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Obstacles and challenges identified by practitioners of non-formal science learning activities in Europe

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ABSTRACT

Despite the increasing demand for non-formal science learning activities, few studies report on practitioners' perspectives and experiences with designing and implementing such activities worldwide. This paper focuses on their challenges by drawing upon twenty-two interviews with practitioners involved in diverse science learning activities in various non-formal settings in seven European countries. By including diverse activities and settings, this study contributes to the existing knowledge base, addresses the aforementioned gap in the literature, and informs future practices. Our findings suggest that despite the existing and celebrated diversity, practitioners face similar challenges related to (a) the activities' organisation and management, (b) the competencies required to run such activities, and (c) the attitudes held by the parties involved in them. Direct interview quotes exemplify each theme, further pinpointing the interconnection of multiple factors that inform the organisation and implementation of non-formal science learning activities. The findings allowed for a deeper understanding of challenges reported in the literature and shed light on the challenges voiced by the practitioners including the multiple competencies required and the workload. We conclude with a discussion foregrounding the need to build a knowledge base of shared practices in the field of non-formal science learning.

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1. Introduction

The ongoing global demand for STEM-related activities (Science, Technology, Engineering and Mathematics) has resulted in the increasing recognition of the value of non-formal science learning (Bevan & Dillon, 2010; Moore et al., 2020). New learning

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opportunities and practices have emerged in various non-formal and informal learning contexts worldwide such as museums, libraries, Fabrication Laboratories (Fab Labs) and coding clubs (e.g. Einarsson & Hertzum, 2020; Milara et al., 2020; Pitkänen et al., 2020).

During the past decade, a number of studies have explored non-formal science learning activities, reporting mostly success stories without reflecting upon the failures/problems encountered by the practitioners in the field (Norouzi et al., 2019). There are relatively limited studies reporting on the concerns, lessons learned, and challenges that practitioners face (Koh & Abbas, 2015; Norouzi et al., 2019; Smith et al., 2016), which, even when conducted, report on a small sample of practitioners either running a particular type of activity (i.e. makerspaces) or working at a specific geographical location. With an aim of evaluating either a particular science learning activity (i.e. digital fabrication, making) or one specific group of practitioners such as teachers or FabLab instructors (Milara et al., 2020; Pitkänen et al., 2020), these studies fail to acknowledge the diversity existing across the field of non-formal science learning (Norouzi et al., 2019). Moreover, as new technologies are becoming increasingly integrated into non-formal science learning activities, a number of studies have highlighted the potential of these technologies to support science learning, leaving the challenges that these technologies might present for the practitioners largely understudied (Smith et al., 2016). At the same time, these studies have treated practitioners more as technology experts rather than as educators (Pitkänen et al., 2019; Smith et al., 2016).

To this day, research on the challenges practitioners encounter while conducting non-formal science learning activities is very limited. The study presented in this paper acknowledges the field's diversity, both in terms of the activities and those involved in them, and addresses the practitioners, their perspectives, and concerns by examining the obstacles and challenges they encounter when designing and running non-formal science learning activities. Although the terms non-formal and informal learning have been used interchangeably in the literature (Colardyn, 2002), we use the term *non-formal* in this study to refer to learning in the framework of planned and structured activities beyond school settings (Eshach, 2007), to which learners' participation is intrinsic and mediated by an educator or facilitator, who we refer to as *practitioners*.

For this study, we collected and analysed interview data from twenty-two practitioners working in seven European countries. By including diverse types of science learning activities across Europe, our aim is to gain a more holistic understanding of the field of non-formal science learning activities and further identify shared obstacles and challenges across the field and across such activities. In our view, it is essential to explore the challenges that the practitioners face as they potentially affect and shape the participants' learning experience and outcomes. The more we learn about the challenges that different actors encounter, the more we contribute to strengthening the potential of non-formal science learning activities; by exploring how to overcome the challenges, we can facilitate the practitioners in their everyday practices.

2. Practitioners' challenges: related research

When going through the relevant research, three main axes seem to emerge in relation to the challenges faced by the practitioners: (a) challenges relevant to the resources available, such as funding and venue of the activities, (b) challenges relevant to the actors involved, such as staff availability and training, and the attitudes of the public, and (c) the content and design of the activities. In this review, we investigated the relevant studies and identified these challenges, which are discussed in detail below:

2.1. Cost, budget, and sustainable funding

One of the most frequently mentioned challenges faced by the practitioners was the lack of financial resources and sustainable funding. Non-formal science learning initiatives became often possible through grant-funded opportunities (i.e. Falk et al., 2012) whose time-limited financial support challenged their long-term sustainability. Those budget constraints in turn challenged further the frequency of those activities, the purchase of expensive equipment often used in informal and non-formal science learning activities, and the number and payroll for permanent or extra staff (Abbas & Koh, 2015; Slatter & Howard, 2013).

