basis to build on their practice. In this direction, King and Tran [26] refer to a professional development course for museum educators that builds on discussion and reflection on the part of the museum educators, both experienced and not, enabling them to hear and talk about relevant research applications and theory on learning and teaching science. According to these researchers, it goes without saying that if non-formal education settings aspire to offer high-level educational experiences to their visitors, they need to pay attention to their educators' learning who provide these experiences.

Karnezou and Zoupidis [27] studied teachers and science museum educators' views about inquiry practices after attending a joined professional development course. Based on their findings, both teachers and science museum educators talked about inquiry, drawing from their empirical experiences, and tried to explain in their own words how they understood this term. As researchers point out, though, those who had attended a postgraduate course on science education shared a better-structured view that bore more resemblances to the scientific one. They also underscore that both the teachers and the science museum educators claimed that inquiry would be easier adopted in a museum than at school, mainly due to time restrictions imposed from the school curriculum.

Research [14] supports the idea that science museum educators would benefit from a community of practice, a concept that draws from the participatory model of learning, an important aspect of inquiry. Working in a community of practice is likely to empower science museum educators to reflect on their own views and practices, discuss with other colleagues, exchange ideas, and utilize this knowledge in order to adopt less didactic, more learner-centered practices. Likewise, Ash, Lombana, and Alcala [28] argue that reflection within a community of practice would support museum educators move from being those who convey information to those who listen, observe and facilitate visitors' learning. Other researchers support that science museum educators' [21] engagement in a guided or open inquiry educational program may affect their perceptions about museum learning and help them perceive learning as a process that entails students' active involvement.

In regard to science museum educators' practices, a rather limited number of studies have actually reported on them [18]. In her study, Tran identified that there are similarities between science teaching at schools and in museums in terms of the discussions held between the museum educator and the students and the way the educational programs were designed in a museum setting. Likewise, Anderson et al. [25] point out that museum educators often employ approaches that seem to have been drawn from the classroom. Research has also revealed that there could be no clear lines between the museum educators' practices. Instead, there were complexities found both in interactions and educators' views which stated the difficulty of studying and categorizing them [18]. Another important finding in Tran's research [18] was the fact that museum educators placed more emphasis on intriguing students and raising their interest in pursuing science rather than on cognitive gains due to the one-off nature of school visits.

In their study, Allen and Crowley [24] studied a number of museum educators in the Carnegie Natural History Museum when they were asked to design a new approach for school visits to the museum. This approach would encompass three guiding principles for inquiry-based learning, namely, learner autonomy, conversation with reflection, and deep investigation. Students would be expected to seek exhibits on their own, interact, and keep records of their observations in a meaningful way for them. Iterative implementation would be employed in order to make educators reflect and discuss with peers sharing ideas and suggestions about the improvement of the initial design. In the end, educators acknowledged that they had made iterative changes in their educational practice, and they reflected on these changes as a community of practice.

Gutwill and Allen [29] report on an activity to support group inquiry in museums. The activity was tested on a number of interactive exhibits and focused on improving two inquiry skills, namely, posing questions and interpreting discoveries. The whole activity was embedded in a juicy question and was co-led both by an adult member of the group, a parent, or a teacher, in families and school groups, respectively, and the museum educator as each of them facilitated distinctive parts of the activity at Exploratorium. The results were quite promising as the targeted inquiry skills in groups were overtly improved.

In a recent study, Tran, Gupta, and Bader [30] presented a professional development program for museum educators. Inquiry into one's practice through reflection was the key point of the program, which could run without bringing in an expert. The museum educators drew on their personal experiences and were engaged in activities and discussions on teaching and learning, integrating research in specific fields such as education, sociology, and psychology. Through their participation in the program, they developed their background in pedagogy and strengthened their reflection skills.

