Collaborative Interactions in Problem-Solving Activities: School Children's Orientations while Developing Digital Game Designs Using Smart Mobile Technology

Sjöberg, Jeanette; Brooks, Eva

Published in:
International Journal of Child - Computer Interaction

DOI (link to publication from Publisher):
10.1016/j.ijcci.2022.100456

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

International Journal of Child-Computer Interaction 33 (2022) 100456

Contents lists available at ScienceDirect

International Journal of Child-Computer Interaction

journal homepage: www.elsevier.com/locate/ijcci

Collaborative interactions in problem-solving activities: School children's orientations while developing digital game designs using smart mobile technology

Jeanette Sjöberg [a,*], Eva Brooks [b]

[a] Halmstad University, Kristian IVs väg 3, 301 18 Halmstad, Sweden
[b] Aalborg University, Kroghstræde 3, 9220 Aalborg, Denmark

ARTICLE INFO

Article history:
Received 25 November 2020
Received in revised form 7 December 2021
Accepted 15 January 2022
Available online 31 January 2022

Keywords:
Collaborative interaction
Game-based design
Mobile technology
Problem solving
School children
Smart learning

ABSTRACT

Digital technologies in combination with creative activities have been introduced in schools as a strategy for learning and teaching activities offering scaffolding opportunities. Additionally, digital game-based learning (DGBL) activities have also been tried out in schools in recent years, as well as different mobile technologies, with the ambition to create smart learning. In this study, we aim to explore how school children's collaborative interactions, while engaged in problem-solving activities using smart and mobile technology, unfolds. Drawing from a contextual perspective on learning, our study combines theoretical views on joint participation, affordances and sense of community in relation to collaborative interactions. Questions posed in this study are: (1) In what ways do children's digital game design activities drive and/or support collaborative interactions while engaged in problem-solving activities? and (2) How are children's digital game design ideas manifested during game design activities involving smart mobile technology? The study is based on a case where a creative workshop involving 22 Swedish third-grade children (9–10 years of age) participating in game design activities carried out in a pedagogical lab setting. By employing a thematic analysis, the results of the study show that the children deployed different orientations in their collaborative interactions, and that a sense of community emerged when the children worked on solving the problem of designing and producing a joint digital game idea, using mobile technology. On the basis of this, we argue that, when designing for educational activities involving smart mobile technology, it is pivotal to be aware of the pedagogical context, since this aspect of the design creates meaningful collaborative interactions; it is only then smart mobile technology becomes smart. These results have important implications for the methodological field of including smart mobile technology in learning situations.

1. Introduction

There is a strong discourse in the field of smart technology stating that mobile technologies, tablets, and different so-called smart technological devices have become essential parts of children's everyday life. In recent years, smart technology has emerged in the educational domain as a tool to make learning more efficient (e.g. Chang & Hwang, 2019; Garshi, Wist Jakobsen, Nyborg-Christensen, Ostnes, & Ovchinnikova, 2020). Enabling children to learn through using smart technology is at the centre of both research and practice. When it comes to learning, however, these technological devices become smart only if grounded in a solid pedagogical foundation; they need to be used in a smart way to become smart (Pesare, Roselli, & Corriero, 2016; Spector, 2014). There seems to be a need to further clarify how children can learn by means of smart technology in meaningful ways in educational settings.

Research shows that the application of mobile learning as well as the use of game-based instructional strategies promotes students' learning and engagement (e.g. Chang & Hwang, 2019). The concept of game-based learning is thus promoted to offer several possibilities for supporting learning outcomes when using educational or commercial games (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Perrotta, Featherstone, Astib, & Houghton, 2013). Similarly, Chang and Hwang (2019) claim that "good gaming or gamification models and learning strategies could be a crucial factor affecting students' learning achievement" [2:86]. Nousiainen, Kangas, Rikala, and Vesisenabo (2016) and Nousiainen, Vesisenabo, and Eskelinen (2015) relates gaming and gamification to game-based learning, which they argue is grounded in four game-based approaches: using educational games, using entertainment games, learning by making games and using game

* Corresponding author.
E-mail addresses: jeanette.sjoberg@hh.se (J. Sjöberg), eb@hum.aau.dk (E. Brooks).

https://doi.org/10.1016/j.ijcci.2022.100456

elements in non-game settings (gamification). While educational games have clearly defined didactic goals and objectives, entertainment games can have relevant subject-related content. For the approach of making games, the learner develops knowledge about making content by using technology. Gamification turns into a non-game activity to make it more attractive and motivating. Compared to playing games, designing games is suggested to provide greater engagement and learning (Vos, van der Meijden, & Denessen, 2011). There is also a potential in using *game creation* as a pedagogical strategy in classroom activities (An & Cao, 2017; Magen-Nagar, Shachar, & Argaman, 2019; Wu, 2018). In this regard, collaboration has been identified as an important element when interacting with smart technology in activities of creating digital games (Kim, Cho, & Lee, 2013; Magen-Nagar et al., 2019). Creating games is not a new idea in teaching activities, but, according to Kafai (Kafai, 2006; Papert, 1989), "Far fewer people have sought to turn the tables: by making games for learning instead of playing games for learning". However, the effects of game-based learning in terms of making games is still largely unexamined (Gallagher & Grimm, 2018).

Designing games can be a complex activity, as game-based tasks must be adapted to children's knowledge and skills. Schmidt (2011) underlines that when activities are perceived as complex by children, their interest and concentration decrease, which potentially can influence their performance and engagement. On the other hand, Kangas (2010) identified that digital game-making activities offered children opportunities to practice collaborative work in groups and, thereby, enhanced a sense of community. Thus, research indicates that the process of creating digital games can be considered as a vehicle for collaborative problem-solving, where acts of making and creating can reveal complexity of tasks as well as of interactions in which children can make sense of the world. This means that the understanding of creation is not only about creation of things, but also about interpretation and meaning making (Ind & Coates, 2013). This perspective is particularly relevant when considering collaborative problem-solving processes by means of digital game creation, as it serves to foster skills in making and creating, as well as those related to working with other people and empathising with them (Koh, Chai, Wong, & Hong, 2015). Despite these recent developments, a broader understanding of how game-based learning activities, in particular focusing on game creation with smart mobile technology, can provide a viable learning tool is still lacking. A clear conclusion from this literature is that this gap in research refers to the importance of transcending digital game creation aspects inherent in the activity to encourage different ways of being productive and, thereby, enable children to probe different orientations towards problem solving and experimentation.

To address this research gap, the overall aim of this paper is to investigate how school children's collaborative interactions, while engaged in problem-solving activities using smart and mobile technology, unfolds. Research shows that when children are involved in game-making activities, they develop problem-solving skills (*E*uropean Commission, 2016; Grover & Pea, 2013; Javrh & Mozina, 2018). This has to do with the fact that they are forced to explore different strategies and possible solutions as well as confronting problems and organising their actions (Bers, Flannery, Kazakoff, & Sullivan, 2014). This is supported by Chang, Wu, Weng, and Sung (2012), who found that children improved their problem-solving performance with a game-based learning approach in comparison with traditional instruction. By creating space for 'making' activities, children experience increased confidence in their problem-solving and project planning abilities (Papavlasopoulou, Giannakos, & Jaccheri, 2019).

Our contribution to this approach is to analyse how Swedish school children (9–10 years of age) work collaboratively with problem-solving in the form of game-based design activities. Furthermore, to emphasise the importance of understanding how school children can explore collaboratively while creating in learning situations and how such processes can be facilitated. This contributes to the clarification of a pedagogical foundation for children's learning with smart mobile technology that can be operationalised in educational settings. Supporting this aim, the following research questions are posed in the study: (1) In what ways do children's digital game design activities drive and/or support collaborative interactions while engaged in problem solving activities? and (2) How are children's digital game design ideas manifested during game design activities involving smart mobile technology? On this note, we wish to contribute to the field by exploring the possible mediating roles of smart mobile technologies used in an educational setting.