2.2. Staff and training

Running non-formal and informal science learning activities requires a ‘deep understanding of the subject matter and appropriate pedagogical practices, knowledge of and experience with appropriate materials and equipment, and sufficient self-efficacy to implement unfamiliar curriculum and navigate unanticipated problems’ (Hira et al., 2014, p. 1679). This imposes several challenges linked to finding the appropriate practitioners to run them (Bar-El & Worsley, 2019; Hira et al., 2014). Additionally, as these activities involve the use of specific tools, especially the use of technology, practitioners often found challenging the lack in their self-efficacy, familiarity, and confidence in using these tools effectively (Bar-El & Worsley, 2019).

2.3. Educational design and implementation

The educational design of the non-formal science learning activities appeared to be challenging, particularly when technology is implemented. This challenge is directly interconnected with the aforementioned skills, experience, and knowledge required by the practitioners. For example, practitioners found it challenging to manage digital fabrication technologies and design materials (Smith et al., 2016) and balance between different modes of teaching without proper pedagogical training (Pitkänen et al., 2020). Additionally, they often either struggled with the design of ill-structured, open-ended projects that include too much content for participants who have limited skills and time (Pitkänen et al., 2019) or with activities that focus too heavily on skills related to the use of the tools and technologies (Einarsson & Hertzum, 2020).

2.4. Space, access, and accessibility

Many of the non-formal learning activities take place in spaces that are ‘special’ or ‘separate’ from the rest of the organisation. This lack of a dedicated space often resulted in limiting the activities' frequency (Abbas & Koh, 2015) and the degree of accessibility by the community members/participants. Not having a fixed, widely accessible space limited further the opportunities for appropriation of the space by the community members in order to 'make it their own' and reinforce the sense of a community (Einarsson & Hertzum, 2020). This is often further intensified due to limited funding and limited personnel, which in turn created an additional challenge both in terms of participation and accessibility with the space being only open and available to the community/participants during a limited number of hours (Abbas & Koh, 2015).

2.5. Attitudes and resistance to change

Another obstacle is the fragmented nature of the community of practitioners, and the lack of a united front among the participants, the educators/practitioners, and the organisations involved in non-formal science learning activities (Falk et al., 2012). This resistance to change is found to be a challenge both for those working and those participating and thus, extends to the wider community (Slatter & Howard, 2013), including for instance the participants' parents (Iivari et al., 2018; Norouzi et al., 2019). This fragmented nature hinders the wider acceptance of the learning potential and adoption of non-formal science learning practices, especially by formal learning stakeholders who might display negative attitudes and subsequent resistance towards non-formal science learning (Milara et al., 2020; Peppler & Bender, 2013; Pitkänen et al., 2020).

3. Methodology

In this paper, we draw upon data collected in the framework of the COMnPLAY SCIENCE project, financed by Horizon 2020 for three years to investigate non-formal playful science learning activities and identify best practices across Europe. We collected data from practitioners involved in the organisation and facilitation of diverse non-formal science learning activities in ten countries. These practitioners were selected based on their experience in the field, following the approach of purposive sampling (Patton, 2002) (Table 1); the project partners used their expertise to select a sample representative of a wide range of loci and modes of coding, making, and playful activities, with a diverse focus, aiming at reflecting the diversity of the non-formal science learning field.

In this paper, we draw upon data from semi-structured interviews with twenty-two non-formal science education practitioners representing seven European countries (Table 1). Approximately 40–60 minute long interviews were conducted, either face to face or online, following a predefined interview protocol including questions on the format of the activities, the skills required, and any challenges encountered (Appendix I). Through the interview questions, we allowed practitioners to talk at length about their experiences, unpacking incidents that may have frustrated or challenged them. Interviews were audio-recorded, translated to English and transcribed in late 2018.

3.1. Data analysis

In the first phase of the analysis, we identified all quotes in which practitioners referred to problems and challenges they encountered. Although we provided the space for the interviewees to discuss potential challenges through a dedicated interview question ('What are

Table 1. Interviews held by each country.

Country	Interviewees	Context of the activities
Finland	3	• Informal robotics and electronics activities in an out-of-school club. • Informal and non-formal digital fabrication activities in a fab lab. • Non-curriculum-based activities in a school makerspace (design, making and repairing activities, as well as a Robotics team).
Greece	2	• Inquiry-based non-formal activities taking place in a natural history museum or at school. • Many of the projects based on the school curriculum. • Project-based learning at school combining various school subjects (informatics, physics, etc.) used in place of using the schoolbook to have a 'lesson'
Malta	3	• Organisation of Science Fairs and workshops for children • Digital game-based learning workshops. • Science learning through games, workshops and exhibitions in science fairs (digital games development and research).
Netherlands	2	• Non-formal science, technology and design learning workshops for children aged 4–12 at a redesigned old factory building, or eventually in the classroom. • Instructors and volunteers led but focus on discovery-learning. • Non-formal and online programming sessions based on BBC micro: bits for children aged 6–12. • Self-led learning from home or eventually from school.
Norway	2	• Non-formal/informal programming workshops for young people visiting the university's premises. • Activities based on software Scratch and hardware Arduino. • Instructors were university students, paid to run the activities.
Spain	2	• Non-formal science activities for young people (5–12 and 17–21) including scientific experiments, programming and robotics. • Non-curriculum-based activities at hospitals and the local University (summer camps). • Volunteer-led activities.
UK	8	• Non formal sessions in different programming languages (Scratch, Python, HTML/CSS, Minecraft) and on hardware (ie., BBC micro: bits) for young people (aged 7–17) at a science museum. • Volunteer-led. • Focus on self-led learning.
Total	22	