Looking at museum educators' professional development with a broader lens, as non-formal education evolves and becomes better organized, it is vital to comprehend the needs of the professionals in the non-formal education context in relation to the knowledge and skills they need [16]. Changing museum educators' practices is beyond the way they interact with pupils. It encompasses the change in the way they perceive their role as educators and the way they talk about it [16].

Drawing from this literature review on museum educators' views and practices, we can conclude that there is still space for more research in this field, especially regarding science museum educators' views about inquiry and their practices, as they usually act based either on their own school experiences or their intuition. Current research in museum settings focuses mainly on the results and the impact of the educational programs and experiences gained during a school visit to a museum and not on the museum educators' practices [18]. It would be really beneficial to study museum educators' views and practices more thoroughly and deepen our understanding of teaching and learning in museums [25]. In this direction, we studied the views of four science museum educators about inquiry and their practices in the context of two educational programs for school groups at NOESIS, the Science Center and Technology Museum in Thessaloniki, Greece. Following, building on our data, we suggest the development of a professional development course that will both enrich science museum educators' inquiry views and practices and empower them to integrate inquiry-based practices into their own.

2. Method

In our study, we selected the multiple case-study method [31] to study the views and practices of four science museum educators about inquiry. Employing this method of qualitative research enabled us both to look in-depth into their views and practices, taking into consideration the actual setting our subjects act and interact and identify potential differences among them in regards to the way they perceive inquiry and adopt it as a teaching approach when designing and realizing educational programs [31]. As case studies may combine various data collection methods such as interviews, observations, and questionnaires [32], in our study, we took interviews to look into museum educators' views and chose non-participatory observation to study their practices.

The museum educators in our sample had all studied Physics, and their work experience as museum educators at NOESIS ranged from 10 to 20 years. Two out of four also took a postgraduate course on science education. Semi-structured interviews were conducted with each of the educators, as it is recommended in qualitative studies with few participants [33]. The interviews were conducted using a web platform (Zoom) due to the COVID-19 pandemic restrictions.

Due to the limited existing research on museum educators' views about inquiry and their inquiry-based practices, we could not find any interview protocol in the reviewed literature that would match the needs of our research. For that, drawing from our readings, we developed an interview protocol (Appendix A) to use in the interviews and cast light on the science museum educators' views about inquiry. The questions in the interview protocol were closely related to issues that reviewed literature points out, such as the existence of a rather weak theoretical background on museum educators' part (e.g., Do you know any types of inquiry?), the way museum educators are likely to receive training in their workplace (e.g., How did you learn about inquiry?) and the way museum educators perceive students' gains when they get engaged in inquiry-driven activities. The latter is directly linked to museum educators' aims when they realize educational programs in non-formal science education settings (e.g., What are students' gains when they do inquiry?). The museum educators' answers were expected to clarify, on the one hand, the way they comprehend and do inquiry and, on the other, the issues that would be targeted during a professional development course. The sub-questions helped the researchers ask for clarifications or examples in order to specify the interviewees' responses [33]. All interviews were recorded and transcribed.

The three aforementioned issues, namely lack of a solid theoretical background, training, and students' gains, made up the literature-driven categories; our data were sorted out and analyzed, following a qualitative content analysis approach [34,35].

As mentioned previously, the four interviews were carried out remotely on the Zoom platform. Then, drawing from the whole transcribed material, two independent researchers sorted out and analyzed the data in the three literature-driven categories. An approximately

80% consensus was achieved between them. Followingthat the researchers discussed and exchanged views before ending up with one joined perspective they employed in order to work further on their data and draw some conclusions.

