COM n PLAY
SCIENCE

PROJECT DELIVERABLE – PUBLIC

D1.2 RESEARCH INSTRUMENTS AND TOOLS

v. 2.0

10 March 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 787476. This document reflects only the authors' view. The Research Executive Agency (REA) and the European Commission are not responsible for any use that may be made of the information it contains.

PROJECT FACT SHEET

Acronym
COMnPLAY SCIENCE

Full Title
Learning science the fun and creative way: coding, making, and play as vehicles for informal science learning in the 21st century

Programme / Pillar / Topic
Horizon 2020 / Science with and for Society / Science education outside the classroom

Type of Action
Research and Innovation action

Grant Agreement
No 787476

Duration
36 months (1/6/2018 – 31/5/2021)

Grant Amount
€ 3,097,715.00

Overview
The project aims to help Europe better understand the new ways in which informal science learning is taking place through various coding, making, and play activities that young Europeans (children, adolescents and young adults) are nowadays increasingly engaged with, outside school and higher education science classrooms, beyond the formal boundaries of science education.

The project's main objectives are to:

a. Develop an appropriate conceptual and methodological framework integrating all aspects of the project into a unifying conceptual map.
b. Setup a European-wide community of stakeholders, including learners, educators, facilitators and policy makers from diverse fields, to contribute, guide and help assessing the conducted research.
c. Identify, pool and analyse diverse existing coding, making and play-based practices taking place outside formal science classrooms which bear some promise for informal science learning.
d. Conduct in-depth learner-centred participatory empirical research on selected practices.
e. Gain a deep understanding of the impact that this kind of informal science learning has on formal science education, traditional informal science learning interventions, young people as learners and citizens, as well as, on society.
f. Communicate and disseminate the messages and outcomes of the project widely, and enable the exploitation of the findings of the research through the development of relevant guidance for practitioners and recommendations for policy development and further research.

The main results stemming from the project include:

- An online inventory of all the identified and pooled practices, appropriately categorized and annotated in the light of the findings of the research, available to stakeholders and the public.
- A set of community building methods and tools for everyone wishing to get involved in community building linked to the project.
- A Web-based game promoting and supporting the continuous prolonged engagement of learners and their facilitators in the field research.
- The *COMnPLAY SCIENCE Knowledge Kit*, a modular set of reader-friendly, practice-oriented publications, encapsulating the findings of the project.
- The *COMnPLAY SCIENCE Roadmap for Europe*, a detailed concerted account by the consortium, the stakeholder communities and policy makers of the potential for short-, medium- and longterm impact of coding, making and play-based informal science learning.
- Numerous public events (workshops, training seminars, conferences, contests, fairs), often combined with training activities (winter and summer schools).

Project Coordinator

Norwegian University of Science and Technology (NTNU)
Prof. Michail Giannakos
Phone: +47 73590731
E-mail: michailg@ntnu.no

Consortium Members

Norwegian University of Science and Technology, Norway (coordinator)	University of Oulu, Finland	Foundation for Research and Technology – Hellas, Greece
Eindhoven University of Technology, Netherlands	Uppsala University, Sweden	Technical University of Munich, Germany
University of Malta, Malta	Design for Change initiative, Spain	ovos media GmbH, Austria
King's College London, UK	Science Museum Group, UK	

Web & Social media

Web Site: http://comnplayscience.eu Facebook: https://fb.me/ComNPlayScience
YouTube: https://bit.ly/2Hq5FsK Twitter: @comnplayscience
ResearchGate: https://www.researchgate.net/project/CoM-n-Play-Science

DOCUMENT IDENTITY

Deliverable code number	D1.2
Deliverable title	COMnPLAY SCIENCE Research Instruments and Tools
Relevant work package	WP1 'Background'
Relevant task(s)	Task 1.2
Short description	Report on the outcomes of Task 1.2 'Methodological framework', including detailed methodological tools that will enable the consortium to: a) identify and pool appropriate practices involving young people in coding, making, and play activities outside formal science education contexts; b) to conduct in-depth learner-centred participatory research into selected practices about the nature of the informal science learning occurring through them, as well as about the potential impact of this and c) to translate the findings of this research into concrete guidance and inspiration for practitioners and recommendations for policy development and further research.
Consortium partners leading	UOULU
Consortium partners contributing	NTNU, FORTH, TUE, UU, TUM, UOM, DFC, OVOS, KCL, SMG
Main authors	Netta Iivari (UOULU), Marianne Kinnula (UOULU)
Secondary contributors	All partners
Reviewers	Michail Giannakos (NTNU), Dimitra Ch
Due date	31 January 2019
Submission date	12 March 2019
Dissemination level	Public

DOCUMENT HISTORY

Version	Date	Handling partners	Description
0.1	18 October 2018	UOULU	Initial draft
0.2	2 November 2018	UOULU	Revised draft
0.3	14 December 2018	UOULU	Advanced draft with content added
0.4	21 January 2019	UOULU	Prefinal draft for review
0.5	30 January 2019	UOULU	Additions to prefinal draft for review
1.0	26 February 2019	UOULU	Final draft for partner review before submission to the European Commission
2.0	10 March 2019	UOULU	Final version for submission to the European Commission

1. Executive Summary

This document reports on the outcomes of Task 1.2 'Methodological framework', of the COMnPLAY SCIENCE project, presenting detailed methodological tools and instruments as those have been shaped and are available at the end of the ninth project month (M9, February 2019).

The work reported in this document has continued based on the Conceptual Framework developed and reported for the use of the COMnPLAY SCIENCE project in Task 1.1 'Conceptual framework.' The Conceptual Framework mapped and organized the central concepts of the project, whereas the Methodological Framework reported in this document is more practical, providing the methodological design, i.e., a general description of the methodological approach of the project, reflecting the overall conception of the research as well as the realities and practicalities of the field as they have been recorded up to the time of delivery of the present report.

Table of Contents

2. Introduction

This document reports on the outcomes of Task 1.2 'Methodological framework', of the COMnPLAY SCIENCE project, presenting detailed methodological tools and instruments to be used in WP3 'Empirical Research', as those have been shaped by the project partners and are available at the end of the ninth project month (M9, February 2019). It is meant to inform not only the consortium in the next steps of the project, but also the interested average reader outside the project.

The work reported in this document has continued based on 'D1.1 Conceptual Framework' developed and reported for the use of the COMnPLAY SCIENCE project in Task 1.1 'Conceptual framework.' The Conceptual Framework mapped and organized the central concepts of the project, whereas the Methodological Framework reported in this document is more practical, providing the methodological design, i.e., a general description of the methodological approach of the project, reflecting the overall conception of the research up to the time of delivery of the present report.

In WP3 'Empirical Research', each COMnPLAY project partner will conduct case studies on selected informal/non-formal science learning practices, following a participatory, learner-centered and mixed methods approach. The practices COMnPLAY project partners have selected for the case studies include variably coding, making, and play activities.

The framework proposed in D1.1 provides a high-level structure for the implementation of the case studies. In this document, more detailed guidelines, instruments, and tools for the case studies will be provided. To avoid overlap, this document will refer to particular sections in D1.1. when describing the research design.

In addition to the instruments described in this document, the partners may use also some additional, individual to each partner, ways to conduct research because the partners come from varying fields of research and varying disciplines and thus, they also have varying needs for research methodology. The instruments described in this document ensure, however, that all the partners follow the same methodology in their case studies when it has effect on the shared COMnPLAY SCIENCE project objectives and outcome.

The selection and nature of the case studies and their target practices are described in 'D2.1 COMnPLAY Science Identified Practices and Research Sample.' In the selection of the practices to be studied, attention has been paid to ensuring relevant aspects of diversity to gain coverage of a broad spectrum of relevant practices and activities (see D2.1.).

The document is structured as follows:

In Section 3, guidelines for the research design in all the case studies are described. These include: guidelines on participatory and learner-centered research process (Section 3.1, see also Section 3.1 in D1.1), on the fun factor (Section 3.2, see also Section 2.1.4 in D1.1), on conducting case studies (Section 3.3, see also Section 3.1 in D1.1), on the mixed methods approach (Section 3.4, see also Section 3.1 in D1.1), on the structure of the case studies (Section 3.5), and on sampling (Section 3.6).

In Appendices for this document, the research instruments are described in detail. The research instruments included in this document are:

- A mobile game for assessing the science capital (APPENDIX A). See also Section 2.2 in 'D1.1 Conceptual Framework' about science learning concepts.
- Two example procedures of case studies (APPENDIX B and C)
- Instructions for how to conduct observation in case studies (APPENDIX D)
- Instructions for how to conduct interviews in the case studies (APPENDIX E)
- Guidance for how to conduct interviews of children together with related survey questions (APPENDIX F)
- Guidance for how to conduct interviews of facilitators together with related survey questions (APPENDIX G)
- Examples for how to conduct self-reflection in the case studies (APPENDIX H)
- Example consent form that follows GDPR (APPENDIX I)
- Survey questions for measuring science capital (APPENDIX J). See also Section 2.2 in 'D1.1 Conceptual Framework' about science learning concepts.
- Example methods for how to evaluate are children enjoying the activities (APPENDIX K)

3. Research design

3.1 Participatory and learner-centered approach

Participatory and learner-centered research approaches include a broad range of traditions, methods and viewpoints from a variety of disciplines. This project draws upon a set of authoritative guidelines on learner-centeredness, user-centeredness, participatory design, participatory research and effective participation of children in research (see Chawla & Heft, 2002; Cornwall & Jewkes, 1995; Greenbaum & Loi, 2012; Henson, 2003; Iivari & Iivari, 2011; Weimer, 2002). By adopting a participatory and learner-centered research approach, the focus of this project is on young learners.