the main difficulties/issues/challenges you face?'), we also identified other instances throughout the interviews in which the practitioners referred to problems or challenges when elaborating, for example, on the learning outcomes or the process of an activity.

In the second phase, the identified data excerpts were coded through Thematic Analysis to allow any categories to emerge from the data (Braun & Clarke, 2006; Clarke et al., 2015; Ezzy, 2002). Two researchers were mainly involved in the two cycles of coding with multiple iterations, comparisons, refinements, and revisions until reaching a dialogical intersubjectivity (Gillespier & Cornish, 2010; Saldaña, 2016). Specifically, during the first cycle of coding, we took an exploratory approach and applied verbatim coding by annotating participants' spoken words, while also applying two or more different codes to the same datum, or passage in the transcripts (Saldaña, 2016). This enabled us to examine any potential links among the codes and categories that emerged. For the second cycle, we applied pattern coding which 'develops the 'meta code' – the category label that identifies similarly coded data' (Saldaña, 2016, p. 235), organising the dataset by reducing the number of categories, themes and concepts developed in the first cycle of analysis (Miles et al., 2014). We then applied Focused Coding – that is, categorising the coded data 'based on their thematic or conceptual similarity' (Saldaña, 2016, p. 235), indicating relationships among the main categories. After several rounds of iterations and discussions among the two main coders to reach a consensus, a final coding scheme was formed (Appendix II).

Additionally, to check the validity of our coding scheme, we invited two additional team members to code thirteen randomly selected interview quotes using the scheme that had emerged. These quotes represented approximately 10% of the total data that were eventually coded according to our coding scheme (see also O'Connor & Joffe, 2020). The quotes were rich in meaning and allowed for the identification of multiple codes, thus allowing us to examine the validity of a wide range of codes and categories. The inter-rater agreement was estimated at 96 present which is a satisfactory level of agreement (Campbell et al., 2013). To present our findings in the following section, we quote direct excerpts from the interviews and cite their ID code consisting of the code of the case (e.g. D2) and the number of the excerpt (e.g. 03).

4. Findings

Three overarching themes were identified as challenging in practitioners' interviews related to (a) the organisational and management aspects of the activities, (b) the competencies required by the practitioners, and (c) the attitudes of parties involved in the activities including parents, participants, and teachers. Each theme entails several subcategories.

4.1. Challenges concerning the organisation and management of the activities

In this section, we discuss all the challenges related to the organisation and management of the activities, such as the number of students participating in the activity, time constraints relevant to the duration and frequency of the activities, coordination, management of the staff, and the availability of resources. These challenges do not involve the learning goals and process of the activities, but they seem to impact them directly and limit their learning potential.

4.1.1. Participants

The varied background of the participants in terms of age, skills, knowledge, and experience and the difficulty for practitioners to know the participants' background well in advance was the second most cited theme by the interviewees, identified in six cases ('the uncertainty in the conditions of the workshop, the number of participants, their ages and their background' (F02-12). Knowing the number and the participants' background, needs, and interests in advance would allow practitioners to prepare better and design activities tailored to the participants' interests and profiles.

This uncertainty becomes even more challenging when practitioners run the activities with school classes, which, apart from being large groups, are also very diverse in their backgrounds and practices ('when you have children […] from a school from one side of [city], they can do other things than children from another side of [city] because not every school does their thing in the same way. And the kind of children that are in the schools are different, so you never know which children you'll get' #D2-03).

4.1.2. Time constraints

The time constraints of the activities are triggering several challenges for the practitioners. As most of them were organised either as one-time events or for a limited time, they required both practitioners and participants to follow 'a very tight pace of the activity' during which 'they have to switch from one step to the other at the correct time' (B2-09). This rigid structure of the activities, with practitioners following specific steps at a specific time, often restricted the time available for the participants to experiment, complete their task and showcase their progress during the final stages of the activity (E1-04; B2-08). Concomitantly, the limited duration of each activity restricts the time practitioners have availale to facilitate all participants ('time was my enemy number one [as] I didn't have time for everybody', G02-20) which sometimes results in participants feeling 'stressed […] that's a bit challenging for them and sometimes they lower a bit the moral [...] because they are stressed, they know they can't breathe, they have to go to the following step now' (B2-08). Such stressful reactions might cause frustration among the participants: 'when the kids get frustrated, they start to do things that nobody likes them to do' (G02-20). Although the time limit is certainly necessary for practical and organisational reasons, it seems that the content and structure of the activities should consider and allow enough time and space for both the participants and practitioners to express themselves and, if needed, deepen or expand the tasks at hand.