In order to observe the museum educators' practices, we modified an existing observation protocol, which is partly presented at the end (Appendix B). It was initially designed and employed during a previous research project [36], which studied teaching practices in class. For the needs of our research, this protocol was modified after being discussed with the research team in order to be employed in non-formal settings. In this direction, there were changes made both in wording and the variables employed. Specifically, the word "teacher" was replaced with "museum educator" since we studied museum educators' views and practices. Further, the variables were reduced in number and focused on museum educators' practices in regard to the teaching approach employed, the way scientific content was addressed, and the verbal interaction with students. The latter is a distinctive feature of cooperative inquiry-based classes, especially in terms of teachers' questioning, which significantly affects classroom discourse [37]. The three aforementioned issues, namely museum educators' teaching approach, scientific content, and verbal interaction with students provided the literature-driven categories our data were sorted out.

Each of these variables/categories encompassed some sub-variables that helped the researchers capture some aspects of the museum educators' practices observed. For example, the variable about the verbal interaction with students included the following sub-variables: The museum educator summarizes the main points of the educational program (educator-centered), inquiry-based outcomes are discussed in plenary (student-centered), and rewards correct answers. These sub-variables were borrowed from the initial version of the observation protocol.

This protocol helped us observe and record the teaching practices of two museum educators. In accordance with the vast majority of qualitative studies which report on practices in a small sample of educators, in our research, we studied the practices of two museum educators as insurmountable restrictions were imposed due to the COVID-19 pandemic. It is our intention to identify any possible correlations between these practices and the museum educators' views we collected in a future study.

We observed two museum educators' practices when they realized an educational program on nanotechnology titled "Nanocosmos: introduction to nanotechnology" and a Tinkering program titled "Scribbling machine" for primary and junior high school groups, respectively, at NOESIS. In regard to the program on nanotechnology, it lasted an hour and comprised a short introduction that addressed basic concepts related to nanotechnology, such as nanoworld, hydrophobic and hydrophylic materials, and nanostructure. Following, students in groups were assigned a number of simple experiments on hydrophobic and hydrophylic materials, filled in a worksheet, and watched some videos related to these materials. The Tinkering program had two distinctive parts. During the first part, students were given a number of parts of an electrical circuit (lamps, cables, switches, motors, buzzers, dimmers, etc.) in turn and were asked to perform a different task each time on their own, drawing from what they had learned at school, e.g., connect the parts in parallel and in series. These tasks were some sort of a prerequisite introduction for students in order to manage the task that would be next assigned to them. In the second part of the workshop, the students were asked to work in groups and build a scribbling machine which is a motorized construction that moves in unusual ways and leaves a mark to trace its path. The students would choose on their own the materials they would use. They were shown a prototype in order to get an idea about the machine they were assigned to build.

Two independent researchers watched as passive participants [38] the two educational programs, and each one filled in the observation protocol for each program without interacting with other people. In each protocol, they wrote down the frequency of the observed practices (sub-variables) in each of the three variables employed, namely, the teaching method, the way scientific content was addressed, and the verbal interaction between the museum educator and the students. For that, the researchers used a scale from 1 to 3 (main practice = 3, sometimes observed = 2, and rarely observed = 1) and provided a quotation that identified the museum educator's practice (Appendix B). There was approximately an 80% consensus attained between the individual protocols. Following, the researchers discussed their notes and exchanged views in order to come up with one protocol which drew from the two individually filled-in ones. During the research, both in interviews and observations, all necessary actions were taken to preserve the rights of the participants as specified by the Helsinki Declaration.

3. Results

3.1. Views

In regard to museum educators' views, the science museum educators talked about inquiry, drawing from their work experience rather than their actual knowledge about inquiry. Therefore, their responses were slightly different, and they tried to explain in their own words how they comprehended the term.

> *" ... it is basically a process, during which when you realize an educational program, you try to intrigue students with various means and hands-on activities to find out more information about the subject matter you want to talk about ... "*
>
> *(museum educator 4)*

> *" ... it is a way to approach science education. It has certain characteristics, which have to be employed during the activity. Certain characteristics and steps which you build the lesson plan on. This is how I understand inquiry."*
>
> *(museum educator 3)*

In regard to the types of inquiry, almost all of them said they could not distinguish any.