To ensure that the focus is on the young learners, the research conducted in this project shall study participants as individuals (e.g. their individual characteristics, skills and capabilities, knowledge, dispositions, attitudes, values, desires, aspirations etc. are examined and taken into account). Participants' participation is comprehensive (including different phases and activities) and influential in the research process. The research process and outcomes are adapted and/or personalized to suit the study of participants (informed by Chawla & Heft, 2002; Cornwall & Jewkes, 1995; Greenbaum & Loi, 2012; Henson, 2003; Iivari & Iivari, 2011; Weimer, 2002). Furthermore, their informal science learning practices will be studied in depth (e.g. the characteristics of the practices such as actual sayings and doings, material aspects involved, motives underlying the practice, participants and communities involved, histories and trajectories leading to the current situation, other practices shaping or being shaped by these practices, discourses circulating around, see e.g. Nicolini, 2013; Ventä-Olkkonen, 2017).

For each of the case study in this project, the following aspects will be considered to the extent feasible (Chawla & Heft, 2002; Cornwall & Jewkes, 1995; Greenbaum & Loi, 2012; Henson, 2003; Iivari & Iivari, 2011; Weimer, 2002):

- Study participants should be actively involved in the research process, at least in data collection, potentially also in analysis and reporting of the research,
- Study participants are involved in defining the research topic/goals of the research,
- Study participants are involved in evaluating the research process and outcome,
- Study participants benefit from the research (in the sense of tangible outcomes and/or competence development),
- There is a clear motivation for the study participants to partake in the research,
- Equalizing power relations between all the participants (researchers and study participants) and democratic practices are advocated,
- Mutual learning among all the participants (researchers and study participants) is advocated,
- Mutual respect, support and encouragement among all the participants (researchers and study participants) is advocated, and
- Study participants are helped to contribute through suitable tools, techniques, tasks and materials, enabling study participants' meaningful participation.

3.2 The fun factor

3.2.1 A short introduction on fun, its use and benefits on learning

There has been a number of studies foregrounding the contribution of fun and enjoyment to learning. For example, Francis (2012) considers fun as an important component of learning, relating to actions and techniques that aid students in learning new material. She also argues that the use of fun in the classroom is not only a complement to learning, but the lack of it may be a detriment. Carroll and Thomas (1988) have also argued that fun is a very important component but studies on it are lacking because, first, it is difficult to empirically measure fun and, second researchers might be afraid to build a professional career on a topic that might not be taken seriously by their peers. They also suggested a research program in fun and motivation. Importance of enjoyment in relation to learning has been found out also in neuroscience research (Willis, 2007), based on neuroimaging studies and measurement of brain chemical transmitters. Willis (2007) suggests that superior learning takes place when classroom experiences are enjoyable and relevant to students' lives, interests, and experiences. When classroom activities are pleasurable, the brain releases dopamine, a neurotransmitter that stimulates the memory centers and promotes the release of acetylcholinem, which increases focused attention. When it comes specifically to school science education, Appelbaum and Clark (2001) emphasise the crucial role of fun as a connection with theories of motivation.

Different kinds of definitions for "fun" exist. Appelbaum and Clark (2001) distinguish "hard fun" in the context of learning in school as a marker of engagement, from (just) "fun", as the opposite of "hard work". Hard fun is a term which has also been used by Seymour Papert (2002), the father of constructionist learning, noting that something can be considered fun because it is hard rather than in spite of being hard. A study by West (1994) with third graders, including observation and in-depth interviews revealed that students had a well-defined set of determinants for what was "fun" and what was "work" in literacy learning. Students' determinants for fun included: personal preference, competence, appropriate level of difficulty, familiarity, time, choice, ownership, caring audience, collaboration, ample support, high engagement, variety, and learning. More recently, Mathers (2008) conducted a study with first, third, and fifth-graders regarding their perceptions of fun as they relate to reading and writing and how they can increase their motivation and engagements. Three distinct aspects of fun emerged: (a) The entertainment factor (mostly related to humour); (b) The information factor (satisfying personal curiosity); and (c) The choice factor (freedom & creativity). Notably, as one third-grade participant said, "You can be entertained and informed."

As regards more general understanding of fun, Monk et al. (2002) use the words *fun* and *enjoyment* interchangeably. On the other hand, Blythe, M. and Hassenzahl, M. (2005) examine the semantics of the word *fun* and other words which are often used interchangeably such as *enjoyment*, *pleasure* and *attraction*. They conclude that during *fun* the senses must be engaged and that *fun* has certain connotations of triviality, frivolity and distraction that distinguishes it from other forms of enjoyment. They also state that enjoyment is a context dependent and relational phenomenon which is never guaranteed. An activity may be enjoyable or not, depending on the situation that the activity is embedded in. In other words, enjoyment is a relationship between ongoing activities and states of mind. John Caroll (2004) in a short article discussing fun in the context of human-computer interaction, attempts to provide a brief account of when "things" are fun: "Things are fun when they attract, capture, and hold our attention by provoking new or unusual perceptions, arousing emotions in contexts that typically arouse none, or arousing emotions not typically aroused in a given context. Things are fun when they surprise us; when they don't feel like they look, when they don't sound like they feel. Things are fun when they present challenges or puzzles to us as we try to make sense and construct interpretations, when they transparently suggest what can be done, provide guidance in the doing, and then instantaneous and adequate feedback and task closure." Ben Shneiderman (2004) describes fun-filled experiences as playful and liberating - they also make you smile. They are a break from the ordinary and bring satisfying feelings of pleasure for body and mind.

Fun and enjoyment can be exploited in learning. While discussing how fun can be used to maximize the learning potential of smart toys using tangible interfaces, Fontijn & Hoonhout (2007) consider three "core sources of fun" (accomplishment, discovery, bonding) along with three factors that enhance the effectiveness of the core sources but, on their own, do not provide fun (fantasy, aesthetics, physicality). Several studies have examined also the use of humour in teaching (Garner, 2006) - which is a very explicit and direct type of fun – and have suggested that it may enhance learning. Physiologically, humour and laughter can aid learning through improved respiration and circulation, lower pulse and blood pressure, exercise of the chest muscles, greater oxygenation of blood, and the release of endorphins into the bloodstream (Berk, 1998, cited in Garner, 2006). A study by Garner (2006) where humorous, content-related stories were introduced in a lecture on statistics, concluded that content-focused humour can help comprehension and has a positive impact on the retention of educational materials.

3.2.2 Assessing "observed" and "reported" fun

In the educational domain, fun is studied through observation and interviews (e.g., West, 1994; Mathers, 2008). In interviews, fun is often assessed through student verbalisations that categorise activities as either "work" or "fun", or, in other cases, as either "boring" or "fun". Different kinds of more sophisticated tools and methods for evaluating or, predicting, the fun have been developed in the context of interactive products (applications, games, toys) for children. Some of them are presented next:

In interactive products, usability of the product and fun are often interrelated. In order to assess fun while analyzing videos of children playing a computer game, Barendregt et al. (2003) use a set of fun heuristics suggested by Malone and Lepper (1987) which includes Challenge, Curiosity, Control, and Fantasy. They also suggest a procedure for distinguishing usability from fun problems. Barendregt et al. (2008) also developed a formative evaluation method (problem identification picture cards - PIPC) which enables young children to express both usability and fun problems while playing a computer game which combines thinking-aloud with picture cards that children place in a box to indicate a certain type of problem. Regarding fun, four types of problems were distinguished: Challenge problems, Fantasy problems, Curiosity problems, and Control problems. The cards represent the feelings children may have when they experience a problem, but a positive card was also included depicting a smiley face which was explicitly labelled as "Fun".

A toolkit targeted for measuring the fun of products with children aged between 5 and 10 has been developed by Read et al. (2002). The toolkit comprises a set of tools that can be used in empirical studies to measure three dimensions of fun: Expectations, Engagement, and Endurability, derived from expectancy theory, user expression of frustration / satisfaction and "the Pollyanna principle".

Expectations are measured with the following three tools:

- Funometer (Risden et al., 1997): A 'thermometer' where the vertical bar represents the amount of fun.
- Smileyometer: A 1-5 Likert scale which uses smileys in conjunction with captions (Awful, Not very good, Good, Really good, Brilliant) in a horizontal row.
- Fun-sorter: A tool for comparing the fun of activities, comprising a grid where rows represent characteristics of activities (e.g., Most fun, Worked the best) and columns are used sort activities from best to worst.

Engagement is measured using video annotation using a set of positive and negative instantiations.

- Positive: smiles, laughing, concentration signs (fingers in mouth, tongue out) excitable bouncing, and positive vocalization.
- Negative: frowns, signs of boredom (ear playing, fiddling) shrugs, and negative vocal instantiation.

In Endurability, two facets were measured:

- Remembrance (only relevant in a comparative fun study): A blank sheet of paper with the prompt 'What did we do?'
- Returnance (desire to do again an activity that has been fun): A table (*Again-Again Table*) entitled 'Would you like to do this again?' which lists activities on the left hand side, and has three columns headed Yes, Maybe, and No.

The Smileyometer (Read et al., 2002) was also used by van der Sluis et al. (2012) to evaluate the enjoyment of children during a quest through a science museum with children 7-15 years old. They conclude that using pictures can provide a reliable scale, and in particular for older children, give fine-grained results.

A Funometer-like (Risden et al., 1997) vertical scale to aid children in answering the question "How fun do you think this game will be?" was employed by Hanna et al. (2004) in the context of an exploratory research on how to evaluate concepts for new computer games with eight- and nine-year-old children.