4.1.3. Financial challenges

Funding and financial insecurity were among practitioners' main concerns, identified in five cases. Sufficient funding, or lack of it, seems to impact multiple aspects of the activities, such as the equipment available, materials and other resources, the duration of the activities, the human resources employed, practitioners' training, and space availability. Indicatively, the practitioners reported that: 'we have people who are passionate and dedicated but this work cannot be paid' [C2-04], 'we don't have enough resources, both in terms of area and then robots and stuff and people helping out' [B1-01]. These limitations become particularly pronounced in non-formal science learning activities in which technology or other specialised material is used. Practitioners reported challenges regarding the adaptation of the activities to the resources available: 'we started using reactive materials that were a bit weird […] but we realised that it wasn't economically sustainable' (F02-02) and 'materials like Lego, the 3D printer, Arduino, we got them last year through an application to a private organisation' (C1-02).

The use of technology and expensive equipment is probably the reason why most of the activities receive external funding from third-party organisations. Nonetheless, securing external funding is not resolving the financial challenges that practitioners may face. In six cases, practitioners reported on the struggles of attracting investments, securing the budget, and trying to turn it into a sustainable business. They found it extremely challenging to 'seek and discover mechanisms for getting money to do things' (C1-01) and 'convincing organisations to support us for a long period of time and to give us financial solvency to forget about fundraising for three years. That way, we can have stability not to earn money, since we are a non-profit organization, but to continue growing' (F01-16).

4.1.4. Space limitations

Practitioners further mentioned how the space where the activities take place often challenged their practices. For instance, space limitations are particularly challenging for non-formal science learning activities which often involve experimentation and the use of specific resources/technologies ('when working with textiles, you have to have space when you cut the textiles' G02-05). At the same time, spatial limitations often imposed further limitations on the number of participants that could physically attend, while at other times posed health and safety challenges because 'when we have bigger groups than 12, it's a safety matter so we have to be careful not to make too big groups' (G02-05).

Similar to the limitations mentioned in 2.4. related to not having a dedicated space, the wider social and physical context in which the activity takes place appeared challenging. This was especially the case of open, public events such as science fairs where several parallel activities take place that might cause a lot of noise, '[making it] difficult (for participants) to concentrate' (E6-01).

4.1.5. Design and availability of educational material and resources

Like all learning activities, designing resources that appeal to all participants was also challenging as 'some love to draw and explore and see while other just want to shoot things in a video game. It's more challenging to make a game that appeals to both, or to everybody's sense of fun' (A1-05). Practitioners also referred to the ways in which the resources are presented, distributed, and updated: 'found the system of worksheets a bit chaotic' (E1-01) as it 'wasn't clear who should take which worksheet' (E1-02) and 'the introduction [to the activity] needs to structure the whole thing, especially for firstcomers' (E1-03). Moreover, 'sometimes, the instructions don't match [the activity]' (E4-04) which implies the need to update the learning resources on a regular basis.

Several practitioners mentioned the availability of learning materials and resources as particularly challenging because 'what we think is based on the materials that we have' (C1-03) and 'depending on whether or not I have the money' (F01-15) as 'we don't make something new before we know whether we get the money' (D2-02). Being unable to use the resources needed challenges the whole design of the activity as 'if we don't have them [Computer Science materials], we will do the activities using simple materials and constructions. It changes. It gets ruined' (C1-04).

This becomes particularly challenging when using digital resources such as digital games due to their fast-paced changing nature (A3-08) and the competition with existing commercial options ('the game on their mobile (being) more appealing than a lot of this stuff that we show them' (A1-01) as 'a lot of the educational games that we have are graphically far inferior' #A1-06).

4.1.6. Practitioner workload

With most non-formal science learning activities taking place out of school hours, a few practitioners mentioned the extra workload it created for them as they combine their regular job with running out-of-school activities: 'It's our hobby and we have to do our work first. And then when we go to the club, we have to just somehow get the time to run it and maybe some time to design the courses […] But we don't have lots of time to discuss together' (G02-19). Furthermore, they also mentioned the demanding nature of their job as 'there is a lot of pressure in terms of working hours' (C1-05) 'which you offer from your breaks' (C1-07) as 'we have to work quite hard […] Because if you start at eight o'clock and stop at six o'clock and it's a full-day job and somebody is all the time asking something and it's the noise and everything. I think someday I have to stop before I break' (G02-01).