> *" ... personally, I have not studied anything in specific but I suppose there has to be more than one way to do inquiry."*
>
> *(museum educator 1)*

> *" ... to be honest, I have not been able to enrich my theoretical knowledge in depth, as my work experience is restrained on a more practical basis all these years at NOESIS."*
>
> *(museum educator 2)*

except from one who set a couple of examples:

> *" ... I think inquiry can be approached in terms of a discussion or a project ... personally, I think even discovery can be perceived as a type of inquiry"*
>
> *(museum educator 4)*

They all agreed, however, that inquiry is easier adopted in non-formal settings than at school where time restrictions, due to curriculum requirements, apply.

> *" ... it is easier for us at NOESIS to do inquiry, as there are no deadlines, no content to be covered ... "*
>
> *(museum educator 2)*

> *" ... I think inquiry is not suited for formal education—teachers do not want it there because they have no spare time ... "*
>
> *(museum educator 4)*

> *" ... by default, non-formal education settings are the places for students to see and experience things that they have never heard about at school. From our part, we have more freedom to employ means and processes ... "*
>
> *(museum educator 3)*

When they were asked whether inquiry could be adopted specifically in their workplace, at NOESIS, when designing an educational program, the museum educators' answers slightly differed.

" ... the way things are done at NOESIS make it feasible to do inquiry, building on critical thinking skills and cooperation ... "

(museum educator 2)

" ... it is rather difficult and quite challenging to make it (inquiry) in an hour—that's how long our educational programs usually last."

(museum educator 3)

Another common view they shared was that when students are engaged in inquiry-based activities, their main gain is the active involvement they experience.

" ... the students do not simply watch, they do stuff on their own and they are thrilled about it ... "

(museum educator 1)

" ... they improve their attitude towards the subject they study, it becomes familiar, and it (inquiry) makes it easier for them to pose questions ... "

(museum educator 4)

All four museum educators identified, in their own words, the transmission of knowledge as the approach opposite to inquiry.

" ... the do this, take that ... the totally guided one ... "

(museum educator 1)

" ... the traditional one, where the learner simply watches a presentation."

(museum educator 3)

With respect to the way they learned about inquiry, they all highlighted the importance of their work experience.

" ... from my work experience and my working with other educators at NOESIS ... "

(museum educator 1)

" ... during my involvement with educational programs and science education ... "

(museum educator 3)

One of the museum educators also stressed the importance of museum educators' professional development in terms of being addressed to new learning approaches and talked about their experience when they participated in a course together with teachers during an EU-funded program.

Two of the educators also commented on their postgraduate studies on science didactics.

" ... I know some things about inquiry based on what I read during my post graduate studies"

(museum educator 3)

" ... it (inquiry) was a theoretical part of my (post graduate) studies ... "

(museum educator 4)

The following Table 1 presents the responses provided by the museum educators.

Table 1. Science museum educators' views about inquiry.

Categories	Questions	Museum Educator 1	Museum Educator 2	Museum Educator 3	Museum Educator 4
Theoretical background	Do you know inquiry?	Limited knowledge	Empirical knowledge	Intuitional knowledge	Intuitional and empirical knowledge
	Do you know any types of inquiry?	Limited, intuitional knowledge	Lack of theoretical knowledge	Limited, intuitional knowledge	Limited knowledge (an assigned project, discovery)
	Can inquiry be adopted in class?	Difficult because of school restrictions	Difficult because of school restrictions	Difficult because of school restrictions	Difficult because of school restrictions, teachers' views, and attitudes
Training	Which is the opposite of inquiry?	Guided	Knowledge transfer	Traditional model	Knowledge transfer
	Can inquiry be adopted when designing a program in a science center?	It can be done	It can be done	It can be done	It can be done (and it should)
	How easy is it to do inquiry at NOESIS?	Very easy	Very easy	Not easy at all (time restrictions)	Quite easy
	How did you learn about inquiry?	Work experience and discussion with colleagues	Work experience and participation in an EU-funded program	Work experience and studies	Work experience and studies
Students' gain	What is students' gain when they do inquiry?	Active participation, cooperation	Active participation, cooperation, critical thinking skills	Active participation, experimental and critical thinking skills, understanding of phenomena and procedures	Attitude change, creation of motives