To evaluate the fun level of a computer game for children between 8 and 14 years old, Obrist et al. (2009) combined 3 different methods:

- They extended the "funometer" (Read and MacFarlane, 2006) to make it easier for children to differentiate between the fun levels.
- They had a question to measure the willingness to play the game again (yes / maybe / no).
- To investigate some aspects of fun (challenge, fantasy, and curiosity), participants were asked to pick from a list of words the ones that best describe the game. The list included words related to both negative / non-fun experience (e.g., boring, confusing, difficult, ugly, bad, childish) and positive / fun experience (e.g., exciting, fun, simple, beautiful, great, surprising).

It should be noted that various studies (Breakwell, 1995; Bruck et al. 1995; Obrist et al., 2009; van der Sluis et al., 2012, Read, 2012) have identified a bias regarding younger children, who tend to provide more positive feedback than older children.

The tools and methods presented above could be applied in educational context as well.

3.3 Conducting case studies: general approach

Case studies are a widely used research method within a number of disciplines (see also D1.1 Section 3). Even if use of case studies as a methodology includes a lot of variety, there are also certain criteria to be met. Hence, in each of our case studies, the following criteria need to be met in order to conform with the overall investigative design (see e.g. Benbasat, Goldstein & Mead, 1987; Eisenhardt, 1989; Myers, 2009; Yin, 1994). The case studies are eligible for inclusion in our research study if:

- they are conducted in a natural setting,
- their focus is on contemporary events,
- multiple methods of data collection are utilized, and
- no experimental control or manipulation is used.

Moreover, the following aspects should be considered in each case study to the extent feasible: The case studies need to acknowledge the context in-depth and in multiple senses – social, physical, cultural, historical, economic, political, ethical, aesthetic, and so forth. The case studies are to be holistic in nature – a comprehensive examination of complexities involved is needed. Then again, one also focuses on specific characteristic of each case: letting the case to tell its story is important. Both qualitative and quantitative data will be collected, with the emphasis on the qualitative dataset (Benbasat, Goldstein & Mead, 1987; Eisenhardt, 1989; Myers, 2009; Yin, 1994).

There is variety in the researcher position each partner can adopt in the case studies: a researcher can act as an 'outsider observer' or as an 'involved researcher' in case studies (Walsham, 1995). As an outsider observer, the researcher is examining the informal science learning practice as an outsider, who does not have 'a direct personal stake' in the outcomes and interpretations (Walsham, 1995: 77). As an involved researcher, then again, the researcher is actively involved and shaping the activities under examination, i.e., acting as a member in the community studied. Both roles have pros and cons. As an involved researcher, richer and more in-depth understanding from study participant perspective may be gained, but also more biased and subjective one, whereas as an outsider observer, more objective and neutral understanding is more likely gained, while lacking in richness and insight.

Data will be collected from three major sources, reflecting researcher perspective (observational narrative), practice centric perspective (interviews using existing protocol with a focus on gaining access to meta-reasoning about the expected/desired effects of the activity/practice), and learner perspective (either collected through the app/game thus accessing partial metrics of science capital, or through interviews with a focus on experience within the context of COMnPLAY project).

3.4 Mixed methods approach

The methodology selected for the case studies in COMnPLAY project is a mixed methods approach. Mixed method approach is "an approach to knowledge (theory and practice) that attempts to consider multiple viewpoints, perspectives, positions, and standpoints (always including the standpoints of qualitative and quantitative research)" (Johnson et al., 2007: 113). Mixed methods research is "an intellectual and practical synthesis based on qualitative and quantitative research; it is the third methodological or research paradigm (along with qualitative and quantitative research). It recognizes the importance of traditional quantitative and qualitative research but also offers a powerful third paradigm choice that often will provide the most informative, complete, balanced, and useful research results." (Johnson et al., 2007: 129)

For this project, we will utilize mixed methods approach that utilizes both quantitative and qualitative data collection and analysis methods, such as interviews (individual and group, see Appendix E, F, G), observation (see Appendix D), collection of artefacts, surveys (see Appendix A, F, G, J, K), logging of user activities, usability and user experience evaluations (e.g. existing survey instruments, thinking aloud protocol), fun evaluations (see section 2.2. and Appendix K) and self-reflection activities (see Appendix H).

The data collection methods result in the following types of data (depending on each country's national regulations and local constraints regarding the personal data protection policy):

- video and audio recordings,
- log interactions,
- survey responses,
- artifacts, objects, products created by the study participants,
- observational notes, fieldnotes, providing detailed reports of the outcomes on a regular basis,
- self-reflection activities and reports created by the study participants.

This data is collected to examine the following aspects:

- Functional and usability characteristics of technology used (e.g. the mobile app, games),
- Science capital,
- Learning outcomes, knowledge and skills,
- Participation and engagement with coding, making, and play activities and the system,
- Fun,
- Attitudes, values, and dispositions,
- Practices,
- Creativity,
- Empowerment,
- Impact on science learning and society.

The data collection methods can be used flexibly to examine the aspects above, while the following general guidelines can be given on their suitability:

- Surveys enable measuring usability, fun, knowledge, science capital;
- Observation, artefact collection and coding and making activity variables enable measuring progress and knowledge obtained, participation, engagement, practices, creativity;

- Interviews, checklists, self-reflection tools and thinking aloud protocol enable measuring participation, engagement, learning, fun, attitudes, values, dispositions, creativity, empowerment, practices, and impact.

3.5 Multi-phase structure in the case studies

To follow the principles of participatory and learner-centric research, the study design builds on a multi-phased structure in which data is collected and then analysed and synthesised in collaboration with learners and practitioners through a series of data analysis and reflection activities where partial results are re-analysed and confirmed through direct involvement of the learners and practitioners whenever possible.

To capture aspects of practices in a flexible and inclusive manner we adopt a multi-phase research approach (Figure 1) based on the methodological framework established in D1.1. This approach is not possible in all our case studies but it is used whenever feasible. See also Appendix 1 and Appendix 2 for examples on how the partners plan to conduct their case studies.

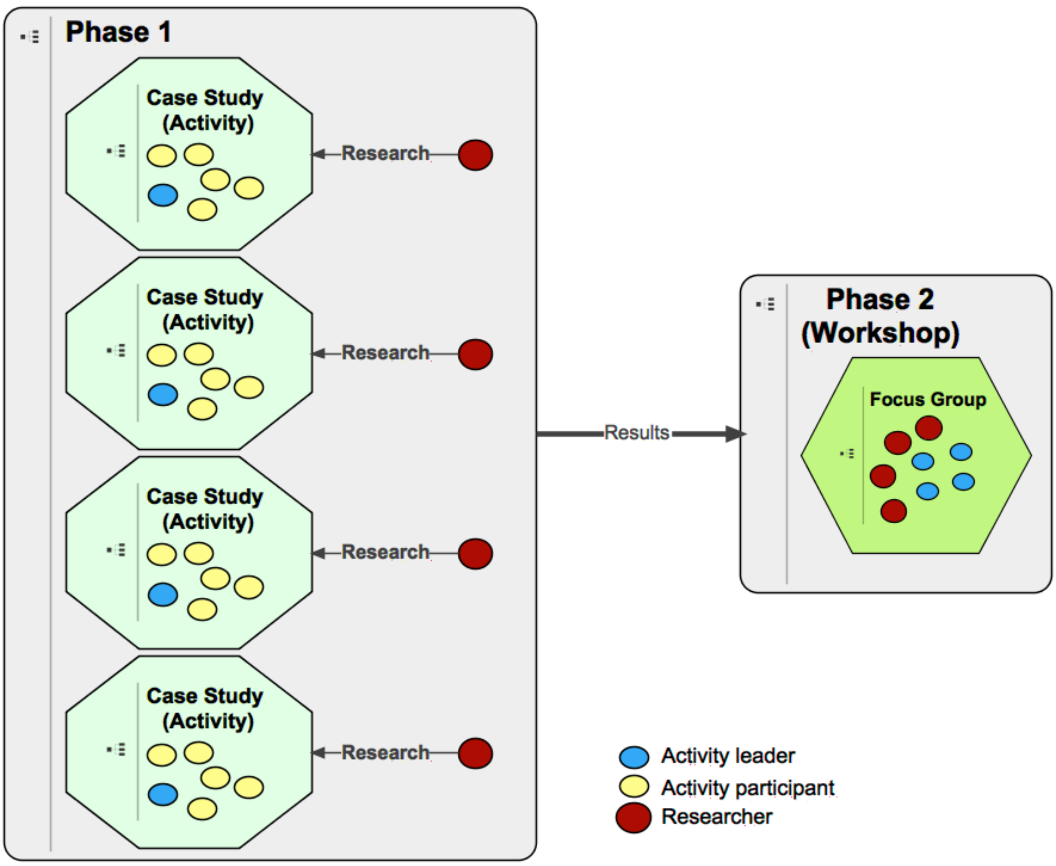

Figure 1. Multi-phase research approach

3.5.1 Phase 1

The researcher conducting the study may be participating as a leader, participant observer, or pure observer in the activity under study.

Before the activity, the researcher collects background data (e.g., intended outcomes) about the activity by interviewing an activity leader/designer.

During the case study, the researcher continuously and iteratively collects, depending on the case study, for example:

- survey data for measuring usability, fun, knowledge, science capital;
- observational data, artefacts, game play videos, coding and making activity variables for measuring progress and knowledge obtained, practices;
- interview data, self-reflection data and thinking aloud data for measuring participation, engagement, learning, fun, attitudes, values, dispositions, practices, and impacts.

