Digital Games in Non-formal and Informal Learning Practices for Science Learning: a Case Study

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Abstract. This paper examines non-formal and informal learning practices for science learning. Through a case study and an exploratory, qualitative approach we identify aspects involved such as the content, the goals, the pedagogical approaches, the settings, the role of fun and playfulness, challenges, and the role of the practitioner. Data was collected through interviews and a survey. Despite the diversity in the format, settings, structure, and target group of the practices examined in this study, there seems to be a convergence in certain themes such as the objectives of the practices, the pedagogical approaches involved, and the importance of fun. These aspects are linked with the design and implementation of digital games in the context of informal and non-formal science learning. Further issues emerged from the analysis such as gender representation, resources required for efficient implementation of practices, and the role of the parents. Strengthening the links between formal and informal or non-formal science learning practices could benefit not only formal education but access of students to and effectiveness of non-formal and informal practices as well.

Keywords: Science Learning, Informal Learning, Non-Formal Learning, Digital Games, Game Based Learning.

1 Introduction

In this study we focus on non-formal and informal practices and activities for science learning within which digital games may be integrated, and explore aspects which could be addressed during the organization and design of such practices in order to increase their learning effectiveness. Research has linked digital games to scientific learning and science education not only as media through which players can explore and understand the learning content but also as artifacts that can trigger the interest for science and technology [1]–[4]. The context within which the gaming practices are situated are also of interest either as a framework supporting the gaming and learning practices or as emerging communities of practice spontaneously formed by the players [5]. As digital games offer players worlds to inhabit and explore, embed problem-solving situations, and support scientific inquiry, we can only assume that they can also promote scientific thinking. On that basis, games have been described as "*well suited for informal learning environments*" [9].

Although in the literature the notions of *informal* and *non-formal learning* are often used interchangeably, in this study we adopt the definition of [10] describing **informal learning** as *emerging spontaneously with no authority figure or mediator* (e.g. at home,

or with friends), while **non-formal learning** *occurs in a planned manner beyond the formal or informal education settings*.

Although informal learning practices involving digital games have been studied to a degree, there is still limited research focusing on non-formal practices. Mapping the field of informal science learning through games [6] has identified four main contexts: everyday peer cultures, intentional gaming groups and communities, family and home life, and commercial and public media culture. Moreover, Fowler [7] and Arya [8], discussed Game Jams as "an informal STEM learning environment" with an educational potential involving interdisciplinarity and the acquisition of knowledge and skills. In [9] attributes of informal education settings are presented in comparison to formal (e.g. schools). Such settings include the flexible time structure, the voluntary participation, the emergent educational goals, and the flexible disciplinary boundaries. Practices such as Game Jams or after-school programs do not share some of these attributes since, for instance, they have a fixed time structure and a set of objectives.

In this study we focus on *non-formal science learning* practices and our main goal is to explore and describe aspects such as the *content*, the *objectives*, the *challenges*, and the *role of the practitioner*, and their *implications* on the design of such practices and relevant digital games. Our main research questions were: *What is the context and content of the informal and non-formal learning activities? What is the role of fun and engagement? What is their relation to learning and formal education? What are the challenges involved in planning and running such activities?*

This study was conducted within the framework of the EU funded project *COMnPLAY Science*[1] aiming to explore non-formal and informal science learning through coding, making, and play activities. In this study we focus on the case Malta as one of the partner countries.

2 Research Methodology

In the case study reported in this paper we combine quantitative (survey) and qualitative (semi-structured interviews) data for our analysis. In this section we describe the data collection process we followed, outline our data analysis methods and present the participants of the study.

2.1 Instruments and Data Collection

The survey and interviews were conducted concurrently in October and November 2018. The survey we used for this study was developed by the COMnPLAY Science project consortium [11] and was addressed to practitioners and facilitators of non-formal and informal activities relevant to science learning. In particular, the survey includes 38 closed (multiple-choice, Likert-scale) and open-ended questions focusing on dimensions such as the content, the goals, and the context of the participants' activities. The survey was distributed through an online link securing free anonymous access via social media and direct emails to institutions organizing such activities such as

[1] https://comnplayscience.eu/

universities, museums, and science fairs hosts; for more details on the instrument and process followed for its design the reader is referred to [11].