3.2. Practices

3.2.1. Practices Observed in the "Nanocosmos: Introduction to Nanotechnology" Educational Program

As mentioned before, the two researchers observed the educational program on nanotechnology, and a consensus observation protocol was delivered.

With respect to the teaching approach employed, the museum educator seems to favor a guided inquiry approach in the second part of the program, as they handed out various materials to the students, asking them to observe and write down the way materials react when contact water.

"Try to figure out the shape of the waterdrop when it contacts glass, or a coffee filter"

As the program continued, the educator asked students to observe and compare the size and the shape of the waterdrops on the materials they were given and then write down their observations filling in a worksheet, while they were not assigned to design and perform experiments on their own at any time.

"What do we have here? Write down everything you see!"

As we can see, in regard to the way the museum educator addresses scientific content, in the first part of the program, they ask students to describe scientific terms, and then they rephrase the answers.

"Hydroliphic/hydrophobic surfaces. Any ideas what are they?"

Regarding the transformation of the scientific content, the educator either gave examples from everyday life or used a video to make things explicit.

«You saw how the water drop reacts when it falls on a leaf of cabbage. What happens with water proof clothes?»

In regard to the verbal interaction between the museum educator and the students during the program, both educator-centered and student-centered interactions were observed mainly in parts A and B of the program, respectively. In specific, when educator-centered interaction prevailed, in part A the educator posed closed questions to the students the museum educator:

"What do you notice? Is it a hydrophylic or a hydrophobic material?"

While in part B, they summarized the main points of the program:

"You all saw the differences between ordinary and nano-materials. Actually, all the groups said what I expected to hear"

When student-centered interaction was in the foreground, the educator posed open questions to students, asking them to justify their answers, and write down their observations,

"What have you written about the wooden surface? . . . Why is that? . . . I want someone to write down everything you share within your group."

and discuss their outcomes in plenary

"Let's talk about what you saw when you dropped water on these materials. Who wants to start?"

Finally, the museum educator expressed their satisfaction every time the students gave correct answers:

"I'm really satisfied! Well done!"

The following Table 2 presents the data gathered including the mean of the frequency of the practices and a relevant quotation:

Table 2. Science museum educator's practices in the "Nanocosmos: introduction to nanotechnology" Educational Program.

Variables	Implementation / Sub-Variables/Inquiry-Driven Practices	MnF	Quotation
Teaching approach	The museum educator adopts inquiry and encourages pupils to do inquiry on a specific subject.	2	"Try to figure out the shape of the waterdrop when it contacts glass, or a coffee filter"
	The pupils design and perform trials and experiments on their own.	1	-
	The pupils perform predesigned trials and experiments or conduct some research.	2	"What do we have here? Write down everything you see!"
Scientific content	The museum educator addresses scientific content by introducing terms and concepts.	2	"Hydrophylic and hydrophobic surfaces. Any ideas what are they?"
	The museum educator transforms the scientific content.	3	"You saw how the water drop reacts when it falls on a leaf of cabbage. What happens when it falls on water proof clothes?"
Verbal interaction	Educator-centered interaction (the museum educator poses closed questions and summarizes the main points of the program).	3 (part B)	"You all saw the differences between ordinary and nano materials. Actually, all the groups said what I expected to hear"
	Student-centered interaction (the museum educator poses open questions, and inquiry-based outcomes are discussed in plenary).	2 (part B)	"What have you written about the wooden surface? . . . Why is that? . . . I want someone to write down everything you share within your group."
	Rewarding of correct answers.	2	"I'm really satisfied! Well done!"