For collecting survey data utilizing the mobile game, see Appendix A. For science capital instrument see Appendix J. For collecting observational data on informal science learning practices, see Appendix D. For conducting interviews in case studies, see Appendix E. For collecting interview data about the nature and impact of informal science learning practices with participating adults and children, see Appendix F and Appendix G. For collecting self-reflection data, see Appendix H. For facilitation and evaluation of fun, see Section 1.2. and Appendix K.

Expected outcome from this phase: Rich description of the nature of informal science learning, impact on science learning, and impact on society.

Example aspects:

- Which participants are reached (broadened participation of widening the gap, lightweight SC)?
- What the activity entails – what, where, when, how?
- How did the participants learn about the activity and why did they participate?
- What did they learn and how does it relate to curriculum?
- Does the activity have an impact on the participants (increased SC: attitude towards science, career aspirations, increased self-efficacy in science)?
- If the participants enjoyed the activity – why/what about it – otherwise – why not?
- Levels of engagement and collaboration e.g. among participants and between participants and facilitators.

It is important to relate the actual outcomes to intended outcomes.

3.5.2 Phase 2

Focus groups consisting of activity leaders/designers and researchers having studied the activities meet to hear presentation of activities and research outcomes. Activities, research outcomes and conclusions are discussed.

Expected outcome from this phase: Additional data, increased reliability in interpretation of results and conclusions, dissemination of results.

4. Sampling

In sampling, equity relating to gender, age, other cultural, socioeconomic, and geographical differences and relevant risks of disadvantage and exclusion that may feature in science education and affect a young person's science capital are taken into consideration (see D2.1).

Appendix A: A mobile game for measuring science capital of participants

As part of the project, a mobile game (Steamo) for measuring science capital is under development. The game contains the same survey questions as presented in APPENDIX J.

When the game is finished, guidance will be provided for how to use the app so the project partners can implement it as part of their studies: how to download the game and how to get the correct language version into use.

An online version of the game exists but only the most current versions of the browsers (Firefox, Chrome, Safari) are supported.

Exemplary scenarios for how to use the game as part of case studies:

- **First scenario**: If there is enough time, have participants read the stories before the study which means that they will answer the questions as a context to the stories. Then have them do the survey deck with all survey questions at once at the end of the study. This might catch a change of mind of participants.
- **Second scenario**: If there is enough time, have participants do the survey deck before the study. Then have them read the stories at the end of the study. This might catch a change of mind of participants.
- **Third scenario**: Have participants do the survey deck before the study and leave it free to them to read the stories afterwards (at home).
- **Fourth scenario**: Have participants do the survey deck after the study and leave it free to them to read the stories afterwards (at home).

As for the story, you can use the app description text (or a simpler version of it) in order to introduce Steamo/the COMnPLAYer app to the participants:

The COMnPLAYer app will help you discover and learn about science and will also enable you to have your say on what it actually means to you. With the active (and fun) support of Steamo, the quirkiest AI Life Coach in the world, you will experience, explore and play with science! The app comprises high quality interactive content developed by a European-wide group of experienced scientists and educators.

Appendix B: An example procedure for a case study, example 1

This is an example of how one of the partners (NTNU) plans to conduct their case study. The activity of NTNU's case study consists of two main parts, interaction with the robots and creating games with Scratch; Figure 2 depicts the flow of these two parts and an early version of this activity can be found in Papavlasopoulou, Sharma & Giannakos (2018).

First of all, each of the children will receive a device that will give them access to the mobile application developed in the COMnPLAY SCIENCE project (i.e., Steamo, see Appendix A). Children will have an adequate amount of time to play with the app and fill in some pre-surveys. After children have engaged and familiarized themselves with Steamo, then, they will engage with the two phases of NTNU's coding activity.

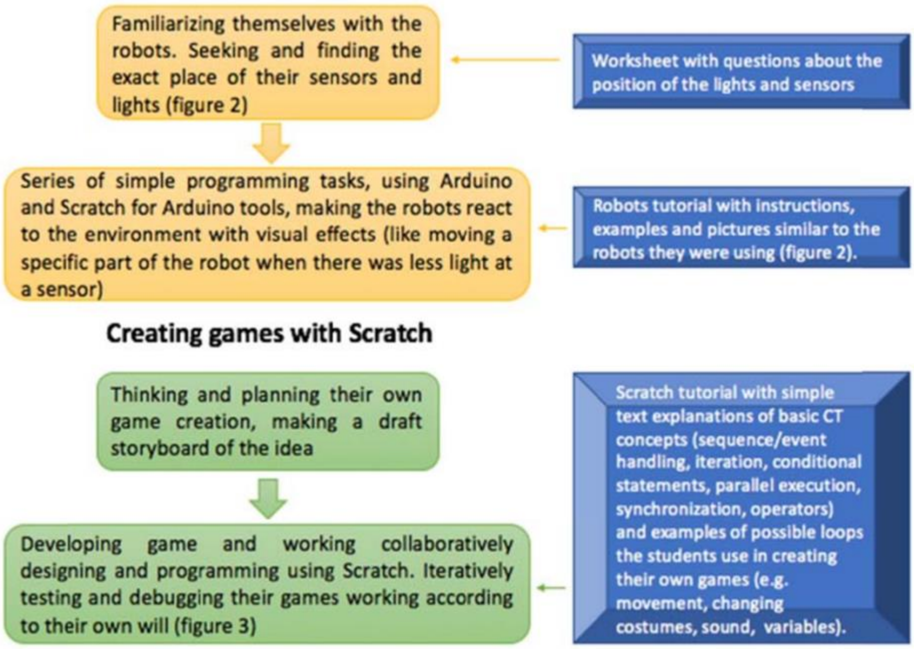

Figure 2: Description of the sessions' activities

The first phase is **Interaction with the robots:** During the first part of the coding activity, the children interact with digital robots built by an artist using recycled materials, mainly from computer parts. First, as the children enter the room and are welcomed by the assistants, they sit in teams next to one robot. The assistants give a brief presentation of the activities and ask each of the children to pay attention to a worksheet placed on the desk next to them. The goal is to familiarize themselves with the robots by filling in simple questions regarding the exact place and number of the sensors and lights on the robots. Then, the children use a paper tutorial with instructions (Figure 3) for how to make the robots react to the physical environment with visual effects using simple loops of Scratch for Arduino (e.g. to make the tongue of the snake robot move when there is less light at a sensor). Children's work in teams and independently to complete this task (Figure 4 left). The duration of the first part varies from 45 to 90 min. When all the teams have finished, the children have a break before the next section begins. This part of the workshop offers a smooth start to coding, including tangible objects. The interaction with digital robots provides a better understanding of STEM subjects by showing the connection with the physical world, helping the children to cope with difficult problems (Bakker, Van Den Hoven & Antle, 2011). The children are introduced to coding by playfully interacting with the robots while they get motivation and inspiration.

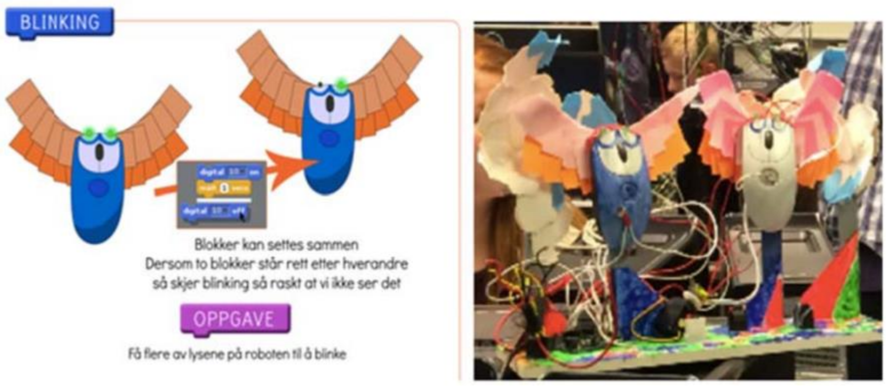

Figure 3: Example of the robots' tutorial on how children interact with robots.

Then, children will have a semi-structured session, in this session they will interact with Steamo and fill in a mid-survey. Besides the given survey, children will be able to interact with Steamo in a more flexible manner.

The second phase is **creating games with scratch:** This section describes the main activity that lasts approximately three hours, without the presence of the robots. The goal is to successfully develop a simple game, coding in Scratch. To achieve this goal, the assistants give another paper tutorial with examples of all the basic Computer Science (CS) concepts and possible loops they should use to complete their own game. The assistants advise the children how to manage the process of game development, working collaboratively. First, they should think about and decide the story for their game and then create a draft storyboard. When they finish that, they start coding using Scratch. The children can ask for support from the assistants whenever they need it throughout the activity. The assistants offer their guidance to the teams, helping them to complete their games and introducing even more complex CS concepts when needed. Finally, after the completion of the games, the children reflect and play each other's games (Figure 4 right).

Figure 4: Children interacting with the robot (left) and example of developed game (right).

At the end of the activity, children will have again a semi-structured session, in this session they will interact with Steamo and fill in an exit-survey. Besides the given survey, children will again be able to interact with Steamo in a more flexible manner, this will allow us to collect various interactions with the app that will have relatively good ecology.

Appendix C: An example procedure for a case study, example 2

This is an example of how the University of Malta, Institute of Digital Games (IDG), one of the COMnPLAY SCIENCE partners, plans to conduct their case study.

The IDG has extensive experience in designing, developing, and researching games for learning domain-specific content and developing communication and collaboration skills. It has also organised a number of training events, workshops and playtesting events involving children, young people, educators, practitioners and stakeholders. For such events and activities participants are invited to play with specific digital games. In these cases, although the games employed do embed learning content or the acquisition of knowledge and skills, the activity is not originally intended as a science learning activity (see Illustration 1).