4.1.7. Availability, management and coordination of personnel

In one case involving a larger scale event, the interviewee raised the issue of the coordination and training of the volunteers. Large scale events such as a Science Fair require many volunteers who work alongside the permanent personnel, mainly due to budgetary constraints. The training and coordination of those volunteers seem to impose an additional challenge to the organisation of the event. As indicatively mentioned in the interview '[the volunteers] want to come, to get trained, and then they just want to come again and deliver, and that's it' (A2-06), hinting at the limited availability of the volunteers and the degree of their involvement in a series of tasks required when designing and running the activities. Furthermore, volunteers' limited availability is challenging for the permanent staff as they need to coordinate and manage them efficiently to 'maintain their enthusiasm, making sure they are delivering the content well, monitoring that, training them beforehand, rewarding them in some way' (A2-04).

4.1.8. Conflict with formal education settings

The integration of non-formal science learning activities into school settings also seems to constitute a challenge, mainly due to the constraints of the curriculum and the available time that appear to be in conflict with the more open-ended approaches and learning objectives of a non-formal science learning activity (C1-06). Specifically, when the activity takes place at schools or has school classes visiting, practitioners might find it challenging to 'align to the curriculum. Because you don't want the teacher to feel like she or he is wasting their time' (A2-01).

4.1.9. Evaluating learning progress

The aforementioned challenges, especially the limited duration and the frequency of the activities as well as not knowing the participants in advance, are particularly challenging when it comes to practitioners' ability to evaluate the progress in students' learning (B1; B2). In contrast to formal science learning, practitioners of non-formal science learning meet the participants once or for a limited number of times ('we see the progress from 9 o'clock to 2 o'clock' #B1-03). As such, they cannot 'see the progress over time' (B1-03). The challenge related to the evaluation of the learning progress was also evident in one of our cases in which the activity took place online, making the evaluation even more challenging as there were not '[…] any points to check whether the child is on the right track' (D1-04).

Nonetheless, the challenge to assess the learning progress, particularly in the case of one-time activities, may trigger an additional challenge for the practitioners related to emerging negative attitudes held by teachers, parents, funding organisations and other stakeholders towards the learning potential and benefits of such activities. This is further discussed in section 4.3. and in the *Discussion and conclusions*.

4.2. Practitioners' competences

The range and diversity of competencies required by the practitioners was in fact the most cited challenge, mentioned in seven cases. These competencies were relevant to the learning content and the cognitive aspect of the activity, the social aspect and the development of a collaborative culture among the participants, and the affective aspect of the activity, the motivation and engagement of the participants. Aspects such as delivering the learning content in a fun and motivating way, communicating with and coordinating the participants, and assessing the learning process were reported as aspects requiring multiple skills by the practitioners, which in some cases they did not feel confident they had.

Acquiring and showcasing such competencies seems challenging in the context of non-formal activities and requires experience and training. Specifically, several of them discussed how challenging it is to communicate the learning content to the participants as '[you have to] create attractive things. To find a way to give life to difficult concepts. To translate science in a way that everyone can understand it' (C2-03). Creating activities that are playful is also important as 'if the workshop isn't fun, you are not able to change the thoughts of those children' (F02-15). This becomes even more challenging when it is a collaborative activity with specific learning outcomes: '[it is] also much harder to employ in order to reach a specific result when we are working collaboratively – a result that we want to achieve. It needs work' (C1-10).

Designing and facilitating science activities can be particularly challenging in the context of non-formal learning as the practitioners have diverse backgrounds and some of them might not have previous or enough experience or pedagogical training, as described in the following quote: 'because I was mainly studying technical mechanical engineering, so I […] didn't prepare for creative workshops, design thinking or these design methodologies or creative methodologies […] I am not a teacher, and I don't have a comparison on the same type of subject when (it comes to) teaching in any other way' (B2-01, B2-02). Several of them mentioned that they 'learned on the job' (E1-06) without knowing 'how to communicate science to children' (F02-17).

Moreover, as 'each kid is different, each group is different' (G01-08) in terms of their background, knowledge, previous experience and skills, practitioners mentioned how challenging it is for them that they 'never know which children (they) will get' (D2-03). Not knowing the participants in advance challenges practitioners in many ways as they 'cannot go prepared with a plan of action' (A3-07) but they rather 'have to be fluid' (A3-07), to be 'flexible' (G01-08) to 'to make some changes in the workshop so that children still like it' (D2-03) as 'sometimes what was working for previous activity for this specific group is not working for this other group' (G01-08). Practitioners also mentioned the challenge of not having previous experience with the specific age groups as it may result in not understanding their cultural references and social practices ('kids who are seven years old talk a language that I have problems to understand […] I don't know, memes that I have never heard of' #G03-13).

Challenges related to group dynamics were also identified in the interview data. Dividing participants into groups 'is also a really difficult part' as 'some people work really well only with people they know […] but others also think it is fun to work with new people' (B1-08). Furthermore, the composition of the group was seen as challenging 'because if there is one person in a group that is really pessimistic and with there is one person who has a lot of control then the rest of the group usually thinks well this isn't fun at all' (B1-06). At the same time, another challenge is to build collaboration skills among the participants as well as a culture of trust and sharing in such a short time as 'they have to learn to work collaboratively, to respect each other, to wait, to be patient' (C1-12).