3.2.2. Practices Observed in the "Scribbling Machine" Educational Program

As described before, the Tinkering program had two distinctive parts. In the first one (part A), the museum educator handed out to students a number of parts of an electrical circuit, in turn, asking them to perform a different task each time, while in the second part (part B), the students were assigned to build a scribbling machine choosing the materials on their own.

In terms of the teaching approach employed, in the first part, the museum educator handed out specific parts of an electric circuit, in turn, and asked students to connect them in series and then in parallel, checking out the way the lamps lit each time.

"Take this stuff and make your lamp lit . . . now use this extra wire and try out another connection . . . "

In the second part of the program, the museum educator encouraged students to get engaged in designing and constructing a scribbling machine by presenting them with a prototype:

" . . . take a look at the model and get some ideas to build your own scribbling machine"

After that, the students were left alone to pick up the materials they would use, design their own scribbling machine and build it, trying to make it work by adjusting a motor and a battery.

"OK, now you can get the materials you want, (try to be reasonable and do not be greedy!), co-design your machine within your group and build it! I'll be of help, once you ask me to."

In the first part of the Tinkering program, the museum educator addressed the scientific content related to electrical circuits:

"Do you know what is the electric current? It's literally the flow of electrons within wires"

using examples from everyday life in order to clarify concepts usually being mixed up by students

"Remember, what happens at our home? We turn on the switch and we actually close the circuit."

With respect to the verbal interaction between the educator and the students, we noticed that mainly in the first part of the program, the educator chose an educator-centered interaction and addressed closed questions to students:

"I want to talk as little as possible. The two lamps light more or less when they are (i) in series (ii) in parallel?"

and summarized the main points of the program themselves.

In the second part of the program, however, the educator employed open questions, placing students in the foreground and trying to engage them in a discussion:

"Your classmates made another connection over here! What did they do?"

Finally, the museum educator expressed their satisfaction every time the students successfully performed the task assigned to them in the first part of the program:

"You did it! You lit both lamps!"

The museum educator's practices, the frequency they were observed and a characteristic quotation, when detected, are shown in the following Table 3.

Table 3. Science museum educator's practices in the "Scribbling machine" Educational Program.

Variables	Implementation / Sub-Variables/Inquiry-Driven Practices	MnF	Quotation
Teaching approach	The museum educator adopts inquiry and encourages pupils to do inquiry on a specific subject.	3 (part B)	" . . . take a look at the model and get some ideas to build your own scribbling machine"
	The pupils design and perform trials and experiments on their own.	3 (part B)	"OK, now you can get the materials you want, (try to be reasonable and do not be greedy!), design your machine within your group and build it! I'll be of help, once you ask me to."
	The pupils perform predesigned trials and experiments or conduct some research.	2 (part A)	"Take this stuff and make your lamp lit . . . now use this extra wire and try out another connection . . . "
Scientific content	The museum educator addresses scientific content by introducing terms and concepts.	2 (part A)	"Do you know what is the electric current? It's literally the flow of electrons within wires"
	The museum educator transforms the scientific content.	2	"Remember, what happens at our home? We turn on the switch and we actually close the circuit."
Verbal interaction	Educator-centered interaction (the museum educator poses closed questions and summarizes the main points of the program).	2 (part A)	"I want to talk as little as possible. The two lamps light more or less when they are i) in series ii) in parallel?"
	Student-centered interaction (the museum educator poses open questions, and inquiry-based outcomes are discussed in plenary).	1	"Your classmates made another connection on their machine! What did they do?"
	Rewarding of correct answers.	2 (part A)	"You did it! You lit both lamps!"