The case study for COMnPLAY Science project will be specifically targeted to studying themes and concepts of the project such as fun, engagement, scientific literacy, critical thinking, and attitudes to science emerging from such type of non-formal activities and events involving playing digital games. It will involve children and young people aged 11-19 y/o. The participants will be invited to play with specific digital games relevant to the scientific literacy and reflect on the emergent meaning of the game and their emotions. The study will also focus on the study of the behaviour, the interactions among the participants and the social context during the gameplay activity.

Research has linked gaming practices to scientific learning and STEM education not only as media through which players can explore and understand the learning content but also as artifacts that can trigger the interest in science and technology (Biles, 2012; Bricker & Bell, 2012; Jeremiassen, 2018; Mayo, 2009). The cultural context and the social networks and communities within which the gaming practices are situated also seem to be of interest either as a framework supporting the gaming and learning practices or as emerging communities of practice spontaneously formed by the players (Williamson & Facer, 2004). In addition, gaming literacy and game preferences seem to also be strong predictors for understanding the models embedded in a game, science understanding, and the development of scientific citizenship (Fraser, Shane-Simpson, & Asbell-Clarke, 2014; Gaydos & Squire, 2012).

The gaming activities of the case study will take place at the University of Malta Campus and/or in the context of outreach activities such as local science fairs and exhibitions (Science in the City, Note Bianca), visits to local schools and colleges.

Initially, the participants will either receive a mobile device or use their own mobile phones to access and engage with the mobile application (i.e. Steamo). They will further fill in the pre-surveys of the study (e.g. demographics, game literacy, game preferences).

They will then be invited to play any of the selected games. Examples of games that will be used include environments developed by the UOM in the framework of research projects, or commercial games. For instance:

- **“ENVISAGE”**: online virtual labs developed for the ENVISAGE project (http://www.envisage-h2020.eu/). Emulates real laboratories where students can accomplish a number of learning tasks which are mainly oriented towards subjects such as physics and chemistry (Science learning goals)
- **“Village Voices”** (http://ecrisis.eu/): the participants have to engage in tasks involving understanding of processes and interdependence of factors and variables, solving problems, be critical, make decisions, and creative thinking
- **"while True: learn()"** (https://luden.io/wtl/): educational game developed by Luden.io to teach machine learning. It is a simulator of a machine learning specialist who uses visual programming to make his living.

After the gaming activity, the participants will annotate the recorded videos of their gameplay using the *PAGAN platform* (see Appendix H) by reflecting on their own emotions and thoughts while watching the video.

Finally, a semi-structured interview (or focus groups) will be conducted with the participants where they will be encouraged to discuss about their experience, their understanding, and their perceptions on the potential learning benefits of the games they played (what they thought the learnt while playing the game). They will also fill-in the post-survey.

Qualitative and quantitative data will be collected from the mobile application (depending on the level of accessibility to the game code), the pre and post surveys, the interviews, the observation (field notes, video recordings) of the gaming activity, and the video annotation session (log files).

This study allows to examine the gaming events and activities from the perspective of the players, the learners, and their intuitive understandings of the games, and also as social spaces.

Appendix D: Observation in the case studies

Each partner will collect data by observing during the case studies. Observation entails going into a social situation and seeing and listening to what is going on. As a result, each investigator describes their experience of the practice from a personal perspective, creating a thick description that can be used as a basis for later analysis in conjunction with others. This will result in thick descriptions, experiential narratives of practices, capturing aspects of the practice that emerged as surprising or noteworthy to the researcher.

Following previous research in the field of informal learning (Shah, Wylie, Gitomer, & Noam, 2018), video recording are recommended for data collection as well as keeping of field notes. Researcher field notes should include facts about what happened but also own thoughts, feelings, interpretations and experiences.

There is variety in the data collection as regards the researcher role: the researcher can act as a passive observer trying not to influence the activities in any way, or the researcher can act as a participant observer, in which case the researcher is actively taking part in the activities studied (learning by doing or even instructing the research participants).

Important is to remember that through observation the researcher learns what people do but does not necessarily learn why they do things (this way) nor how they think and feel while doing things. Hence, interviews are needed to complement the observational data.

During observation of informal science learning practices, the researchers should pay attention to the following aspects (see Ventä-Olkkonen, 2017; Nicolini, 2012):

- Performances: what people are doing and saying, who are involved, where and when
- Material aspects involved: the space, artifacts, tools, bodily choreographies.

In addition, the following aspects may be noted by observing (also by a survey), even if interviews are needed to study these aspects as well:

- Aim of the practice: why people are doing and saying these things, what are the motives
- Creativity of the practice: is there creativity and change involved in the practices, are they modified and evolving in time and place
- Durability of the practice: is there a community of practice involved, how do people learn the practice, how the artifacts and tools used contribute to the durability of the practices
- Effects of the practices: what kind of effects are these practices having on people's lives and other practices, how other practices are affecting the practice in focus, are existing social arrangements being reproduced or are there tensions or conflicts involved
- History of the practice: how it has been shaped, by whom, how the practice ended up being like this

- Discourses circulating around: what kinds of discourses (ways of talking about things) are shaping the practice as well as being shaped by the practice

Advisory Note: Due to the extremely diverse set of activities selected for observation in the COMnPLAY study developing a holistic observation protocol was determined to be unrealistic and too cumbersome to deploy in practice. However, observation is an important aspect of the mixed-methods approach deployed in this study. Access to best practices relies on the ability to understand the nature of an activity in its context, and consequently judge the suitability of aspects of that activity for deployment in another context.

To collect relevant information about the practices we are observing, we suggest that each study develops an approach to observation that results in a reflective narrative surrounding the activity and its implications in regard to the primary research questions. This approach draws on the "thick description" technique (See Ponterotto, 2006 and also Geertz, 2008 for additional explanation of the method). The reflective narrative approach consists of three parts:

1. An observation of the practice under investigation following the guidelines in Ponterotto.
2. A reflection relating aspects of practice to the research questions identified for the work-package (see the first section of this protocol advisory for details).
3. An executive summary of the analysis indicating the key observations which are considered relevant to the transfer of that practice to other contexts.

Observations of the

- nature of the activity can include
    - task - e.g., coding, designing, inventing, many small tasks, one larger task
    - type - e.g., collaborative, competitive
    - organisation - number of leaders, number of participants, division into smaller teams/units
    - scheduling - how much time is spent on the activity, breaks
- participants can include
    - participant age
    - parents' engagement
- educational setting can include the aspects
    - mood - e.g., happy, playful, focused, frustrated
    - participant activity - e.g., talking, thinking, typing, building
    - interaction - e.g., group work/discussions, scaffolding, no interaction
    - engagement - e.g., all participants engaged, some participants more active than others, a few participants very engaged, changes in engagement over time

Appendix E: Interviews in the case studies

Each partner will collect data by interviewing during the case studies. Interview entails collecting research data of interest by discussing with research participants – researcher has at least figured out a theme or topic for the discussion if not a full list of questions. Interviews are based on interaction between the researcher and participants. Researcher flexibility and sensitivity are needed during interviews: reacting to new and interesting information as well as to the situational aspects and atmosphere. As a result of interviews, study participants, both adults and children interviewed, will have a voice in the research process: they will be able to describe issues related to the research topic in their own words. Interviews enable generation of rich data, new perspectives and insights, and thorough understandings.

There is variety in interviews: they can be individual or focus group interviews and they can range from highly structured to very open. In individual interviews researcher can discuss the topics in depth with each individual and concentrate on his or her perspective and insight. This is recommended especially for sensitive topics. In group interviews the participants may stimulate but also dominate others. Not too sensitive subjects and a homogenous group of interviewees is recommended. Structured interviews follow a set of questions in a specific order. This may be useful, e.g., if response rate is poor with survey research. However, usually interviews are semi-structured, i.e. a set of questions or themes is identified but new ones can be added, the length of discussion around each can vary and the order is not fixed. In an open interview, only a general theme might be planned, and the discussion can flow to any direction. For this project, semi-structured interviews are recommended.

Audio and video recording are recommended during interviews.

Important is to remember that through interviews researcher learns what people say they think, feel and do as well as why, but does not necessarily learn what people do and their sayings can also be biased in many ways (socially desirability, courtesy etc.) Hence, observation is valuable to complement the interview data.

During interviews addressing informal science learning practices, one can address any of the following:

- Functional and usability characteristics of the prototypes (mobile app and platform),
- Science capital,
- Learning outcomes and skills,
- Participation and engagement with coding, making and play activities and the system,
- Playfulness and fun,
- Attitudes, values, and dispositions,
- Practices,
- Creativity,
- Empowerment,
- Impact.

However, particularly for research on attitudes, values, and dispositions, interviews are highly recommended. For research on learning, participation, engagement, playfulness, fun, creativity and empowerment, interviews provide valuable data complementing observational data. For research on practices, interviewing enables particularly focus on (see Ventä-Olkkonen, 2017; Nicolini, 2012):

- Aim of the practice: why people are doing and saying these things, what are the motives.
- Creativity of the practice: is there creativity and change involved in the practices, are they modified and evolving in time and place.
- Durability of the practice: is there a community of practice involved, how do people learn the practice, how the artifacts and tools used contribute to the durability of the practices.
- Effects of the practices: what kind of effects are these practices having on people's lives and other practices, how other practices are affecting the practice in focus, are existing social arrangements being reproduced or are there tensions or conflicts involved.
- History of the practice: how it has been shaped, by whom, how the practice ended up being like this.
- Discourses circulating around: what kinds of discourses (ways of talking about things) are shaping the practice as well as being shaped by the practice.