1.1. Smart mobile technology and digital game creation

Smart mobile technology in the form of tablets and smartphones is a widely available tool for most people, no matter age (Samaha & Hawi, 2016). This kind of technology has been identified as multi-functional, which contributes to its attractiveness as a tool for learning (Schilhab, 2017). In their book chapter, Kearney, Burden, and Schuck (2019) identify that learning with smart learning technology is effective through its holistic characteristics, which can empower the learners to e.g., practice agency. In particular, and in line with Kim et al. (2013), they (Kearney et al., 2019) have identified collaboration as an essential element when interacting with smart mobile technology. Chang and Hwang recently conducted a systematic literature review of published journal articles between 2007 to 2016 on the topic of mobile technology-supported game-based learning (Chang & Hwang, 2019). The aim of their review was to highlight the research domain and to identify trends in mobile game-based learning. They conclude that this is an important research field and that "future studies could focus more on how to develop mobile game-based learning strategies and models which are more diverse, educational, and appropriate for all ages after examining the learning strategies adopted in the existing digital game-based learning and mobile learning studies" [2:86]. Furthermore, they claim that "good gaming or gamification models and learning strategies could be the crucial factor affecting students' learning achievement" [2:86].

Pedagogical activities that include iPads or tablets together with various apps can serve as examples of learning with smart mobile technology. Research shows that the application of smart mobile technology in combination with game-based instructional strategies promotes students' motivation and learning (e.g. Chang & Hwang, 2019). Furthermore, research shows that combining tangible objects with mobile apps to access new content can assist children in capturing details of what they find interesting to explore (Delprino et al., 2018). The authors show how the use of smart technology in the form of pervasive games encouraged children to conduct in-depth investigations of the physical environment. In the present study we included both smart mobile technology and creative material through the 'making' of a stop-motion video via a smart app. This was envisioned to impact the children's engagement (cf Yannier, Hudson, Wiese, & Koedinger, 2016). Another way to engage the children was by the means of collaboration. Researchers have pointed out that collaboration and promoting interactions among students while working with developing game designs is helpful in improving their learning performance (e.g. Hwang, Wu, & Chen, 2012; Sánchez & Olivares, 2011; Sung & Hwang, 2013; Triantafyllakos, Palaigeorgiou, & Tsoukalas, 2011).

Despite the fact that children of today have access to and can use different kinds of mobile smart technologies to practice collaboration, further research is needed to nurture it while involved in game-based learning activities (Behnamnia, Kamsin, Ismail, & Hayati, 2018). In this regard, creating games as a pedagogical problem-solving strategy shows promising learning results. Previous studies have elucidated how children learn through the activity of production (cf Papert, 1989). In the present study, we have framed a game making activity as a way to push collaborative problem-solving among school children by creating an environment that allows them to explore smart mobile technology. Similarly, Cebeci and Tekdal (2006) have pointed out that activities involving creation have positive learning potentials when children are making podcasts. Kinnula and Iivari (2021) identified the significance of context in relation to promoting children's participation in digital technology design and making. On that note, Makhaeva, Frauenberg, and Spiel (2016) found that the design space has an effect in a creative process. As a crucial aspect of this, Cumbo, Eriksson, and Iversen (2019) underline the importance of a combination of a child-led activity and a respectful adult guidance can lead to new insights. All in all, this shows how the context of a collaborative problem-solving design task can influence children's participation and engagement while using smart mobile technology. As Kinnula and Iivari [38:5] express it, "children's genuine participation in digital technology design does not happen in isolation/.../ it happens as part of the complex web of life". Thus, the complexity of children's social actions, their experiences and interactions need to be considered to create conditions for a meaningful activity as well as in the subsequent analysis of it.

The above-mentioned complexity issue goes hand in hand with the complex task of designing a game including the use of smart mobile technology as it has to be adapted to all participating children's knowledge and skills. Gennari et al. (2017) suggest that such an activity should be split into different phases so that the activity forms a meaningful continuity for children. While studies by Gennari et al. (2017) and Schmidt (2011) propose that such an approach should be split into different days or weeks, we have chosen to apply this kind of segmentation of the game design activity taking place over half a day. In doing so, children will step through different phases while designing digital game ideas including analysis of game goal, ideating solutions and conceptualising this ideation (Adams, 2014). This is what is considered as a prolonged problem-oriented design activity. While Sanders and Stappers (2014) underline that children learn about designing through practical and joyful hands-on experiences, developing game designs using smart mobile technology not only include creation but also cognitive skills, such as problem solving as well as social skills. In this paper, we consider the combination of creative, cognitive and social aspects of a design process as foundational. Kress (2010) states that abstract matters of teaching become tangible through different materiality. When creating games, children can interpret abstract aspects into tangible and collaborative dynamics in environments that allow them to explore subject matters through meaningful creations. Therefore, a digital game design activity and the tasks involved has to carefully consider children's ways of expressing themselves, for example by providing them with a variety of suitable tools. In this regard, Khaled and Vasalou (2014) created generative toolkits to support children's game design activity through brainstorming and story-boarding techniques. This is in line with Landoni, Rubegni, and Nicol (2018) as well as Mazzone, Iivari, Tikkanen, Read, and Beale (2010), who suggested using props to get children started on an activity and the use of different media to encourage imaginative outcomes. This means that children's performance in collaborative problem-oriented design tasks and their engagement in design become important values. The next section will elaborate on the theoretical framework of this paper introducing analytical concepts that will guide the data analysis to answer the previously mentioned research questions.

2. Theoretical framework

Based on the above presented related work section, a contextual perspective on design and learning has evolved, which implies a consideration of complex relations between individuals, an activity, and the contextual environment as mutually integrated (Lave & Wenger, 1991). Furthermore, it implies that human action, social and individual, is mediated by tools and signs (Engeström, Miettinen, & Punamäki, 1999). In particular, we focus on how these kinds of interactions come into play when groups of children work together to solve a problem-oriented design task (Dillenbourg, 1999). In such situations, negotiation, joint construction, and understanding between children are considered as essential to collaboration and problem solving (Littleton & Hakkinen, 1999; Mercer, 1994). The first research question about how children's digital game design activities drive and/or support collaborative interactions while engaged in problem solving activities concerns how children *orientate* towards this kind of activity. This refers to a sociocultural take on children's talk, which, among others, can be focused on the task or related to social aspects of the digital game creation (i.e., the problem-solving task) (Damşa, Ludvigsen, & Andriessen, 2013). The second research question, how children's digital game design ideas are manifested during the activity, directs towards aspects of the collaborative design activity, i.e., the creation involving smart mobile technology. Here, we draw on Kress' (Kress, 2010) take on the concept of *affordances*, which refers to their distinct meaning-potentials. The remainder of this section elaborates on these two core analytical concepts: *collaborative orientations* and *collaborative affordances*.

2.1. Collaborative orientations

Through collaboration people create shared meaning and understanding when they participate in domain-specific activities. This acknowledges an inclusion of tools that participants' take on board as meaningful in a problem-solving activity, for example when trying out ideas and providing arguments in discussions. When collaboration is part of a scientific study, institutional aspects also become part of the analysis (Damşa et al., 2013). In the context of the present study, institutional aspects refer to the goals and tasks included in the activity and are realised in the interaction by the children involved. This means that children, while collaborating, orient themselves towards the given task or the social dimension that is part of the task. Studies have identified how children move between these different orientations (cf Furberg, 2010). In an educational institutional context, children interpret how they are expected to act and interact, as well as what they are expected to do and learn. Learning the content related to the task is part of this context (Damşa et al., 2013). The content refers to the domain-specific procedures of creating a digital game design: the task, the goals and the resources at hand thus give direction to children's problem-solving activity. In the present study, task orientation refers to children's eagerness to finish the task rather than spend time on the social aspects of problem-solving.