4. Discussion

In our study, we found that all the educators underlined the fact that inquiry-based practices can be easier adopted in non-formal settings than at school because of restrictions that apply in the school context, as other researchers argued [15]. Yet, when they were specifically asked how easy it was for them to make inquiries at their workplace, one of them expressed their reservations, referring to time restrictions that may prevent them from adopting inquiry-based practices. While discussing the same question, two of the science museum educators mentioned that they would consider making changes related both to the teaching approach and the content after receiving feedback from colleagues. This procedure seems to be closely linked to the notion of a community of practice that a number of researchers [14,24,28] address as the proper context for science museum educators' professional development and inquiry-based practices. The truth is that none of the museum educators in our study referred explicitly or seemed to be familiar with the terms "community of practice" and "iterative implementation" [24], though they seemed to value processes that usually take place in a community of practice such as discussion and sharing ideas with colleagues. A professional development course that would introduce them to the notion of a community of practice would empower them to integrate discussion and reflection with colleagues in their daily routine instead of relying mostly on intuition and work experience.

All the interviewees also claimed that students' active engagement is a critical consideration when they design and realize an educational program. This view seems to be on the same wavelength with other studies, which underscore that once museum educators perceive learning as a process that entails students' active involvement [21], their role becomes of great importance as they are expected to facilitate students' involvement in inquiry procedures [17]. This is likely to be the case in our research since the museum educators shared a student-centered approach, though they did not seem to have a theoretically based knowledge about inquiry [1].

With respect to museum educators' practices, we noticed that the science museum educators' teaching approach was moving along a continuum, from a rather teacher-centered approach to a guided inquiry-based one, in the program about nanotechnology and from a guided inquiry one to a more open-like type of inquiry in the Tinkering program. In both cases, this transition was observed between the distinctive parts of the programs. More specifically, we noticed that this change seemed to be content driven and was aligned with the activities assigned to the students. The fact that there were some elements of open inquiry observed, such as student-museum educator verbal interactions and the way scientific content was occasionally addressed, is likely to be due both to time restrictions applied, following a rather tight daily program with school group reservations together with some conceptual restrictions that would come up related to students' previous knowledge.

In both implementations, the museum educators urged the students with closed questions to present either their outcomes or constructions in plenary. Both the presentation of outcomes and the discussion with others are indicators of an inquiry-based approach [24]. However, both at the end of the nanotechnology program and the first part of the Tinkering program, those who summarized the program and the conclusions driven by the students were primarily the museum educators instead of the students themselves. Either because of time restrictions in the Tinkering program or the new terms being addressed in the nanotechnology program, namely conceptual restrictions, both museum educators seemed to be adopting a teacher-centered approach. Based on the frequency and the type of practices observed, it seems that both museum educators drew from a repertoire of teaching approaches. The latter cannot be significantly categorized as teacher-centered or inquiry-driven, as there were subtle differentiations observed that could be interpreted considering the aforementioned reasons. These assumptions seem to match Tran's findings [18] about the complexities that characterize museum educators' interactions when implementing educational programs in non-formal settings.

Taking into consideration the above, it seems that the museum educators we studied shared some views and employed a number of practices that were close to an inquiry-based approach. The fact, though, that they found it difficult to talk about inquiry drawing from a theoretical basis highlights the necessity for science museum educators' training. It is highly likely that time restrictions and hectic working hours mentioned by other researchers [25] may also apply in this case and make opportunities for theoretically driven discussions among museum educators not realistic.

Evidently, if science museums and non-formal science education settings, in general, aspire to offer high-quality services, museum educators' professional development should become a priority for them [26].

5. Conclusions and Implications

In our study, we found that the science museum educators talked about inquiry, drawing from their work experience rather than their actual knowledge about inquiry, and tried to explain in their own words how they comprehend the term. In addition, no one could identify or name a type of inquiry when asked. This fact seems to strengthen further the lack of theoretical background on inquiry on the museum educators' part.

All the educators in our study consider that it is easier to employ inquiry in non-formal than formal settings, mainly because of the time constraints posed by the curriculum. Still, some of them recognize that similar problems maybe apply in non-formal settings, as well. They also all consider the active involvement of visitors to be a key element of the inquiry approach.