In addition to the logistical challenges for the evaluation of the learning progress discussed in the previous section (i.e. time constraints, previously unknown background of the students), the practitioners' skills required for assessing the learning outcomes, the activities themselves, and the practitioners' own work were also reported in one case as a critical challenge for the practitioners ('how to evaluate things, how to deliver things, it's a huge skill-set to learn' #A2-07).

4.3. Attitudes

The attitudes held by those involved in the activities including the parents, the participants and the teachers further emerged as a theme among the challenges discussed by the interviewees. Non-formal activities may be viewed as *a waste of time*, teachers may be skeptical towards them, and participants may not have yet developed a relationship of trust with the practitioners.

4.3.1. Parents' attitudes

The role of the parents/guardians is significant in the participation of their children in the non-formal science activities as 'some kids are coming because the parents signed up' (E7-02). Parents may be interested in the type of activity or use the activity as an excuse to 'have a down time on their phone' (E1-05) while someone else keeps their kid busy. Such attitudes can be challenging for practitioners as they might need parents' assistance during the activity: 'they are supposed to help as well, [but] the parents sit in distance with their phone' (E1-06). Parents' negative attitudes toward the type of the activity potentially hinder their children's participation 'because they still have this idea of games as a waste of time, so games are just for leisure, entertainment […] For them, games are shooting, and football, driving cars. They have certain stereotypes of games' (A3-01).

4.3.2. Participants' attitudes

Children are not always willing to participate in the activity, particularly when the activity is brought into school settings. In one case, the interviewer described the students as having 'the sort of attitude at the beginning like I do not want to do this […] and they don't really give it a chance. They just say "this is hard, I do not want to do this", and they sort of haven't tried' (B1-02). This reluctance to engage may be due to the children not trusting the practitioners as they have not previously met them or practitioners being perceived as inexperienced and less authoritative by the children: 'if you are very young and a [practitioner] comes, and you see him once, [kids] don't trust you, they are not interested, they can just avoid to listen to you, and nothing will happen' (B2-06). This highlights practitioners' challenge to earn participants' trust in such a short time as without trust participants are not 'able to feel that they are safe, and they can ask questions' (B1-04).

4.3.3. Teachers' attitudes

The negative attitudes of formal education teachers often reflected through their limited engagement and, in some cases, skepticism towards non-formal learning activities were among the most cited challenges, identified in five cases. Involving schoolteachers seems to be challenging, particularly when the activity requires schools visiting the venue as 'the teachers that are very traditional, they don't move (i.e. to come to the science museum)' (C2-05) and 'it's very difficult to motivate a part of the teachers who are not interested in changing their lessons or trying new things' (D1-02).

5. Discussion and conclusions

Despite the growing popularity of non-formal science learning activities worldwide, there is a lack of evidence-based resources that allow practitioners to make informed decisions about their interventions (policies, practices, and programmes). This can be perhaps linked to the fact that only few studies view practitioners of non-formal science learning activities as educators (Pitkänen et al., 2019; Smith et al., 2016) or examine the practices from their perspective and viewpoints. Without identifying both the strengths and weaknesses of their practice, practitioners may lack the evidence necessary to design and run similar activities effectively.

In this study, we built upon previous research on non-formal learning, and particularly non-formal science learning. We adopted a more participatory and inclusive approach, and gave voice to the practitioners themselves, focusing on their perspectives and their concerns. The analysis of our interviews shows that the obstacles and challenges identified involve a wider system of factors relevant not only to the design and implementation of the activities but also to the management, the coordination, the organisation, prior training of the practitioners, and the perspectives of the actors involved. Specifically, we identified three interrelated themes relevant to the (a) management and organisation aspects of the activities, (b) practitioners' competencies, and (c) parents', students', and teachers' attitudes towards the activity.

In line with previous research (Abbas & Koh, 2015; Bar-El & Worsley, 2019; Hira et al., 2014; Slatter & Howard, 2013; Tisza et al., 2020), practitioners named aspects related to organising and running the activities as challenging, including limited space, financial resources, materials, and people involved. For instance, practitioners in our sample often mentioned the limited financial resources and the pursuit of sustainable funding as a constant challenge since they must cover the costs related to renting a space, creating and updating educational materials, purchasing equipment that can be expensive, and covering practitioners' wages and their training.

The multiple competencies required by the practitioners emerged as the most cited challenge in our data. Content and pedagogical knowledge and competencies are certainly essential for educators (Koehler et al., 2013) but they can be a challenge for non-formal science learning practitioners who might have diverse educational backgrounds. Unlike formal education teachers who generally must have very specific credentials and follow a set path for their profession, many non-formal practitioners do not have an analogous or mandated path of study or degrees (Pitkänen et al., 2019). Non-formal science learning practitioners, as discussed by our interviewees, are required to show competencies regarding (i) the teaching of content, particularly for science teaching which requires deep understanding of the concepts, as well as knowledge of the didactics of science (Hira et al., 2014), (ii) the group facilitation and interactions, (iii) the development of a community culture, and (iv) the participants' engagement and motivation.