The interviews, designed also by the project consortium, involved 5 main dimensions: the *content* of the activity, possible *challenges*, the *relation of the activity to formal education*, the background and the *role of the practitioner*, and *fun and playfulness*. These dimensions would allow us to gain a better insight of the context and nature of the activities. Interviews were mainly conducted via online teleconferencing platforms and their duration was approximately 45 minutes.

2.2 Data Analysis

The interviews were recorded, transcribed, and coded in two cycles: a) structural coding based on the 5 dimensions described earlier and *in-vivo* coding for identifying emerging and potentially interesting phenomena and b) pattern coding for summarising the issues identified into meaningful categories [15, p. 66, 74, 152]. Open-ended survey questions were similarly coded and analyzed. Quotes from the interviews and open-ended questions are referenced in the text so as to validate results and give a better insight of the issue addressed. Each quote is followed by the reference number of the interview (e.g. "int01"). For the closed survey questions, although the frequencies of the responses are described, no statistical analysis was conducted due to the small sample examined.

2.3 Case Study Participants

The total number of survey responses (N) from several European countries is 128, at the moment of writing. In this paper, however, we only focus on respondents from Malta (N=7) as our initial analysis of the underlying practices of informal learning on that country. The interviewees were 3 experts from Malta that were purposefully sampled. They were, therefore, specifically invited for their potentially interesting and information-rich cases [16, p. 230]. All participants were volunteers and practitioners or facilitators of informal or non-formal science learning activities. They had different backgrounds, such as law, biology, and education. They were all affiliated with different institutions such as universities, museums, and governmental organisations. Three of the survey respondents were male and four female. All three of the interviewees were male and their practices involved digital games.

3 Results

In this section we describe the results obtained from our analysis in relation to our research questions.

3.1 Description of Activities

The activities described vary regarding their context, settings, subject, duration, age range, and gender representation of the participants. Respondents in our survey and interviews described contexts such as invited workshops at schools, coding and robotics workshops, guided experiments, science theatre, playing digital games, summer camps,

after-school programmes, science events, career orientation days, game exhibitions, demonstrations, and game development contests (e.g. Game Jams).

Sciences such as Technology, Biology, Chemistry, Mathematics, and Computer Science were the fields most activities were situated in. In particular cases though (1 case in the survey and 3 cases in the interviews) the activities were also oriented towards Arts, Philosophy, and social issues.

The activities take place either in classroom settings (invited by the teacher), or in fairs, museums, science centres, outreach centres, depending on who is organising or hosting the activity. The duration of the activities described varied from a few minutes, to 6 hours, or 5 consecutive days, usually as a single-occasion activity, as reported in the interviews and in 6 out of 7 survey cases, with groups usually participating in the activity only once (see Fig. 1).

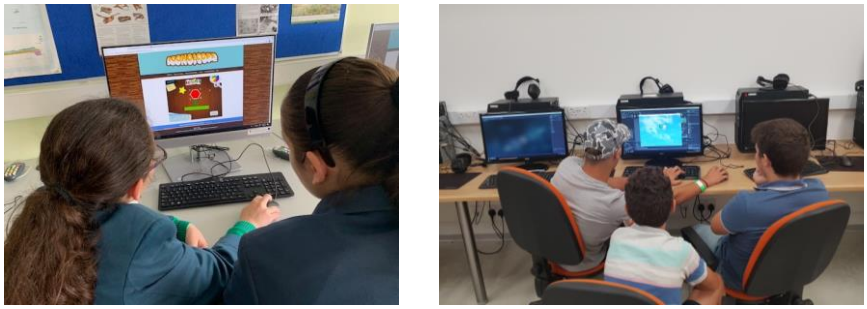

Fig 1. Indicative non-formal learning practices with digital games

The ages of the participants also ranged from 4 to 18 years old, or even families and the general public, in most cases separated in age-groups. Regarding the gender of the participants, although girls and boys seemed to have equal representation in the activities in most cases–approximately 50%, as reported in the survey–one of the respondents reported a near 0% of girls for robotics and coding activities. This was consistent with another response indicating a 4% of girls also for activities in robotics and coding. Similar findings were also described in [11]. The same respondent further observed that "*If booked by school, [the percentage of girls/females is] 50%. If booked by parents, 10% to 70% depending on the topic and name […]*".