The social orientation of collaboration includes both joint agreement and diversity between participants. Barab and Plucker (2002) emphasise diversity between people as a resource for generating new ideas. In a collaborative setting, disagreements can happen when individuals experience difficulties in creating a connection between the goals of their actions and the task

at hand (Barab & Plucker, 2002; Damşa et al., 2013), or when different solutions are proposed by the participants included in the collaboration (Barron, 2000). Damşa et al. (2013) state that such diversities or contradictions can be productive if they result in further negotiation or elaboration of the disagreement in question. Another difficulty is related to group conversation matters related to disagreements and negotiations as these require children's turn taking skills, which are rather abstract for children to manage. In their study, Gennari, Melonio, and Rizvi (2019) have addressed this issue by implementing tangible objects to foster children's turn taking in groups. This showed to positively influence children's conversational behaviours (Gennari et al., 2019). Lave and Wenger (1991) state that successful collaboration is a result of a movement from being a peripheral participant in an activity to becoming a central contributor in a collective and productive way.

These two orientations (task or social) towards collaboration are the units of our analysis, where the interaction between the children constitutes the analytical starting point. Here, we are interested in how the children unpack the specific task to make sense of what they want to do as well as how they define themselves as participants in the activity (Krange & Ludvigsen, 2009). Thus, we look at which orientations become activated in the collaborative design process and how they influence the collaboration. The analytical concepts emerged after repeated analysis of the data and were thus not elaborated beforehand.

2.2. Collaborative affordances

In our analysis, contextual understandings, in particular how the different tools at hand afford children's collaboration to generate and manifest their ideas by means of these tools. Here, we lean on a social semiotic perspective and apply Kress' (Kress, 2010) definition of affordances in the sense that they, on the one hand, rest on the materiality of a certain tool and, on the other hand, how they function in social environments. Thus, affordances as such have distinct meaning-potentials (Kress, 2010), both when it comes to smart mobile technology and to collaboration. Consequently, children's collaborative interactions cannot be defined by a certain set of properties, but in terms of how these properties are used, i.e., how they become operational in context (Winograd, 2001).

In Kress' writings on affordances, he also brings up the term 'aptness', which focuses on 'fitness for its purpose', e.g., is this the best fit (the most apt) for a specific purpose [44:156]. In this way, aptness speaks about the resources which are available in the making of signs (e.g., digital game designs). Kress (2010) emphasises that what people identify as being the 'best fit' depends on their interests in context. Consequently, we apply the analytical concept of *aptness* to identify the affordances that children use to generate and manifest their ideas. Hence, the questions that need to be asked in relation to affordances are 'apt for whom?, 'apt to what?', 'apt to whom?', and 'apt when?'. Here, the *linking* and *framing* of entities, for example of different game scenarios or of various game details/props, constitute a resource for children's meaning making (Kress, 2010), i.e., how affordances invite children to link (or separate) and/or frame specific content while realising ideas. Linking can in this way link different items in time as well as in space, for example the temporal or causal links between participants and props in a game design scenario. The two main types of linking are *elaboration* and *extension*. The latter adds new information to a preceding item, whereas elaboration contains the same information as the preceding item (van Leeuwen, 2005). Framing creates a sense of connection or disconnection between the elements of a creation. The significance of this is that disconnected elements will be understood as separated, while connected elements will be understood as belonging together. Hence, linking and framing are two key aspects of a creation of some kind.

In this section we posit how collaborative affordances as a unit of analysis are identified through the analytical concepts of aptness and linking, where our analytical interest refers to how the affordances enable the children to realise the ideas they find relevant to materialise. Thus, we look at what kind of affordances become activated during the creative design activity involving smart mobile technology.

3. Methodology

We have conducted a qualitative study, which included a case where a workshop on game design activities with smart mobile technology was applied in a pedagogical laboratory setting, which was located at a university. The smart mobile technology consisted of iPads with the Stop Motion Studio software app installed, which were used by the groups of children to illustrate their game-designs. The workshop case involved 22 Swedish third grade children between 9–10 years of age and it was designed to promote collaborative problem solving through the use of smart mobile technology. To capture the children's collaborative interactions, we used video recordings as the primary method for data collection. Below the method and material, data collection, and analytical approach is further described.

3.1. Method and material

The workshop was introduced and briefly described prior to the workshop in a written document sent to the principal of the school, the class teacher and the participating children's parents. Before arriving at the workshop location within the university premises, the children were divided into six groups by their class teacher, with 3–4 participants in each group. In the introduction of the workshop the whole class together with their class teacher and a teacher assistant, was gathered in the same room where a university teacher alongside the researchers welcomed the children and their teachers. Initially, the content and purpose of the problem-solving workshop was described and explained to the children. Their task was to create a prototype of a digital game design idea, which should be presented to their fellow classmates by means of a stop-motion film. The workshop was divided into three phases: an introductory phase, an idea generation phase and a prototype presentation phase (see Table 1). During the workshop, the children's class teacher alongside the teacher assistant also participated in the workshop activity but kept themselves in the background. In addition, there were four university assistants available for the children when they needed help and they also supplied them with water and fruit. This setup gave space for the researchers to observe the activities and take notes during the full duration of the workshop.

3.2. Implementation of the designed workshop phases

In the first phase, the introductory phase, the university teacher introduced the workshop for the children and explained the content and procedures of the three workshop phases. Throughout the workshop she also helped the children by keeping track of the time of each phase (Table 1). Besides giving the introduction, the university teacher and the researchers had a discussion with the children about their prior experience and use of digital games and their knowledge on different game elements (for example, rules, structure, plots). In this way, the researchers were able to get a clear picture of the children's prior experiences of digital games. In this first phase, all children sat together in one room.

Table 1
Workshop phases.

Workshop phases	Description of workshop phases	Duration of workshop phases
Phase 1: Introduction	which instructed the children about the framework of the workshop as well as introducing the iPads, Stop Motion Studio software, and the creative material	15 min
Phase 2: Ideation	where the children could explore ideas and solutions using the iPads as well as the creative material through which they could materialise their ideas	90 min
Phase 3: Prototype presentation	which focused on the groups' presentation of their game design solutions and included description of how they have used the smart mobile technology	45 min

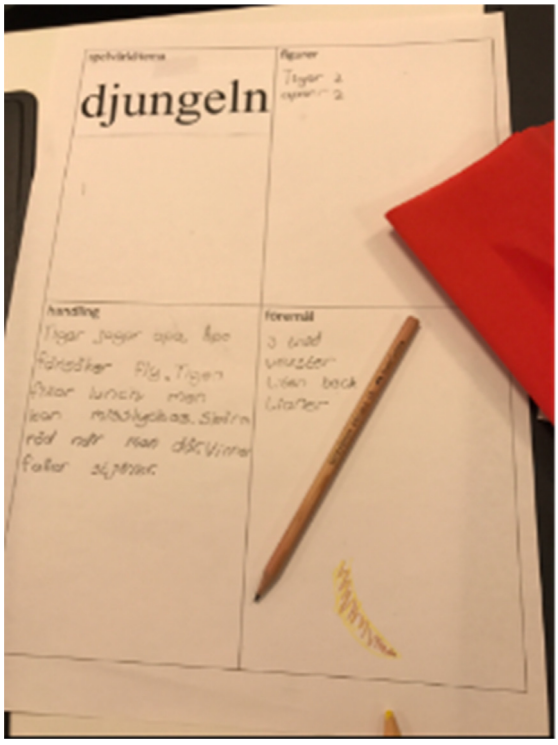

Fig. 1. Instructional material provided in the initial phase of the workshop. [Translation of Fig. 1: in the upper left corner the theme 'jungle' is spelled in Swedish (djungeln), in the upper right corner it says 'characters', in the lower left corner it says 'plot' and in the lower right corner it says 'props'. Under 'characters' the children have written "tigers: 2, monkeys: 2". Under 'plot' they have written "Tiger chases monkey. Monkey tries to flee. Tiger fixes lunch but can fail. Screen red when you die. If you win, stars are falling". Under 'props' they have written "3 trees, plants, small creek, lianas".].