Considering the skills and knowledge required for the activities, practitioners in our study often reported feeling insecure regarding their own skills, **particularly** when they had no previous pedagogical experience. This became more challenging due to the excessive workload reported by our interviewees, specifically in cases in which the non-formal learning activities were their second job, and the overall time limitations they encountered when running their activities. Time constraints, as argued by Teig et al. (2019), are detrimental in shaping teachers' self-efficacy when implementing scientific inquiry.

This challenge is further amplified by the main principle of non-formal learning regarding participants' voluntary attendance and involvement (Rennie, 2007). Not knowing the number, previous knowledge and background of the participants in advance challenges the practitioners when attempting to tailor the activities to their audience. That requires, according to our interviewees, to be flexible to adapt the activities *on the go*. Addressing an unfamiliar and heterogeneous audience when it comes to their degrees of expertise and interests raises a challenge for the practitioners, particularly for those with no pedagogical training, and those with little or no previous teaching experience (Hira et al., 2014).

In cases where non-formal science learning activities were implemented into school settings, practitioners discussed facing additional challenges relevant to the activities' structure and goals as well as their facilitation. Particularly, there seems to be a conflict between the open structure of non-formal science learning activities and the curriculum-based structure of formal education practices at school (Smith et al., 2016) which imposes restrictions both on the structure and goals of non-formal science learning activities (i.e. linked to the curricula and implemented during a typical 45-minute class). At the same time, several practitioners facing challenges with the facilitation of the participants during the activities suggested that having the teacher present during the activity could help, as teachers are familiar with the participants and can mediate the group interactions among them (see also Pitkänen et al., 2019).

Furthermore, practitioners found challenging the negative attitudes or skepticism they faced from parents, teachers and participants. Especially formal educators' skepticism towards the non-formal learning activities has been reported in previous studies and attributed to the limited understanding of the full learning potential of non-formal activities (Clarke-Vivier & Lee, 2018; Çil et al., 2016; Halonen & Aksela, 2018). A number of actions to address this skepticism, as also suggested by our interviewees, is the building of 'a community of teachers that are interested in making and they can collaborate with children and they can build activities together' (G01-11) and arranging parallel events for children and adults in order to help them familiarise themselves with the nature and the learning benefits of the non-formal science learning activities. This would allow adults to witness and actively participate in collaborative activities with the children while giving the opportunity to the children to demonstrate their work to their parents. Similarly, it seems crucial to disseminate further the activities and their learning potential in order to reach out wider audiences and reinforce public trust in non-formal science learning activities. Enhancing the activities' visibility and widening participation can also increase the evidence of their learning potential that might, in turn, attract initiatives for investment (Werquin, 2009) and result in sustainable funding.

A critical trend that seems to emerge from the analysis of the interviews is that practitioners require additional support when it comes to designing and running non-formal science learning activities. The diversity of competencies required and the limitations in resources such as time, trained staff, and material, call for additional support for the practitioners. The availability of resources such as lesson plans addressing various learning goals, differentiated versions of activities to address various participant groups, as also suggested by some of our interviewees, varied previous skills and background knowledge, and available resources, could reduce the workload of practitioners and provide them with solutions to a range of pedagogical needs. In the formal education field, such resources can be available through the education providers, but in the scattered field of non-formal education with numerous actors, the availability of such kind of material cannot be taken for granted.

Following findings from previous research (Tran et al., 2013), the development and implementation of professional learning communities seems to be pivotal in providing support to those involved. For example, building (virtual) communities of practice through which non-formal science learning practitioners exchange expertise and practices can contribute to this professional learning. When implemented by each organisation, this exchange of practices has the power to transform it into a place that values and supports learning and growth and encourages change. Additionally, when this is implemented to the wider field, an easily accessible repository or database of good practices and relevant resources adaptable to different goals and needs could help practitioners find inspiration and potential solutions to overcome some of the aforementioned challenges.

This study allowed for a deeper understanding of the obstacles and challenges experienced by practitioners of non-formal science learning activities. Challenges similar to those identified in previous studies emerged including the funding, the availability and training of practitioners and staff, the appropriate design of the educational activities, the availability of a fixed and appropriate space, the conflict with formal education settings, and the attitudes of formal learning stakeholders. Light was further shed to previously unexplored issues such as the heterogeneity of the participants and the fact their backgrounds and interests are not known by the practitioners in advance, the time limitations and limited duration of the activities, the multiple competencies required by the practitioners and their workload, the attitudes of parents and participants, and the challenges in evaluating the learning outcomes and the learning progress of the participants. Most of these obstacles could apply to non-formal learning activities of diverse fields. The science learning-specific aspects seem to mainly be linked to challenges relevant to practitioners' pedagogical competencies in conveying complex or abstract concepts to the children, and the funding, since specialised materials and equipment are used in most of the non-formal science learning activities we investigated (Table 1).