3.2 Engagement, Playfulness and Fun

Fun, playfulness, and engagement were reported as the strong points of their activities by the survey respondents in 5 of the 7 cases, for instance: "*Children like to play games during these events, they are engaged and like to spend time.*", "*it is fun and the participants are very engaged and excited*". Engagement, playfulness, and fun are actually primary goals when designing such activities e.g. *"*[fun and playfulness for achieving the goal are] *very important. That if the children in particular don't feel that they are having fun and you are trying especially to do extra work or work about the school work, you are just going to drive them more away. There is such a thing as bad science*

communication where you get negative outcomes. It doesn't mean because you are doing an intervention it's going to make them better." (int02)

Fun and engagement, though, is one of the most challenging goals to achieve mainly due to the heterogeneity and diversity of the participants and the quick turnaround. An indicative quote: *"One of the challenges is that there is no universal definition of fun. So when you are making an experience fun you have to tailor it very specifically to the audience. Like I was saying, some kids love to draw and explore and see while other kids 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."* (int01)

But what motivates children and young people to participate in such activities in the first place? As reported by the practitioners in this study, the novelty and distinction from the school environment were strong motivations. Commenting on the aspects of the activity they thought young people appreciated the most, the majority of the participants selected the option "Doing something that is not 'school-like' (in 6 of the 7 cases), followed by "Making something by themselves" (5 out of 7), and "Doing something new" (4 out of 7). The contrast between the school setting and informal or non-formal activities as a motivation was also reported by 1 of the interviewees: *"[…] it's really different from when I used to teach. You know, when the bell for the break rings they are already out of the room. But in these workshops, they want to stay there [...]"* (int03).

Specifically, for practices involving digital games, the use of digital games was reported to be an *a-priori* motivator: *"[...] immediately, when you are talking about games students are already enjoying. They haven't even started playing the game and they are already looking forward and enjoying the session [...]"* (int03). For sustaining, though, this engagement, the appeal of the games used during the activity in relation to commercial games is critical, as reported by one of the interviewees *"The problem is that often there is better games on their mobile. So at this age, 16, the game on their mobile is more appealing than a lot of this stuff that we show them."* (int01).

It seems that parents and educators also play an important role in the selection of the activity. In a 5 point Likert-scale question on the frequency young people, parents, and educators decide participation of the children in the activity, in 5 cases it was the parents that "often" made that decision, in 4 cases it was the educators, and in 3 cases it was the young people. The highest label ("always") was not selected in any of the cases. As one interviewee similarly commented on what makes children join their informal activity: *"Their parents. Basically they are public events. The parents take them and they walk around the city."* (int01)

The concepts of fun and playfulness were further elaborated by the participants in our interviews recognising that even though these terms seem to overlap, playfulness tends to involve action and interaction. Two indicative quotes: *"I think playfulness is maybe more interactive. You can have fun watching, but it's not playful."* (int01), *"Fun is something enjoyable, laughter, whatever. Playful is something maybe related more to doing, and activities, and games.* (int02)

3.3 The Learning Aspect

Learning Goals. It seems that informal and non-formal activities are not necessarily designed to achieve specific learning goals but rather raise the awareness and interest on a topic; as one survey respondent commented *"they are not focused on conveying the content of a scientific concept."* More specifically, "Engagement or interest in a particular scientific topic, concept, phenomenon, theory or career" was selected by the majority of the survey participants (5 out of 7) as the main aim of their activity. When asked specifically about the objectives, 4 of the 7 respondents agreed that their activities had explicit learning goals and elaborated providing examples such as "coding", "collaborative work", and "acquiring a few key facts". Similarly, when discussing the strong points and success indicators of their activities, survey respondents described objectives such as "improving people's confidence towards science." and "raise awareness". One interviewee elaborated on similar learning outcomes: *"the content, the scientific content, the technological content, whatever we want that to be. So we would want them to learn that. But if, for example, they do something collaboratively, we would want them to learn how to work in a team and so on. We have other learning outcomes such as motivation towards science or science careers, or confidence in science. Those are the underlying goals in many of the things that we do: building their own self esteem, empowerment, and ability in that field."* (int02)