The problem given to the groups to solve was to collaboratively develop and agree on a game design idea linked to a specific game world that was predetermined by the researchers. At the end of the introductory phase, each group was handed an empty storyboard sheet to fill in jointly (see Fig. 1). The storyboard included four sections: (1) game world/theme (predetermined); (2) characters; (3) plot; and (4) props.

At the start of the second phase of the workshop, the Idea generation phase, each group was assigned to their own workstation, which were setup in two different rooms (three groups in each room). The workstations were all equipped with one iPad per group to use and share between the group members. The iPads had the Stop Motion Studio software installed (see Fig. 2), which was used by the groups of children to produce a short film or a "pitch" capturing their game-design idea i.e., their prototype (final phase of the workshop). In addition, the groups were provided with creative material, such as clay, paint, LEGO, pencils, and markers. Each workstation was equipped with a fixed camera facing the centre of the table, which recorded the activities taking place around the table.

In this second phase, each group was introduced to their individual and predetermined game design context (the jungle, the ocean, the desert, the city, the forest, the space), which formed the framework for starting to ideate (see Fig. 2). The storyboard, which was handed out to the groups during the first phase, needed to be finished before they continued to the ideation, where they used the smart mobile technology and creative material. Here, the ideas for their specific game theme, plots and characters were discussed and negotiated by the children in parallel with the construction of props for the stop-motion film. During this phase, the children worked closely in their assigned working groups. First by filling out the storyboard and agreeing on the plot for the game, the characters and props. After this, they started to create different items and props for their game design. Here, the children also moved around a lot within and between the two rooms, getting material and looking at the other groups' creations. The collaboration in the groups varied a bit but they all had a strong result-orientation.

At the start of phase three, Prototype presentation, the children started to produce their stop-motion films while at the same time deciding on the final plot of the game design (see Fig. 3). During this phase, the children started to negotiate more about the plot, what props to use, and different choices that had to be made about the stop motion production, for example in relation to how many props they could create within the given time frame. In one case, a group of three boys finished quite early with their production, and after reviewing their result and realising that they had quite a lot of time left, they decided to add some more elements to their film. Here, the iPad (i.e. the smart mobile technology) had a clear central role in the workshop, since it was used to produce the stop motion film, but also used to find other effects, such as music. In addition, the iPad served as an engaging and motivating resource for the children in their collaborative problem-solving work. This phase ended with the groups presenting their final productions for each other explaining the plot of their games while they ran their stop-motion films. After the three workshop phases, the workshop was finalised with a joint lunch, where the phases of the workshop as well as the inclusion of smart mobile technology was informally discussed and reflected upon (see Fig. 4).

3.3. Empirical data and ethics

The empirical data included video recordings from the six workstations (a total of 11 h), the groups' final presentations, and observation notes by the two authors. The video recordings were primarily used to capture the children's collaborative interactions, and, as an added value, we could study the recordings multiple times afterwards. Teachers and guardians were informed about the study in writing and all guardians agreed to let their child participate by signing informed consent forms. This consent form included guardians' approval of using video and photos for scientific purposes. In addition, children were, at the workshop, informed that they could withdraw from their participation at any time if they in any way felt uncomfortable. In line with ethical guidelines, all names of the participants as well as of the school are anonymised.

Fig. 2. Overview of one of the groups' workstations. In the midst they are creating props for their stop motion film (with the iPad in the foreground).

Fig. 3. One of the groups working on the production of their stop-motion film.

3.4. Analytical approach

The analysis of the collected data was carried out through a thematic approach (Braun & Clarke, 2006; Fereday & Muir-Cochrane, 2010). The transcripts were reviewed by both authors to identify categories and themes in verbal and non-verbal actions and interactions between the children and the digital game-based design activities. The analytical phases are detailed in Table 2, where we also describe how the procedure was carried out.

Aligned with the analytical steps presented in Table 2, the empirical data was transcribed and reviewed by both authors (phase 1) to generate initial codes (phase 2) and organise these codes into initial themes (phase 3). Next, the themes were carefully checked by both authors (phase 4), which initiated more distinct definitions of the themes (phase 5). Finally, selected excerpts were again analysed, now in relation to the research questions (phase 6). This analytical procedure resulted in three themes: (1) Different orientations in collaborative interactions; (2) Affordances fostering collaborative interactions; and (3) Affordances hindering collaborative interactions. These themes are further elaborated in the below results section.

4. Results

4.1. Different orientations in collaborative interactions

Some of the recurring patterns in the material which emerged in the thematic analysis can be linked to the children's different ways of relating to each other and to the task at hand in their collaborative interactions during the workshop. It has to do with how they oriented themselves, usually either by being *task-oriented* or oriented towards others, so called *other-oriented*. These patterns of different orientations were closely connected to how the collaborative interactions unfolded during the workshop

Fig. 4. One of the groups presenting/demonstrating their stop-motion film and pitching their digital game-design idea in front of the class.

Table 2
Phases in the thematic analysis (Braun & Clarke, 2006).

Phases in thematic analysis	Description of the analysis procedure
1. Familiarising with the collected data	Transcribed the data, (re-)read the data, noting initial ideas.
2. Generating initial codes	Coded noteworthy details of the data and arranged data relevant to the codes.
3. Searching for themes	Organised codes into initial themes.
4. Reviewing themes	Checked if the themes and selected excerpts worked in relation to coded excerpts from phase 1 and the entire data set (phase 2) and generated a thematic mind map of the analysis.
5. Defining and naming themes	Refined details of the themes and generated clear definitions and names of the themes.
6. Producing the analysis paper section	Finalised the analysis of selected excerpts by relating them back to the research questions.

and how the children jointly used the smart mobile technology as a means to manifest their ideas about the plot of their common game-based design. As such, they were revealed to be crucial elements of the collaboration process, something which is to be kept in mind when designing for educational activities including smart mobile technology and group work amongst school children.

4.1.1. Task-orientation

The pattern of task-orientation was uttered most commonly by the children's joint ambitions to finalise the task at hand within the given time frame. In their collaborative interactions they acted rather goal-driven in the sense that they were negotiating details in their joint productions in order to keep the groupwork moving forward (as can be shown in excerpt 1 below). This strong sense of task-orientation was evident in all six groups, and the fact that all groups actually finished their productions in time supports this claim.

Negotiating, moreover, was something that took place during all phases of the workshop and the nature of the negotiations also changed during the course of the workshop and as the work progressed. The groups negotiated meaning about the game design, about the game itself and how to present it, about the content of the game, and about numerous aspects regarding the production of the stop-motion films. The negotiations often proved to be an important feature in progressing with the task: while they were negotiating different aspects of the task, they were at the same time defining details concerning the task which kept the development in motion, moving forward. As mentioned above, in the initial phase of the workshop the negotiations were mostly characterised by being goal driven. Towards the end of the workshop the negotiations turned more critical, where the time-aspect became an issue to consider.