Although there are variations among different types of non-formal science learning activities in different settings, we attempted to identify the shared challenges emerging in the field and discuss some main points of consideration when planning, organising, and implementing such activities. We certainly cannot generalise our findings to the whole spectrum of non-formal science learning activities; further research including larger numbers of practitioners and diverse types of activities in varied contexts would add to our understanding of potential barriers and deterrent factors, and help us address the challenges emerging. Through this study, we hope to support the informed planning and design of inspiring non-formal science learning activities and to encourage providers of non-formal science learning to consider the challenges and obstacles voiced by the practitioners across contexts and types of activities.

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Appendices

Appendix I

1. Interview protocol with ISL practitioners

   ********* Main part *********

   Let's get warmed up by first talking about some of the basics of your current situation.

1. We have identified you as a person committed to Informal Science Learning (ISL). What is your personal story? How did you get involved in this?

   Key aspects to approach:

- Could you tell me briefly what do you do with the young people/Europeans?
- What is your role in these activities?
- About your background
- Have you worked in a similar field previously?
- What type of education and training has prepared you for your current work?
- What motivates you to engage in this form of work?
- Why do you want to do this?

2. What is unique in what you do, compared to formal science education?

   Key aspects to approach:

- Where do you place your organisation/activities in the context of the broader educational system (which might include schools, faith groups, holiday activities, and so on)?
- How would you characterise people like yourself and what they do?
- Is there something different or unique about your work compared to formal science education?
- If someone were to ask you what is particularly special about practitioners working in a similar way to you (ie outside of the school context …) how would you answer them?

o What makes you say that?

3. Can you describe what happens in your (typical, recent) activities? (if respondent doesn't know where to start, prompt with 'choose your favourite/most popular activity')

   Key aspects to approach:

- Please describe all the participants involved (adults and children): children's ages, group size, how they become participants, adults' roles
- Please describe the tools used
- Do you mix ages during the activities?
- Can you tell me a little bit more about why you do it like that?
- Do the participants learn collaboratively?
- How can you relate these activities to formal education?
- What do you hope that children get from taking part in this activity?
- Why do you think they participate?
- Do you do things differently from others working in this field?
- In what ways?

4. There are two terms that are frequently used in combination with informal science learning. Fun and play(ful(ness)). Would you say that your activities are 'fun' or 'playful'?

   Key aspects to approach:

- Do you think of your activities as 'fun' or 'playful'?
- How important is fun in the way you set up your activities?
- How important is playfulness to the way you set up your activities?
- If applicable: What convinces you that participants experience the activities as fun?
- If applicable: What convinces you that participants experience the activities as play(ful)?

- Do you think that fun and playful attributes are important to achieving your desired vision/outcomes?

5. What are the main difficulties/issues/challenges you face?

Key aspects to approach:

- Can you tell me how you have tried to resolve these?
- What resources (equipment / software / social network / training) would you need to overcome these difficulties?
- Did you change the activity (nature of, timings of)?

********* Closing up*********

- What else about either your own role, and or similar roles in informal contexts more generally would you like to share with me?
- Do you have any concerns about what you have shared with me today?
- Do you have any questions for me?

********* Credit *********

- Participant data will be used in aggregated forms to protect individual and organisational anonymity. However, if you, or your organisation, would like to be credited as having contributed to this research there are opportunities to be associated with some of the outcomes of the project and its web resources.
- Would you or your organisation like to be credited on the project web site as a part of the project community or be listed among the practices?

○ In case yes: I will send you another consent form for that and make sure to check with you the content before it is presented on the website.

********* Signoff *********

Thank you again for your time and valuable input. We will keep in touch with you. Enjoy the rest of your day.

Appendix II

Table A2. Coding Scheme as finalized after the two cycles of coding.

Theme	Category	Codes
Organisation & Management	Number of Practitioners	Uncertain number/no registration
		Too many/large groups
	Time Constraints	limited duration of activity
		One-time event
		Not enough time for everybody
		Specific steps
		fast pace of the activity
		Stressed participants
		Not enough time to prepare
	Financial Challenges	finding money
		lack of money
	Space Limitations	distractions by the environment
		limited space
	Design and Availability of Educational Material and Resources	appropriate design of games needed
		limited availability of learning materials
	Workload	Not enough time to prepare
		a lot of tasks required
		requires a lot of time
	Availability, Management, and Coordination of Personnel	more people needed to support activities
	Evaluating Learning Process	difficult to track participants' progress
		difficult to evaluate practitioners' own progress
		assess your work
Practitioners' Competencies		communicate learning content
		pedagogical experience
		planning the activity
		assess learning outcomes
		build relevant culture
		build skills of collaboration among students
		build trust with children
		manage group dynamics
		make it fun and playful
		address students' interests
		adapt the activity
		Flexibility to adapt to unknown audience
Attitudes	Parents	negative attitudes towards the theme of the activity
	Participants	children not interested
		lack of trust for practitioner
	Teachers	negative attitudes towards the theme of the activity