Appendix F: Semi-structured interview guide for participating children to assess the nature and impact of the activity + related survey questions

Aims of the interview and survey

The aim is to understand the effects of informal science learning on formal science education and to understand the contribution of informal science learning towards scientific citizenship

- Attitudes, values and dispositions towards science, scientists and science-related information
- Potential for more scientifically informed behaviours and decisions
- Potential for involvement in citizen science
- Potential for better linking of science to societal needs and concerns

The questions cover general research aims to be explored in all case studies. This is a minimal set of questions that allow researchers to add questions that are specific to the activity under study. If a question is clearly irrelevant for a particular activity, it should be rephrased or removed. However, the remaining set of questions must still cover the general research aims.

Interview questions

[Participants own description of the activity and their participation]

- What did you do in the activity?
- Did you enjoy it? What was fun/interesting? What was not/less fun?
- Did you learn something new? What? How/when do you think your new knowledge can be used?

[Relation to formal education]

- Was this different from what you (usually) do/learn in school? How?
- Do you think what you learnt will help you do better in school? How?

[Contribution towards scientific citizenship]

- How could you use what you did here in the future?

[Attitudes]

- Would you like to do something like this again?
- Would you recommend/tell a friend to go to this activity? What would you tell your friend about it?

- Would you like to have a job where you do something like this when you grow up? What would you do?

[Perception of the activity]

- Was there something hard about what you did?
- What was the easiest part of the activity for you? How/Why?
- Was there some frustrating/irritating part of what you were doing?
- If you were to suggest how the activity could become even better, what would you say?

Survey questions

What were you doing in the activity? (multiple choice, choose all that fit)

- Coding
- Making
- Playing
- Meeting friends
- Meeting new people
- Solving puzzles
- Learning
- Creating
- Competing
- Working in a group
- Working alone
- Having fun
- Thinking
- Reading
- Listening
- Talking
- Moving around

What do you think about the activity? (multiple choice, choose all that fit)

- Fun
- Boring
- Interesting
- Difficult/Hard
- Useful
- Too long
- Too short

Questions on a scale of enjoyment (place a mark between the sad and happy face indicating how you feel):

Did you learn something new today?

☹--☺

Will what you learned today help you do better in school?

☹--☺

Will what learned today help you in your everyday life?

☹--☺

Do you have similar activities in school? (Y/N)

Would you like to do something like this again?

☹--☺

Would you recommend this activity to a friend?

☹--☺

Would you like to have a job where you do something like this when you grow up?

☹--☺

Additional interview questions

How did you get involved in this activity?

Could you tell me briefly what do you do?

How long have you been involved in this activity?

What type of education or training, if any, do you have as a background?

What motivates you to engage in these activities? Why do you want to do this?

How would you characterize people like yourself and what you do?

Could you describe what happens in your (typical, recent) activity/project? Please describe all the participants involved (adults and children): children's ages, group size, how they become participants, adults' roles

Please describe the space, and the materials and tools used

Can you tell me a little bit more about why you do it like that?

Do you think the activities are "fun" or "playful"?

How important is fun in the activities?

How important is playfulness in the activities?

If applicable: why do you experience the activities as fun?

If applicable: why do you experience the activities as play(ful)?

What do you like/enjoy most during the activity?

What are the main difficulties/issues/challenges you face? Can you tell me how you have tried to resolve these?

What do you think is the easiest part in the activity?

What frustrates you the most in the activity?

What impresses you the most in the activity?

Do you learn collaboratively? Do you feel that you are actively part of collaboration in the team during the process? How do you feel about the collaboration in your team?

How much do you think you contribute in the team/do you feel that your opinions are taken into account by the team members?

What do you think you learn during the activity? What do you gain through participating in this activity?

Appendix G: Semi-structured interview guide for facilitators to assess the nature and impact of the activity + related survey questions

Aims of the interview and survey

The aim is to understand the effects of informal science learning on formal science education and to understand the contribution of informal science learning towards scientific citizenship

- Attitudes, values and dispositions towards science, scientists and science-related information
- Potential for more scientifically informed behaviours and decisions
- Potential for involvement in citizen science
- Potential for better linking of science to societal needs and concerns

Interview questions

[Facilitator's own description of the activity and their role in it]

- What did the participants do in the activity?
- Do you think they enjoyed it? What was fun/interesting? What was not/less fun?
- Do you think they learned something new? What? How/when do you think their new knowledge can be used?

[Relation to formal education]

- Do you think this is different from what the participants (usually) do/learn in school? How?
- Do you think what they learnt will be useful for them in school? How?

[Contribution towards scientific citizenship]

- Do you think what they learnt will be useful in their everyday life? How?

[Attitudes]

- Do you think they would like to participate in more/other activities of this kind?
- Do you think they would recommend/tell a friend to go to this activity? What do you think they might say to their friend about it?
- Do you think that the activity could have had an impact on participants' future career aspirations?

[Perception of the activity]

- Did you get suggestions on how the activity could be improved, what did they say? What do you think about the suggestions?

Survey questions

What did the participants do in the activity? (multiple choice, choose all that fit/at most 5?)

- Coding
- Making
- Playing
- Meeting friends
- Meeting new people
- Solving puzzles
- Learning
- Creating
- Competing
- Working in a group
- Working alone
- Having fun
- Thinking
- Reading
- Listening
- Talking
- Moving around

What is your main impression of how the participants experienced the activity? (multiple choice, choose all that fit/at most 2-3?)

- Fun
- Boring
- Interesting
- Difficult/Hard
- Useful

Do you think they learned something new today? (Y/N)

Do you think what they learned today will help them do better in school? (Y/N)

Do you think what they learned today will be useful in their everyday life? (Y/N)

Do you think they have similar activities in school? (Y/N)

Do you think the participants would like to participate in more activities of this kind? (Y/N)

Do you think that the participants will recommend/tell a friend to go to this activity? (Y/N)

Do you think that the activity could have had an impact on participants' future career aspirations? (Y/N)

Additional interview questions

1. 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 characterize 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?
  - 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)?
- 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 to me?

Appendix H: Examples of self-reflection methods

Reflect over your experience

Material needed: Paper, pencils, markers and post-its. **Time**: 1-3 hours.

These two tools are for the evaluation facilitate a final team reflection, whereby more informally, participants can share what they wish. Dedicate time to this final group moment because the most valuable reflections will probably appear in this moment.

- **Anecdotes**: Ask participants to draw an anecdote which has occurred to them during the practice and which awakens emotions. Share these drawings, discussing each anecdote or sticking them on the wall so that the whole group can see them.
- **Different, Difficult, Learnt**: Divided in groups of three, propose participants to reach a team consensus over something that they have felt seemed different, something difficult, and something that they have learnt during the experience. Ask them to write it on a post-it and to stick it on three panels in which the following questions appear: What has seemed different? What has seemed difficult? What have we learnt? Then, they are read out loud and discussed together.

Make your project evolve

Material needed: Markers and post-its. **Time**: 30 min - 3 hours

This tool is meant to identifying those aspects that could have worked better or worse.

This method allows the participants to understand what has worked in the practices and what has not. It's an excellent moment for the reflection of the group, and it can be very useful to establish the foundation for future projects.

- **Start/Stop/Continue:** Divided in three groups, suggest your students to reach a team consensus in terms of three aspects. Firstly, something that has not been done during the practices which they would have liked to have done (START); secondly, something that has been done but they consider that is worth leaving and not doing (STOP); lastly, something that has been done and that is valuable to continue doing (CONTINUE). Ask them to write each aspect on a post-it and to stick it on three panels, each one belonging to each block (START/STOP/CONTINUE). Afterwards, you can read them out loud, and discuss it with all the group.

PAGAN: Platform for Affective Game Annotation

PAGAN is an online platform allowing efficient first- or third-person continuous video annotation. The user can upload a video (e.g. of a recorded gameplay from a play session, in .mp4 format), and annotate in real-time, while watching the video, the perceived intensity of a single emotional dimension (e.g. fun, tension, challenge, stress) elicited from the video. This emotional dimension is defined by the user (or the researcher) before the annotation session begins (see Illustration 2). The annotator is using the arrow keys of the keyboard (see instructions in Illustration 3), or other input devices as will be described later, to label the video. Through this platform self-reports are therefore collected of the annotators' perceived experience while watching a recorded gameplay video they or someone else previously played.

Participants of the case studies will play specific videogames and then use the PAGAN platform to annotate the videos of their own (or others') gameplay in relation to a specific concept or emotion (e.g. engagement, fun, frustration). This process allows for the self-reflection of the participants on their own actions. Annotations about the gameplay experience are obtained directly from the players allowing for a more player (learner) centred approach for the study of an activity in accordance with the project's core research concepts (e.g. participatory and learner-centered approach).