In excerpt 1, one of the groups (consisting of two boys and two girls) has the jungle as the theme for their game design. They have jointly come up with a plot for their game which basically revolves around two tigers chasing two monkeys (player 1 and player 2) and are now in the midst of developing the background material for their particular game design. In the example, boy 2 seems hesitant of making more than one tiger, being aware of the time frame, and in their collaborative interaction, a negotiating dialogue emerges between the children that has to do with finalising the joint idea about the game's design but without challenging the given time frame.

Excerpt 1.
Girl 2: -The only thing strange about just having one (tiger), because there are two monkeys and it can only chase after one at a time and in that case…
Boy 2: -But we only have one (tiger)
Girl 2: -Now, but then that sort of can only be one monkey as well, otherwise it will be really weird because it can't chase both
Boy 1: -Can't we make a jaguar?
Boy 2: -Yes, but it will chase both and, but, then you can see who is taken by it and they win…
Girl 2: -A, but it will be a bit strange because it will say "victory" in the end and ...
Boy 2: -Yes but we shouldn't do the whole game
Girl 2: -No, but a part of it
Boy 1: - Can't we make a jaguar too?
Girl 2: -But it won't take long to do two tigers.
Boy 2: -Not two more!
Girl 2: -One more!
Girl 1: -I can make one more. Can I do one more then?
Boy 1: -But then I haven't done anything in clay.
Boy 2: -But now we are thinking too big!
Boy 1: -No, we are not! It is easy. Can't we make a jaguar?

Boy 2: -No, we will not add another animal!
Girl 2: -One more tiger.
Boy 2: -Yes, that's enough.
Girl 2: -Because otherwise it will be strange, for that ....
Boy 2: -If we are having too many animals, we will not be able to make it in time.

Here in excerpt 1, the children's negotiations regarding details in their common game design are evident. Girl 1 is determined to stay true to their initial game-design idea with two tigers and two monkeys, whilst boy 2 is more concerned about meeting the time aspect and suggests cutting one of the tigers out of the plot. Girl 2 continues by accounting for possible consequences of such a decision, having effects on the entire game design. Through negotiating arguments, they end up with a joint decision about how to move forward (to produce one more tiger). This example of joint participation in the collaborative interactions mirrors how the children's ideas manifested during the workshop activities through smart mobile technology and in relation to what was possible to achieve given the time frame and the affordances of the technology.

In excerpt 2, another group (consisting of four boys) has 'space' as their particular game theme. They have conducted a rather plain design for their game plot: a spaceship is simply moving through space, trying to avoid bumping into meteors and other obstacles. They have just finished producing their stop motion film and are satisfied with doing so well within the given time frame. They are glancing at the two other groups in the same room, both groups busy working.

Excerpt 2.
Boy 1: -We were really fast!
Boy 2: -Yeah, the others are not done yet.
Boy 1: -Do you think ours is too short?
Boy 2: -No.
Boy 3: - I don't know.
Boy 4: -It is kinda short…and we don't have so much stuff.
Boy 3: -Yes, a bit short perhaps.
Boy 4: -We could have had another.…
Boy 1: -Should we add some more then?
Boy 3: -I think so.
Boy 2: -We have time, so.

In this example, the group who finalised their stop-motion film quickly, quite long before the time was up, reflects upon their work in relation to the given task and to the other groups, still working. As they are watching their film, they start to express a slight nervousness that their production perhaps is not good enough, expressed by boy 4 in terms of "It is kinda short…and we don't have so much stuff". It turns out the group has been too focused on the time frame resulting in them almost having compromised their game design idea. However, since they have much time left, they decide to make some additional work both on the stop-motion film and with their game design, resulting in a more qualitative final production. During this stage of their joint collaboration, they start experimenting with different features available in the stop motion app (such as music) and add some of them to their stop motion film. This example shows the dedication and the task-orientation that was displayed by the children during the workshop.

4.1.2. Other-orientation

The pattern of other-orientation is mainly characterised by how the participants were acting towards each other, especially in the first and second phases of the workshop, with a general sensitivity for each other's views and ideas for their joint task of creating a stop motion film of their game-design. Especially in the initial phase, encouragement was shown between the children when someone expressed an idea that would fit the game design and/or develop it further. Towards the end of the workshop, however, in the final phase, the children usually were more reluctant to new ideas that could delay the work process. Throughout the workshop the children discussed and valued each other's ideas in relation to what was possible to do given the affordances of the mobile smart technology (stop motion app on the iPad) and the structure of the workshop. This pattern of other-orientation was evident in all six groups.

In excerpt 3, one of the groups (three girls and one boy) are working with the desert as their theme. They have not established a clear story for their game design yet, but they have started to create a scenic reproduction of a desert with a large sheet of yellow paper on which they have painted some palm trees, an oasis and some huts. During this work, they are discussing different objects normally related to a desert.

Excerpt 3.
Girl 1: How about if we use these... these huts, like for instance these huts, like an obstacle you [as a player of the game] have to... or if there are some dangerous animals in the puddles so you can't go in there, for then they will take you...
Girl 2: Like sharks or, or crocodiles...
Girl 1: Yes, like dangerous animals, so you have to jump over here...
Boy 1: Yes, and you can climb this liana then, up the palm tree...
Girl 2: Or you can hide in the huts...
Boy 1:...and throw coconuts
Girl 3: We need to make some coconuts

In this example, girl 1:s idea of creating different obstacles in the game is received with enthusiasm and support from the others in the group; they are clearly other-oriented in their approach towards her and her idea, and consequently her initial idea sparks and generates new ideas from the others. This example shows that the other-orientation often supported creativity and development of ideas within the groups and facilitated the progression and completion of the task. In addition, a sense of community emerged in the groups while discussing each other's ideas in relation to the task and to what was possible to do with the smart mobile technology.

Another example of how the pattern of other-orientation was manifested in the material, was by the appointment of leadership within the groups. As in all group work, the participants took on themselves (or imposed on others) different roles in the groups and the most prominent role was the leader role. In all groups one or sometimes two participants were appointed as leaders either by the rest of the group members or by their own choice and led the joint work forward. This was most prominent during the initial stages of the first phase of the workshop, as well as during the duration of the final phase of the workshop. In the initial phase, the emergence of a leader or leaders within the group(s) were important for the work to get started and not get stuck in the ideation. Here, the paper sheet with the given theme for the groups which served as a template for the formation of game designs, usually were filled out by the group leader. In the final phase of the workshop, the role of the leader was more characterised by being the one keeping track of time and deciding what choices to make in order to keep progress in the workshop.

To sum up, both patterns of orientations show that the children's collaborative interactions were designated towards how to solve the task/problem given, considering the smart mobile technology and its affordances.

4.2. Affordances fostering collaborative interactions

The analysis of the second theme uncovered instances where properties of the iPad and the stop-motion app as well as of the 'making' aspects of producing a stop-motion film and the

social environment afforded the children's production of their game designs. In particular, these affordances related to how the children in a solitary and collaborative manner were *linking and framing resources* targeting a fixing of the final stop-motion film. Yet another pattern in the empirical data was related to how the children *channelled their interest* relative to being knowledgeable game players themselves. The patterns are elaborated in the following section.