Two interview participants that reported using digital games for their activities also agreed that an additional goal for their use was the awareness that digital games, beyond entertainment, can be tools for learning, for expression, or career opportunities. Indicatively: *"they can see that they can do more philosophical more meaningful game development and more meaningful coding in the sense that they can make something that makes people think."* (int01) and *"Through these workshops, the parents start to realise that the games aren't just a waste of time. So they start to realise that there is some potential of learning in using games. [...] mainly we want to let children know that there are also games that can be used for learning purposes."* (int03)

The short-term involvement and short duration of the activities though seem to make it difficult to assess or follow-up the learning outcomes. An indicative quote: *"The response and learning results are difficult to say because they are there for like 5 minutes and then they go out again."* (int01)

Relation to Formal Education. There was a slight shift regarding the learning goals when these non-formal learning activities were transferred into formal education settings, e.g. when schools invited the practitioners to organise the activities in their classrooms. In many cases, both in the surveys and the interviews, the participants commented that in such settings the activity would have to align to "specific syllabi" and curricula: *"We are more concerned with engagement, but teachers want to see explicit learning objectives to justify booking with us, especially in Secondary where it's harder to organise/justify outings as they're so disruptive to the school day."* (survey response, open question) and *"If we are going to schools then we have to align to the curriculum. Because you don't want the teacher to feel like she or he is wasting their time. You want to make it that you are helping them. So you are covering content for them."* (int02). Three out of seven survey respondents agreed that the goals and objectives of their

activity were explicitly connected to school curricula; three respondents disagreed, and the remaining respondent did not answer this question.

An interesting finding is that the fun and playful aspect of the activities is linked to the learning outcomes and is also an element distinguishing them from formal education. As one of the interviewees commented: *"I think the main difference between these informal and non-formal activities and the formal, traditional school setting is that students are actually learning through fun."* (int03).

Learning strategies involved. Constructivist and social constructivist approaches to learning emerged as the main learning approaches involved. The active role of the participants was further highlighted as a strong point of the activity and an indication of success for 3 of our survey respondents: *"*[people] *show interest by doing the hands on activities, many ask questions.", "Often they also interject and collaborate with other players"*, *"interactive and not passive"*. In the survey question on what describes best what happens during the activity, 5 reported discovery-learning, 4 reported problem-based learning, and 3 reported collaborative-learning. Similar approaches were also commented in the interviews: *"*[during the Game Jams] *the fact that you are in a team, that really helps because you get guidance from other people. [...] you are still learning things because you're explaining them"* (int01), and *"I try to make the students work in [groups of] two. Because I think it's important for them to have this collaborative aspect between two."* (int03).

3.4 Challenges

Respondents and interviewees identified specific challenges with respect to the resources and support required for running such activities. Survey respondents described the (lack of) institutional support, the resources, the (limited) number of activities and volunteers, and the appropriate marketing for communicating and disseminating the activities to the public, as weak points that needed improvement.