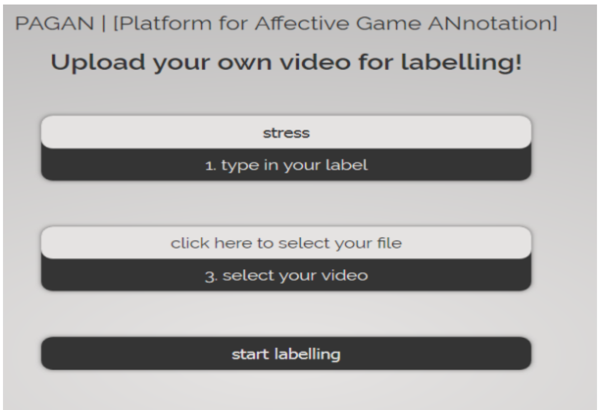

Illustration 1. The first step of video annotation. The user defines the label (e.g. emotion to be recorded), selects the video, and starts the annotation

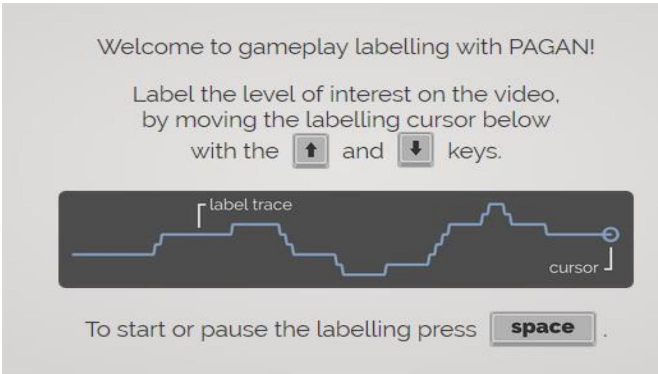

Illustration 2. Guidelines for the users. The emotion set for this annotation is the "interest". The user labels a video using the arrow keys

The annotation is not binary or categorical (e.g. the presence or not of an emotion and any point) but rather relative and ordinal as the user annotates the increase or decrease of the specified emotion throughout the video. The changes of affect over time are, therefore, recorded as a continuous trace. During the annotation, the annotators can observe their own annotation trace over time without being bounded by predefined scales and measures.

The annotation data is stored and can be later analysed in comparison with the gameplay video annotated to identify, for instance, game events that triggered, increased or decreased the specified emotion.

The effectiveness of the annotation method implemented in the PAGAN platform regarding the recording of perceived emotion has been established by previous research in the field of affective computing as well as psychology. Emotion and its intensity is perceived by the individual in relation to his or her previous experiences and the context. Annotation of emotion in relative and ordinal terms has further been found to be a more valid and reliable method for modeling affect compared to interval, categorical, or nominal annotation involving constraining absolute scales. A continuous annotation signal which is treated as a relative (ordinal) variable has higher validity and with higher predictive capacity. This tracing method has been described by Lopes et al. (2017), where the researchers used horror games gameplay videos to annotate the user's tension levels by watching their video-captured playthroughs. Another example of the implementation of this tool and annotation approach in research for affect modeling is described in (Camilleri, Yannakakis, & Liapis, 2017) where the self-reported continuous annotations of arousal were mapped to gameplay and physiological features across games. For a full review of the theoretical background on recording affect and for comparative studies see (Yannakakis, Cowie and Busso, 2018).

Combination with data from other hardware devices: Input from other devices, such as a bracelet measuring skin conductance, can also be combined with and compared to the user's annotations. Such biometric data can be analyzed in combination with and tested against the self-annotation data so that the researchers can obtain a complete and more objective view of the user's (player/gamer) experience. Alternative input devices for annotating the video can also be used such as the Griffin PowerMate wheel interface (Illustration 3). Such devices allow the participants to increase or decrease the emotional intensity while watching the video, intuitively and with low fatigue and cognitive effort.

Illustration 3. Griffin PowerMate wheel interface

Although the PAGAN platform is focused on videogames, the platform can be used to label (annotate) any type of video content.

Appendix I: Example of a consent form for adults, following GDPR

INFORMED CONSENT FORM

This document gives you information about the interview you are invited for on the topic of informal/non-formal science education. Before the interview begins, it is important that you learn about the procedure followed in this study and that you give your informed consent for voluntary participation. Please read this document carefully.

Title of the study: Interview with informal/non-formal science education practitioners

Purpose of the study: The interview is a part of the studies carried out by the COMnPLAY SCIENCE project. The project aims to understand the new ways in which non-formal and informal science learning is taking place through various coding, making, and play activities, outside school and higher education science classrooms, beyond the formal boundaries of science education. The purpose of the interview is to gather a deep understanding of the informal/non-formal science learning practices and ongoing activities.

Procedure and duration: The one-to-one interview will be conducted by Skype. The duration of the interview is approximately 30 minutes, which can eventually be extended up to 60 minutes.

Potential risks and benefits: The interview does not involve any physical or psychological risks nor is it physically or psychologically beneficial. It is not possible to get compensation for the participation.

Withdrawing participation: The participation is totally voluntary and it may be withdrawn at any time for any reason without explanation and negative consequences.

Confidentiality: The interview will be audio recorded. The audio record will not be distributed and will not be played back in the presence of persons other than the researchers. The material will be used only for scientific analysis. The information that we collect from this study is used for writing scientific publications. It will be completely anonymous and it cannot be traced back to you. Only the researchers will know your identity.

Certificate of consent:

I have read and understood the foregoing information and I have had the opportunity to ask questions. I agree to voluntarily participate in this interview.

Participant's name and signature, date

Contact information for the researchers

Appendix J: Science capital questionnaire

This survey measures science capital level. The scoring rubric is linked to the longitudinal data set collected in the UK, which provides a validation for the results gained through this survey.

When translating the questions to other languages some minor changes will have occurred in the translation process as some terms/phrases do not make sense in other languages.

The survey can be used separately as a pen and paper tool. The same questions can also be found in the Steamo game (see APPENDIX A).

Questions:

With which gender do you most identify?

- Male
- Female
- Not listed [option here to insert own description]
- Prefer not to say

Are you:

- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- Age not listed

How much do you agree with the following? It is useful to know about science in your daily life and in the future

- Yes, I strongly agree
- Yes, I agree
- I am undecided
- No, I disagree
- No, I strongly disagree

How important do your parents / guardians think learning science will be for your future?

- Very important
- Moderately important
- They don't have an opinion either way
- Of little importance
- Not important at all

- I don't know

Have your teachers specifically encouraged you to continue studying science when you are older?

- A great deal
- Some
- A little
- Not at all
- I am not sure

How useful will science knowledge and skills be in helping you get many different sorts of jobs?

- Very useful
- Moderately useful
- Of average use
- Not very useful
- Not useful at all

Do you know someone who works in a science-related job?

- Yes
- No
- I don't know

Who do you know who works in a science-related job (tick all that apply)?

- Parent/guardian
- Member of wider family (aunts, uncles, grandparents)
- Friend's parent
- Neighbour
- Other
- No-one

When you're not at school, do you talk about science (including coding and making) with other people?

- Frequently
- Occasionally
- Rarely
- Very rarely
- Never

If you do talk about science outside of school, who do you talk with? (tick all that apply)

- Parents/guardians
- Friends
- Brothers/sisters
- Wider family (aunts, uncles, grandparents)
- Community members (eg staff at youth clubs, or leaders of faith groups)

- Others

How often do you do the following outside of school?

- Read science books or magazines, or look up science content online
    - All the time (at least every other day)
    - Regularly (at least once a week)
    - Sometimes (about once a month)
    - Seldom (a couple of times a year)
    - Never
- Go to museums, or science centres, or zoos / aquaria
    - Regularly (at least once a month)
    - Occasionally (at least once a term)
    - Sometimes (about once a year)
    - Rarely (at least once every other year)
    - Never
- Go to a coding club/workshop, making club/workshop, or science club/workshop
    - Regularly (at least once a month)
    - Occasionally (at least once a term)
    - Sometimes (about once a year)
    - Rarely (at least once every other year)
    - Never

How are you doing in science lessons at school?

- I'm doing really well!
- I'm doing well!
- I'm acceptable!
- I'm not doing very well!
- I'm doing really badly!
- I don't know!

Appendix K: Methods for evaluating fun

Interviews

When conducting interviews, we can:

- Explicitly ask children if the activity felt more like "work" or more like "fun".
- Explicitly ask children if the activity was fun. And if yes, how much fun did they have.
- (c) Ask the children's opinion about the activity in general and note negative words related to fun like "work", "boring", "not interesting", "like school lesson" and positive ones like "fun", "exciting", "surprising".

Observation (live / video analysis)

In video analysis, we can look for the following cues which can be related to fun:

- Positive: smiles, laughing, excitement, positive vocalizations.
- Negative: frowns, signs of boredom, shrugs, negative vocalizations.

Structured Questionnaire

Measuring Fun with FunQ: The TUE has developed FunQ [read Funky] to define and measure experienced fun for adolescents (age 11-18), see *Tisza & Markopoulos (2019). FunQ: Measuring the fun value of an activity with adolescents. Manuscript submitted for publication.*

Despite the approaches reviewed in this document, to this point, a validated multi-dimensional instrument for measuring fun with adolescents has not existed. Further, adolescents are a demographic group that has been relatively understudied in the field of interaction design for children and child computer interaction. FunQ was developed using a deductive scale development approach and we took the psychologist's perspective to shed light on a network of related concepts. Tisza and Markopoulos argue that for adolescents to experience an activity as fun they need a) to feel in control of the activity and be intrinsically motivated for participation (*Autonomy*); b) to experience an optimal level of challenge matching their level of skills (*Challenge*); c) to feel *well* during the activity (*Enjoyment*) and d) to not feel *bad* (*Stress*, contra-indicative); e) to be immersed in the activity losing one's perception of time and space (*Immersion*) and f) to let go of social inhibitions (*Loss of Social Barriers*).

The questionnaire consists of 31 items along the above-described six dimensions and the statements are evaluated by the children on a 5-step Likert-type scale. Because the manuscript is under evaluation the questionnaire cannot be attached in this document yet.

References

Appelbaum, P. & Clark, S. 2001. Science! Fun? A critical analysis of design/content/evaluation, Journal of Curriculum Studies, 33:5, 583-600.

Bakker, S., Van Den Hoven, E., & Antle, A. N. (2011). MoSo tangibles: evaluating embodied learning. In Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction (pp. 85-92). ACM.

Barendregt, W., Bekker, M.M. & Baauw, E. 2008. Development and evaluation of the problem identification picture cards method. Cognition, Technology & Work. April 2008, Volume 10, Issue 2, pp 95–105.