4.2.1. Linking and framing as resources for fixing stop-motion video prototypes

In general, the contextual setup of the workshop activity as well as the smart mobile technology provided group cohesion and space for collaboration. At the workstations, the children gathered around the workshop table, mostly standing up and sharing ideas. They talked about how these ideas could be materialised and divided the work of making the different parts to the stop-motion prototype between themselves. They were concerned to not talk too much but to proceed effectively with their game design prototype. While doing this, they also advised each other about different techniques and ways of making the characters and props for the stop-motion prototype to fit with their overall game design idea. After having discussed and divided their work, they continued in solitary modes with producing game props. This was followed by again gathering around the workstation table showing each other their creations and discussing how the different individually created props and details could come together in the stop-motion video. This kind of process continued in an interactive manner until the stop-motion video was finished. The main concern in the discussions was to check that the details they created were apt for the overall game design idea. This concern led to the children putting much effort into what kind of material they used, how colours and shapes could convey a trustworthy message and how the solution space was organised.

This example shows how the children were linking and framing game design ideas and props to finally being able to fix an authentic stop-motion prototype. The overall question for the children concerned in what ways the meaning of their prototype could become fixed. By 'fixed' we refer to how the different properties of the prototype were held together to represent a specific idea, i.e. how the props afforded the children's idea. In other words, for the props to afford the ideas in authentic ways, they had to have a certain fix. This resulted in that it mattered for the children which material and technique they used and how those could help fix the meaning that the children wanted to convey. Accordingly, the 'making' process of the stop-motion prototype and its affordances (the props and characters) provided a distinct way for the children to organise and shape not only the stop-motion prototype, but also their collaborative interactions. In this way, the fixing provided a physical property that could be organised and shaped via the children's linkings, framings, and discussions of different kinds, which represented the children's particular take on the prototype as well as on their collaborative interactions.

Another example concerning linking and framing to fix an authentic stop-motion prototype was the children's concern of conveying an aesthetically well composed game design. They put much effort into the balancing of different perceptual properties such as colour, texture, motion, and sound. In other words, the children wanted to achieve a desirable outcome. Here, the matter of having opportunities to make choices played a role. This was shown through the ways the children explored different choices of sound and music to accompany the overall game design idea. The Stop Motion Studio app offered different sound and music tracks, which the children playfully and humorously tried out to get the best fix for their stop-motion prototype. This trying-out undertaking permitted the children to become particular about the style of the message they wanted to convey. The option of choices became a significant aspect of the design process as it empowered the children to realise their imagined solutions, which they wished to be original.

4.2.2. Channelling of interest when producing stop-motion films

The second pattern concerned the ways children channelled their interest in digital games coming from their knowledge of being experienced game players. Illustrating this was the different game design characteristics that they implemented in the stop-motion prototype, e.g., audio-visual feedback, different challenge levels, social play, and rewards. For example, the group who had 'the city' as a game theme, placed coins on the streets in the city for the player to collect and, if successful, become rewarded. Another example is from the group who had 'the jungle' as a game theme, where they used a level-based and multi-player game design. The level design was designed to increase in difficulty and when successful the player became rewarded with more player-lives. The multi-player aspect included competition between the players, when failing the player received audio-visual feedback, where the sound was fading while a visual sign showed "Game over, sorry Player 2".

Based on the two above-described recurring patterns, the second theme uncovers how the smart mobile technology promoted the game design process, but also how it instigated it. The way the Stop Motion-app offered a variation of design choices helped the children to compose a balanced stop-motion prototype that represented a production that they felt pride in.

4.3. Challenges hindering collaborative interactions

The third analytical theme demonstrates how two of the groups experienced challenges that hindered the collaboration and the 'making' process. In particular, this was expressed through conditional contradictions and controversies. While all groups started out with the ideation by framing and detailing potential content of the initial game designs, one of the groups was hindered by this and got stuck in the process. After guidance from the assisting teachers, it became clear that their way of approaching the ideation was to start with using the technology. In this way, they could explore how different ideas and solutions worked in a 'smart' way, i.e. a kind of rapid prototyping, which helped them to end up with a content solution. This example shows how a critical situation triggered the group to apply another approach to get started with the game design process, which could be considered as a form of productive contradiction (Damşa et al., 2013).

Another example illustrates how some group members in different groups got stuck in details, which created tensions between the group members' individual ideas. In one of the groups, a boy enjoyed making monkeys as characters of their game plot and wanted to make more of them. However, the two assigned group leaders argued that it was not a good idea to make more monkeys as it would take time away from the rest of the production work they had planned to do. The argument ended up with the boy instead helping out with making other props of their game plot. This has some useful implications for smart mobile technology insofar as carefully considering how, when, and in what form bridging a collaborative activity and personal factors to enable productive interactions.

The third theme demonstrated how contradictions can instigate a change in courses of action and furthermore how controversies can shape situations where collaborative interactions become challenged (Damşa et al., 2013).

5. Discussion

By means of a creativity workshop case performed with school children, this article aims to explore how school children's collaborative interactions unfolds, while engaged in problem-solving activities using smart and mobile technology. Recurring patterns of the children's collaborative interactions identified in the material, show that they deployed different orientations of *other-orientation* and *task-orientation* during the workshop. The task-orientation among the children was obviously connected to their (or an) eagerness to perform the task within the given time frame. In this way, the children approached the task according to an educational institutional context acting on what they understood was expected of them, i.e., to finish the task in time (Furberg, 2010). The other-orientation was closely connected to the children's sensitivity for the other group members, as well as an insight into the importance of the social interaction and scaffolding for the progression of the collaborative group work. In line with Lave and Wenger (1991), the children were concerned with supporting each other to become active participants in a collective and productive way. Even though the collaborative and social aspects keep up the balance in the group, it is the task completion that becomes the primary target for the groups. This can be seen when, for example, disagreements do not reach a conflict situation in the group or when processes of negotiation due to disagreements do not continue for too long, but rather are shortened by the group's choice of a pragmatic solution. Barab and Plucker (2002) underline that disagreements between people can be a resource for developing new ideas. On the contrary, we argue that completion became the most important for the groups. However, ideas and disagreements also contributed to children's awareness of the implications of their thoughts and choices. They explicated them and created joint groundings for their efforts through which they could challenge ideas and understandings of the problems they approached. This is to say that divergent ideas can be beneficial if they lead to further elaboration and negotiation (Barab & Plucker, 2002).

Given the combination of other-orientation and task-orientation in the collaborative interactions among the children, there was a need for group leaders to take charge within the group constellations. This combination of orientations also resulted in the unfolding of disagreements and negotiations taking place during the problem solving (Barab & Plucker, 2002). These elements had an important impact on how children's ideas eventually manifested during the workshop activities. Negotiations were used by the group to drive elaboration of ideas, but only up to a certain point. Due to the time issue of finishing the task, the group leader often dealt with this in a pragmatic way with the opinion of the group member with a different viewpoint. In such situations it was clear that to solve the design problem, the group used the smart mobile technology as well as the creative material to make their viewpoints transparent. Here, the children could build on each other's creations through which they reached a decision, but not necessarily consensus. This is in line with studies by Damşa et al. (2013).

We have emphasised that creating a stop-motion video representing the group's game idea was not a linear or easy task to do but required intense negotiation. This, in turn, created an increased motivation as some of the group members realised that achieving this goal was dependent on not only themselves but also their peers. This seemed to influence how they provided both emotional and instructive support to each other. This kind of collaborative motivation also seemed to increase the individuals' desire to be timely on the task. In addition, and in line with Lave and Wenger's idea that successful learning is a result of an increasingly central participation in a collective and productive activity (Lave & Wenger, 1991), a sense of community emerged when the children worked on solving the problem of designing and producing a joint digital game idea using smart mobile technology.