In relation to the practices, and despite the lack of theoretical background, museum educators apply practices from the entire spectrum of inquiry (teacher-centered, guided, open) guided mainly by content-driven difficulties. Open inquiry cases, in specific, were identified in terms of prompting students to summarize their findings or demonstrate their constructions.

Given the recognition and value attributed to non-formal education currently, these findings point to the need for institutionally based training for museum educators, which would address non-formal science education issues, as well as current science education trends for these settings, such as inquiry and constructivist teaching approaches. Building on that, we propose a professional development course that draws both from professional development proposals for teachers [39] and museum educators [26,28].

Initially, a short yet dense introduction would address the main theoretical issues, namely, the definition and the different cases of inquiry [40], as well as one of the models of applying inquiry in the educational practice, such as 5-E [41]. In the second phase, it would be useful to deliver to the trainees some key examples of inquiry teaching, e.g., the control of variables method [39], in order to study, transform, apply, and discuss it with their trainers. Following, they would be asked to design in groups a similar example that would be part of an educational program realized in a non-formal learning setting. These examples will then be discussed in plenary and corrected if necessary. These processes will help museum educators move beyond the traditional teaching methods, which they probably taught themselves [14] to some extent, and adopt more student-centered approaches. Yet, it is well known that comprehending inquiry methods is not enough to persuade teachers, as well as museum educators, to integrate them into their teaching practices [39]. It is equally necessary to focus on the differences between these inquiry methods and increase teachers' and museum educators' self-confidence to adopt innovative and less structured approaches when teaching science.

Reflection and discussion would be applied to empower educators to get engaged in collaborative processes [26] that are typical in a community of practice [28]. In our case, both reflective and metacognitive discussions on the similarities and differences of various kinds of inquiry methods, as well as on the importance of understanding the reasoning behind these scientific methods, would support this effort [39].

In the current research, we focused on the science museum educators of the biggest science center in Greece. We focused on some actually important issues that are likely to play a significant role in the science education field in the future, as major changes are due. Though the specific study is a small-scale one, we believe that it can contribute to the relatively unknown field of science museum educators' views and inquiry-based practices in terms of providing some useful insight into the conditions that apply in the museum sector for the specific group of museum professionals together with a professional development proposal that will enrich the existing field.

Undoubtedly, further research is in need on museum educators' views and practices, which would provide enlightening information on the potential relationship between them, enable us to generalize drawing from extensive data, and develop meaningful content for museum educators in terms of their professional development targeting from a broader-perspective high-quality museum experience for museum visitors.

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Appendix A

Table A1. Interview protocol.

1	Do you know inquiry?
2	Do you know any types of inquiry?
3	Can inquiry be adopted in class?
4	Can inquiry be adopted when designing a program in a science center?
5	How easy is it to do inquiry at NOESIS?
6	What is students' gain when they do inquiry?
7	Which is the opposite of inquiry?
8	How did you learn about inquiry?

Appendix B

Table A2. Observation protocol.

Variables	**Implementation** / **Sub-Variables/Inquiry-Driven Practices**	**Frequency** **3: Main Practice** **2: Sometimes Observed** **1: Rarely Observed**	**Quotation**
Teaching approach	The museum educator adopts inquiry and encourages pupils to do inquiry on a specific subject.		
	The pupils design and perform trials and experiments on their own.		
	The pupils perform predesigned trials and experiments or conduct some research.		
Scientific content	The museum educator addresses scientific content by introducing terms and concepts.		
	The museum educator transforms the scientific content.		
Verbal interaction	Educator-centered interaction (the museum educator poses closed questions and summarizes the main points of the program).		
	Student-centered interaction (the museum educator poses open questions, and inquiry-based outcomes are discussed in plenary).		
	Rewarding of correct answers.		

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