Barendregt, W., Bekker, M.M., and Speerstra, M. 2003. Empirical evaluation of usability and fun in computer games for children. Proceedings of Human-Computer Interaction INTERACT-03', 9 March 2003 Zürich, Switzerland, IOP Press (2003) 705-708

Benbasat, I., Goldstein, D. K., & Mead, M. (1987). The case research strategy in studies of information systems. *MIS quarterly*, 369-386.

Berk, R. 1996. Student ratings of ten strategies for using humor in college teaching. Journal on Excellence in College Teaching 7(3): 71–92.

Biles, M. (2012). Leveraging insights from mainstream gameplay to inform STEM game design: great idea, but what comes next? *Cultural Studies of Science Education*, *7*(4), 903–908.

Blythe, M. and Hassenzahl, M. 2005. The semantics of fun: differentiating enjoyable experiences. In Funology, Mark A. Blythe, Kees Overbeeke, Andrew F. Monk, and Peter C. Wright (Eds.). Kluwer Academic Publishers, Norwell, MA, USA 91-100.

Breakwell, G., 1995. Research Methods in Psychology. SAGE Publications, London

Bricker, L. A., & Bell, P. (2012). “GodMode is his video game name”: situating learning and identity in structures of social practice. *Cultural Studies of Science Education*, *7*(4), 883–902.

Bruck, M., Ceci, S. J. and Melnyk, L., 1997. External and internal sources of variation in the creation of false reports in children. Learning and Individual Differences, 9(4):269 –316

Camilleri, E., Yannakakis, G. N., & Liapis, A. (2017). Towards general models of player affect. In *2017 Seventh International Conference on Affective Computing and Intelligent Interaction (ACII)* (pp. 333–339). San Antonio, TX: IEEE.

Carroll, J.M. 2004. Beyond fun. Interactions 11, 5 (September 2004), 38-40.

Carroll, J. M. and Thomas, J. C. 1988. FUN. SIGCHI Bull. 19, 3 (January 1988), 21-24.

Chawla, L., & Heft, H. (2002). Children's competence and the ecology of communities: a functional approach to the evaluation of participation. *Journal of environmental psychology*, *22*(1-2), 201-216.

Cornwall, A., & Jewkes, R. (1995). What is participatory research? *Social science & medicine*, *41*(12), 1667-1676.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review*, *14*(4), 532-550.

Fontijn, W. & Hoonhout, J. 2007. Functional Fun with Tangible User Interfaces. 119-123.

Francis, M. (2012). Using Fun to Teach Rigorous Content. Communications in Information Literacy. 6. 151-159.

Fraser, J., Shane-Simpson, C., & Asbell-Clarke, J. (2014). Youth science identity, science learning, and gaming experiences. *Computers in Human Behavior*, *41*, 523–532.

Garner, R. L. 2006. Humor in Pedagogy: How Ha-Ha can Lead to Aha!, College Teaching, 54:1, 177-180.

Gaydos, M. J., & Squire, K. D. (2012). Role playing games for scientific citizenship. *Cultural Studies of Science Education*, *7*(4), 821–844.

Geertz, C. (2008). Thick description: Toward an interpretive theory of culture. In *The Cultural Geography Reader* (pp. 41-51). Routledge.

Giannakos, M. N., Holme, F. I., Jaccheri, L., Marquez, I. D., Papavlasopoulou, S., & Visser, I. G. (2015). Can Interactive Art Installations Attract 15 Years Old Students to Coding?. In International Conference on Entertainment Computing (pp. 529-532). Springer.

Greenbaum, J. & Loi, D. (2012). Participation, the camel and the elephant of design: an introduction, CoDesign, 8:2-3, 81-85.

Hanna, L., Neapolitan, D. and Risden. K. 2004. Evaluating computer game concepts with children. In Proceedings of the 2004 conference on Interaction design and children: building a community (IDC '04). ACM, New York, NY, USA, 49-56.

Henson, K. T. (2003). Foundations for learner-centered education: A knowledge base. *Education*, *124*(1).

Iivari, J., & Iivari, N. (2011). Varieties of user-centredness: An analysis of four systems development methods. *Information Systems Journal*, *21*(2), 125-153.

Jeremiassen, K. S. (2018). *Differences in students' stem identity, game play motivations, and game preferences* (Doctoral Dissertation). University of Houston-Clear Lake. Retrieved from https://uhcl-ir.tdl.org/handle/10657.1/996

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of mixed methods research*, *1*(2), 112-133.

Lopes, P., Yannakakis, G. N., & Liapis, A. (2017). RankTrace: Relative and unbounded affect annotation. In *2017 Seventh International Conference on Affective Computing and Intelligent Interaction (ACII)* (pp. 158–163). San Antonio, TX: IEEE.

Malone, T.W. Lepper, M.R. (1987). Making learning fun: a taxonomy of intrinsic motivations for learning. In: Snow, R.E. and Farr, M.J. (Eds.) Aptitude, learning and interaction III. Conative and affective process analysis. Hillsdale, N.J.: Erlbaum.

Mathers, B. G. 2008. Students' perceptions of "fun" suggest possibilities for literacy learning: "You can be entertained and informed". Reading Horizons, 49(1), 71–88.

Mayo, M. J. (2009). Video Games: A Route to Large-Scale STEM Education? *Science*, *323*(5910), 79–82.

Monk, A., Hassenzahl, M., Blythe, M., and Reed, D. 2002. Funology: designing enjoyment. SIGCHI Bull.: suppl. interactions 2002 (September 2002), 11-11.

Myers, M. D. (2009). Qualitative Research in Business & Management. SAGE Publications Ltd.

Nicolini, D. (2012). *Practice theory, work, and organization: An introduction*. OUP Oxford.

Obrist, M., Igelsbock, J., Beck, E., Moser, C., Riegler, S., and Tscheligi, M. 2009. "Now you need to laugh!": investigating fun in games with children. In Proceedings of the International Conference on Advances in Computer Entertainment Technology (ACE '09). ACM, New York, NY, USA, 81-88.

Papavlasopoulou, S., Sharma, K., & Giannakos, M. N. (2018). How do you feel about learning to code? Investigating the effect of children's attitudes towards coding using eye-tracking. International Journal of Child-Computer Interaction.

Papert, S. (2002). Hard fun. Article for the Bangor Daily News (Bangor, Maine). Retrieved January 31, 2019, from: http://www.papert.org/articles/HardFun.html

Ponterotto, J. G. (2006). Brief note on the origins, evolution, and meaning of the qualitative research concept thick description. *The Qualitative Report*, *11*(3), 538-549.

Read, J. C. 2012. Evaluating artefacts with children: age and technology effects in the reporting of expected and experienced fun. In Proceedings of the 14th ACM international conference on Multimodal interaction (ICMI '12). ACM, New York, NY, USA, 241-248.

Read, J. C., MacFarlane, S. J., and Casey, C. 2002. Endurability, engagement and expectations: Measuring children's fun. Proceedings of Conference on Interaction Design and Children (pp. 189-198). Eindhoven: Shaker Publishing.

Read, J., C. and MacFarlane, S. 2006. Using the fun toolkit and other survey methods to gather opinions in child computer interaction. In Proceedings of the 2006 conference on Interaction design and children (IDC '06). ACM, New York, NY, USA, 81-88.

Risden, K., Hanna, E., & Kanerva, A. 1997. Dimensions of intrinsic motivation in children's favorite computer activities. Society for Research in Child Development, Washington, DC.

Ross, S. M., & Morrison, G. R. (2004). Experimental research methods. Handbook of research on educational communications and technology, 2, 1021-43.

Shah, A. M., Wylie, C., Gitomer, D., & Noam, G. (2018). Improving STEM program quality in out-of-school-time: Tool development and validation. Science Education, 102(2), 238-259.

Sharma, K., Papavlasopoulou, S., & Giannakos, M. N. (2019). Coding Games and Robots to Enhance Computational Thinking: How Collaboration and Engagement Moderate Children's Attitudes?. International Journal of Child-Computer Interaction.

Shneiderman, B. 2004. Designing for fun: how can we design user interfaces to be more fun? Interactions 11, 5 (September 2004), 48-50.

van der Sluis, F., van Dijk, E. M. A. G., & Perloy, L. M. 2012. Measuring fun and enjoyment of children in a museum: evaluating the smileyometer. In A. J. Spink, F. Grieco, O. E. Krips, L. W. S. Loijens, L. P. J. J. Noldus, & P. H. Zimmerman (Eds.), Proceedings of 8th International Conference on Methods and Techniques in Behavioral Research, Measuring Behavior 2012 (pp. 86-89). Wageningen: Noldus Information Technology bv.

Walsham, G. (1995). Interpretive case studies in IS research: nature and method. *European Journal of information systems*, *4*(2), 74-81.

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*. John Wiley & Sons.

Ventä-Olkkonen, L. (2017): The characteristics and development of urban computing practices. Utilizing practice toolkit approach to study public display network. Acta Univ. Oul. A 705.

West, J. 1994. Children's Perceptions of Fun and Work in Literacy Learning. Perspectives in Reading Research No. 7. [S.l.]: Distributed by ERIC Clearinghouse.

Williamson, B., & Facer, K. (2004). More than 'just a game': the implications for schools of children's computer games communities. *Education, Communication & Information*, *4*, 255–270.

Willis, J. 2007. The Neuroscience of Joyful Education. Educational Leadership. 64.

Yannakakis, G. N., Cowie, R., Busso, C., (2018). The Ordinal Nature of Emotions: An Emerging Approach. *IEEE Transactions on Affective Computing*, 20.

Yin, R. K. (2009). Case study research: Design and methods. SAGE.