The study applied a contextual approach (Damşa et al., 2013; Furberg, 2010; Lave & Wenger, 1991), which highlighted the importance of the physical environment (the workstation and its attributes) and the distinctive opportunities and limitations it created when including smart mobile technology. This includes a recognition of the reciprocal relationship between context and 'smart'-based activities to drive and support collaborative interaction. This is aligned with previous research (cf Kearney et al., 2019; Kim et al., 2013; Kinnula & Iivari, 2021; Makhaeva et al., 2016). We claim that these issues are vital to consider when it comes to the use of smart mobile technology in educational settings. In line with Chang and Hwang (2019), the present study pinpointed how the pedagogical framework contributed to meaningful interactions as it included a topic where the children had prior experiences and a space that afforded open-ended as well as focused learning opportunities. In this regard, we stress that a pedagogical framework applied together with smart mobile technology should acknowledge the structure of a social practice rather than only putting forward a pedagogical structure as a source of learning.

Lave and Wenger (1991) underline that participation in learning activities are not necessarily directly dependent on pedagogical goals, even when they appear to be a central factor (like in classroom activities). Instead, they argue that learning should be holistically understood including its multiplicity of interactions and relations. Hence, based on our findings, we argue that affording children's interest and an open-ended pedagogical structure allowed for contradictions and controversies among the children's viewpoints (cf Barab & Plucker, 2002; Damşa et al., 2013). Here, the guidance by the research assistants contributed to respectful conversations (Cumbo et al., 2019). This, in turn, gave space for meaningfulness where different viewpoints and agreements became constitutive of collaborative interactions. By using terms of Lave and Wenger [48:116], this is to say that to be part of collaborative interactions including smart mobile technology "does not take place in a static context". Considering all this, in what ways were the different affordances appropriate, i.e. 'apt'?

This study showed that the affordances of *linking*, *framing*, and *interest* (Kress, 2010; van Leeuwen, 2005) was apt for children's physical exploration to drive their use of smart mobile technology. The 'driving' was apparent when they tried out different ways of representing their game idea to *fix* their stop-motion prototype, which as such included several discussions and negotiations. Furthermore, it was visible as the topic (game design) appealed to the children's interest and experiences (cf Lave & Wenger, 1991). On the other hand, smart mobile technology embraced the affordance of *choice*, which became a driver of collaborative interactions in situations where the children should, for example, choose what kind of sound and/or music that should accompany their game plot. In line with Kress (2010), we point out these affordances as such have distinct meaning-potentials contributing to meaningful collaborative interactions. Furthermore, the study showed how physical and smart attributes either supported or drove collaborative interactions. This was the context where discussions, disagreements and negotiations became materialised and where new meanings emerged. When considering collaborative problem-solving processes and their implications for fostering skills in making and creating, it is important to acknowledge interpretation and meaning making as part of understanding creation (Ind & Coates, 2013), but also regarding fostering of social skills (Koh et al., 2015). In the present study,

we have pointed out that children's prior knowledge and skills are of importance when using game-based tasks. This contributed to the fact that children could overcome hindrances when they considered a task too complex (Kress, 2010; Schmidt, 2011) or when they were engaged in collaborative interactions (Kangas, 2010), as well as regarding problem-solving (Sánchez & Olivares, 2011) and meaning making (Ind & Coates, 2013).

The present study includes limitations related to being context bound and to the absence of a baseline study or control group. Further studies including larger samples and initiated with a baseline study on children's problem-solving tendencies, aptitudes, interests, etc., are needed to determine causality relations as well as to generalise the study results regarding school children's collaborative interactions in problem solving activities while developing digital game designs using smart mobile technology. In particular, the absence of a control group did not permit to univocally understand the influence of smart mobile technology compared to other collaborative design approaches. This would have strengthened the rigour of the study. Nevertheless, this paper provides a rich account of collaborative interaction instances, which provides a clear overview of the study. The results also demonstrate that even though they cannot simply be generalised, the findings clarify the complex relationship related to children's collaborative interactions when engaged in problem solving activities using smart mobile technology. By having included other forms of evidence from different types of research, the outcomes of the present study become more robust.

5.1. Conclusion

This article investigated how school children's collaborative interactions developed, while engaged in problem-solving activities using smart and mobile technology to develop digital game-based designs. The activity pushed the children towards two kinds of collaborative orientation; (1) task-orientation and (2) other orientation. Task-orientation emerged when children's ambitions were directed towards finishing the game design (or solving the problem) within the given time frame. Thus, their collaborative interactions were goal-driven, where the goal of the children's negotiations was to keep the work moving forward in an as straight-forward way as possible. Other-orientation emanated from the children's acting towards each other by showing sensitivity toward the others' views and ideas. The activity also demonstrated how the children's collaborative interactions were challenged and for a while hindered them in solving the problem at hand. However, these challenges opened up for the children to elaborate and negotiate the situation, which by the end changed the situation from being challenging to becoming productive.

During the digital game design activity, the children's ideas were manifested through linking and framing to convey an aesthetically well composed stop-motion prototype. The matter of having opportunities to make choices was important, e.g., by exploring sound and music to accompany their overall game design idea. This explorative and experimenting with choices allowed the children to become particular about the style of the message they wanted to convey. It was clear that the children's game design ideas were manifested through their interest and experiences of playing digital games themselves. This was explicated when the children presented their stop-motion prototype.

A main contribution of this study relates to the activity's workshop design including different phases, and a combination of smart mobile technology and creative material as a foundation for applying game-making in educational contexts to support collaboration and energise problem-solving. In particular, this has implications for how to develop mobile game-based learning strategies where children's interest and experiences are crucial values when fostering their learning through collaborative problem-oriented tasks. Another contribution of this work relates to the limited research about making games as a way to apply game-based learning. The results showed how this form of learning creates a source of togetherness, which, in turn, creates not only awareness of a joint purpose, but also in the extended collaborative experience of working towards a collective goal. This has implications for new ways of designing for learning that include viable tools to nurture innovative learning experiences, which as such contribute to a broader understanding of game-based learning activities. We suggest that outcomes from this study have important implications for the methodological field of including smart mobile technology in education.

SELECTION AND PARTICIPATION OF CHILDREN

We recruited an entire class of third graders (22 children) aged 9–10 in a Swedish elementary school. Initial contact was made to the school principal, who approved the researchers to approach the class teacher in asking about participation in the study. Written information of the study was sent out to the class teacher, who forwarded it to the children's guardians. All guardians approved their children's participation in the study through written informed consent. Furthermore, the teacher read out loud the written information about the study for the children, and the children gave their verbal consent to participate. When arriving at the university, where the study was carried out, the researchers explained the study procedure to the children and their teachers and answered any questions. During the workshop session, the children were orally informed that they could discontinue the study at any time if they wished to do so. The whole duration of the study was carried out under supervision of the children's class teachers.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement and funding

We thank all the children, teachers, and workshop facilitators. We gratefully acknowledge the grant from Nordplus Horizontal, NPHZ-2016/10071.

References

Adams, E. (2014). *Fundamentals of game design* (3rd ed.). USA: New Riders,Peachpit.

An, Y.-J., & Cao, L. (2017). The effects of game design experience on teachers' attitudes and perceptions regarding the use of digital games in the classroom. *TechTrends*, *61*, 162–170. http://dx.doi.org/10.1007/s11528-016-0122-8.

Barab, S. A., & Plucker, J. A. (2002). Smart people or smart contexts? Cognition, ability, and talent development in an age of situated approaches to knowing and learning. *Educational Psychologist*, *37*(3), 165–182. http://dx.doi.org/10.1111/j.1365-2729.1994.tb00279.x.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *The Journal of the Learning Sciences*, *12*, 307–359. http://dx.doi.org/10.1207/S15327809JLS0904_2.