Similar issues were described in the interviews. Indicatively: *"recruiting volunteers, […] monitoring that, training them […] having the money to run these sort of things. And the people, the institutional stuff to run this. […] Logistical staff […]."* (int02). In one case the cost of making games for learning that could compete with commercial games and appeal to children and young people was mentioned as a challenge requiring more resources and funding: *"[…] a lot of the educational games that we have are graphically far inferior. So the challenge is to find the budget and investment for people to make the graphics. You have to make a game that attracts [the children's] attention at least in the beginning* […]*"* (int01)

The crowded areas and the distractions particularly in public events and science fairs, and the short duration were further reported in the interviews and in 4 instances in the survey as some of the challenges of such activities that need improvement. Our study participants reported that such challenges make it difficult to employ more personalised learning approaches and increase the risk that children may disengage the activity. Indicative quote: *"We only get 1 hour with the kids, so no opportunity for larger or long-term projects. 1 or at most 2 presenters / facilitators with 25 kids, so very little one-on-one."*

4 Discussion and Conclusions

Despite the diversity in the context and content (i.e. format, settings, structure, and target group) of the non-formal learning practices examined in this study, there seems to be a convergence in certain themes such as the objectives, the pedagogical approaches involved, the importance of fun and the challenges for achieving it. The participants of this initial study within the Maltese context, emphasized awareness and interest for a topic as a core objective, similarly to findings in [12] and [17], and favoured learner-centered approaches. Links (curriculum subjects) and differences (playfulness) to formal education settings were identified. Also, challenges such as the resources required, the time constraints and their implications, were described. Some additional interesting issues, though, also emerged from the data, such as the mediating role of the parents and gender representation.

The mediating role of the parents in the participation of minors to such activities may be an issue to further consider, particularly in the cases where digital games are involved. Parents, as reported in the interviews, are likely to be biased against digital games ("a waste of time"). Such stereotypes and attitudes towards games could potentially affect their decision of the activities their children –particularly younger children- will attend or not attend. The role of the parents may also be an issue for further study regarding the gender representation in such activities. As reported by a facilitator in robotics and coding workshops when children were registered by their parents the percentage of girls is nearly 0%; this percentage however increase substantially when children are invited by educators at schools. This seems to be a case where integration of such activities to formal education settings could support access by a wider range of children regardless of their gender.

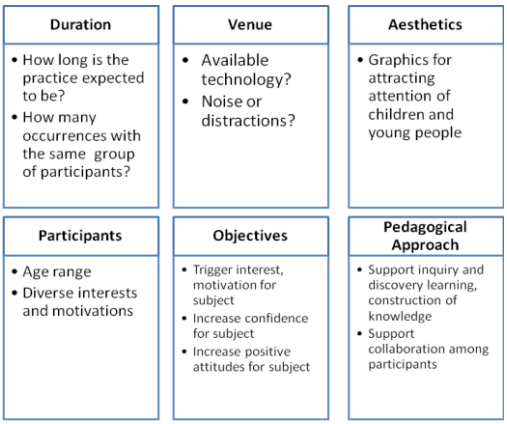

Fig. 2. Game design considerations for non-formal and informal learning practices for science learning.

The implications of these issues on the design of digital games to be implemented in informal and non-formal science learning practices involve the diversity, the goals, the

settings, and the time constraints of the practices. Their diversity could give game designers the freedom and opportunity to create a variety of games, as also noted in [9], but also be a challenge to adapt a game to the different learning practices. The development of games for science learning seems to be presented with the additional challenge of competing with the budget and marketing of commercial games as also noted in [13]. Additionally, although games can support the development of expertise and the formation of a scientific identity [14] the short-term engagement in activities and practices that last one hour or even a few minutes as described here could rather raise interest for a specific topic [13]. In Fig. 2, we summarise the considerations–as emerged from our data–to be considered for the design of digital games directed to non-formal and informal learning practices.

The implementation of digital games in informal or no-formal learning practices has to further consider and address factors such as the marketing of commercial games and parents' stereotypes that shape the selection and use of games in informal settings such as for recreation at home [6]. By doing so, more structured or guided practices with the appropriate learning context could expand the use of games for science learning to a wider audience of children and young people and support the understanding and learning of science concepts and positive attitudes towards science.

Science education and science literacy may benefit from research in public engagement with science and links to everyday life as described by Feinstein in [18]. Since this papers offers an initial study of a specific case with a relatively small number of participants, our findings are limited to the local context and cannot be general enough. The in-depth accounts of the practitioners and the themes that emerged, however, can provide some first insights for the study of informal and the design of non-formal practices for science learning, as well as the design of digital games that can support such practices.

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