Behnamnia, N., Kamsin, A., Ismail, M. A. B., & Hayati, A. (2018). Game based social skills apps to enhance collaboration among young children: a case study. In M. Miraz, P. Excell, A. Ware, S. Soomro, & M. Ali (Eds.), *Emerging technologies in computing. iCETiC 2018. lecture notes of the institute for computer sciences: vol. 200, Social informatics and telecommunications engineering* (pp. 285–291). Cham: Springer, http://dx.doi.org/10.1007/978-3-319-95450-9_24.

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, *72*, 145–157, 8.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. http://dx.doi.org/10.1177/2F1360940690600500107.

Cebeci, Z., & Tekdal, M. (2006). Using podcasts as audio learning objects. *Interdisciplinary Journal of E-Learning and Learning Objects*, *2*(1), 47–57. http://dx.doi.org/10.28945/400.

Chang, C-Y., & Hwang, G-J. (2019). Trends in digital game-based learning in the mobile era: a systematic review of journal publications from 2007 to 2016. *International Journal of Mobile Learning and Organisation*, *13*(1), 68–90, http://dx.doi.org/10.1504/IJMLO.2019.10016603.

Chang, K. E., Wu, L. J., Weng, S. E., & Sung, Y. T. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. *Computers & Education*, *58*(2), 775–786.

Connolly, T., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686. http://dx.doi.org/10.1016/j.compedu.2012.03.004.

Cumbo, B. J., Eriksson, E., & Iversen, O. S. (2019). The least-adult role in participatory design with children. In *Proceedings of the 31st australian conference on human-computer interaction* (pp. 73–84). https://dl.acm.org/doi/proceedings/10.1145/3369457.

Damşa, C., Ludvigsen, S., & Andriessen, J. (2013). Knowledge co-construction – epistemic consensus or relational assent?. In M. Baker, J. Andriessen, & S. Järvelä (Eds.), *Affective learning together, Social and emotional dimensions of collaborative learning* (pp. 97–119). London: Routledge.

Delprino, F., Piva, C., Tommasi, G., Gelsomini, M., Izzo, N., & Matera, M. (2018). ABBOT: A smart toy motivating children to become outdoor explorers. In *AVI '18: Proceedings of the 2018 international conference on advanced visual interfaces* (pp. 1–9). http://dx.doi.org/10.1145/3206505.3206512, article no: 23.

Dillenbourg, P. (1999). Introduction: What do you mean by collaborative learning?. In P. P. Dillenbourg (Ed.), *Collaborative learning: cognitive and computational approaches*. Oxford: Elsevier-Pergamon.

Engeström, Y., Miettinen, R., & Punamäki, R.-L. Introduction. (1999). In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on activity theory* (pp. 1–16). New York: Cambridge University Press.

(2016). DigiComp 2.0: the digital framework for citizens. In *JRC science for policy report*. European Commission.

Fereday, J., & Muir-Cochrane, E. (2010). Demonstrating rigor using thematic analysis: a hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, *5*(1), 80–92. http://dx.doi.org/10.1177/2F160940690600500107.

Furberg, A. (2010). Scientific inquiry in web-based learning environments: exploring technological. In *Epistemic and institutional aspects of student's meaning making* (Doctoral thesis), Norway: University of Oslo.

Gallagher, D., & Grimm, l. R. (2018). Making an impact: The effects of game making on creativity and spatial processing. *Thinking Skills and Creativity*, *28*, 138–149.

Garshi, A., Wist Jakobsen, M., Nyborg-Christensen, J., Ostnes, D., & Ovchinnikova, M. (2020). Smart technology in the classroom: a systematic review. In *Prospects for algorithmic accountability*.

Gennari, R., Melonio, A., Raccanello, D., Brondino, M., Dodero, G., Pasini, M., et al. (2017). Children's emotions and quality of products in participatory game design. *International Journal of Human-Computer Studies*, *101*, 45–61. http://dx.doi.org/10.1016/j.ijhcs.2017.01.006.

Gennari, R., Melonio, A., & Rizvi, M. (2019). Turn taking with turn-talk in group: Actions and reflections with children and teachers. *Multimedia Tools and Applications*, *78*, 13461–13487. http://dx.doi.org/10.1007/s11042-018-7090-2.

Grover, S., & Pea, R. (2013). Computational thinking in K–12 a review of the state of the field. *Educational Researcher*, *42*(1), 38–43. http://dx.doi.org/10.3102/0013189X12463051.

Hwang, G. J., Wu, P. H., & Chen, C. C. (2012). An online game approach for improving students' learning performance in web-based problem-solving activities. *Computers & Education*, *59*(4), 1246–1256.

Ind, N., & Coates, N. (2013). The meanings of co-creation. *European Business Review*, *25*(1), 86–95. http://dx.doi.org/10.1108/09555341311287754.

Javrh, P., & Mozina, E. (2018). The life skills approach in Europe. Summary of the LSE analysis. Retrieved July 28th 2021 from: https://eaea.org/wp-content/uploads/2018/03/Life-Skills-Approach-in-Europe-summaryEN_FINAL_13042018-1.pdf.

Kafai, Y. B. (2006). Playing and making games for learning: instructionist and constructionist perspectives for game studies. *Games and Culture*, *1*(1), 36–40. http://dx.doi.org/10.1177/1555412005281767.

Kangas, M. (2010). Finnish children's views on the ideal school and learning environment. *Learning Environments Research*, *13*(3), 205–223. http://dx.doi.org/10.1007/s10984-010-9075-6.

Kearney, M., Burden, K., & Schuck, S. (2019). Disrupting education using smart mobile pedagogies. In Daniela L. (Ed.), *Didactics of smart pedagogy*. Cham: Springer, http://dx.doi.org/10.1007/978-3-030-01551-0_7.

Khaled, R., & Vasalou, A. (2014). Bridging serious games and participatory design. *International Journal of Child-Computer Interaction*, *2*(2), 93–100. http://dx.doi.org/10.1016/j.ijcci.2014.03.001.

Kim, T., Cho, J. Y., & Lee, B. G. (2013). Evolution to smart learning in public education: a case study. In *Open and social technologies for networked learning, Vol. 395* (pp. 170–178). Korean public education, http://dx.doi.org/10.1007/978-3-642-37285-8_18.

Kinnula, M., & Iivari, N. (2021). Manifesto for children's genuine participation in digital technology design and making. *International Journal of Child-Computer Interaction*, *28*, 1–14. http://dx.doi.org/10.1016/j.ijcci.2020.100244.

Koh, J. H. L., Chai, C. S., Wong, B., & Hong, H. Y. (2015). Design thinking and education. In *Design thinking for education*. Singapore: Springer, http://dx.doi.org/10.1007/978-981-287-444-3_1.

Krange, I., & Ludvigsen, S. (2009). The historical and situated nature of design experiments - implications for data analysis. *Journal of Computer Assisted Learning*, *25*(3), 268–279. http://dx.doi.org/10.1111/j.1365-2729.2008.00307.x.

Kress, G. (2010). Multimodality. In *A social semiotic approach to contemporary communication*. London: Routledge.

Landoni, M., Rubegni, E., & Nicol, E. (2018). A comparative study into how pupils can play different roles in co-design activities. *International Journal of Child-Computer Interaction*, *17*, 28–38. http://dx.doi.org/10.1016/J.IJCCI.2018.04.003.

Lave, J., & Wenger, E. (1991). *Situated learning: legitimate peripheral participation*. New York: Cambridge University Press.

Littleton, K., & Hakkinen, P. (1999). Learning together: Understanding the processes of computer-based collaborative learning. In P. Dillenbourg (Ed.), *Collaborative learning: cognitive and computational approaches*. -Pergamon, Oxford: Elsevier.

Magen-Nagar, N., Shachar, H., & Argaman, O. (2019). Changing the learning environment: teachers and students' collaboration in creating digital games. *Journal of Information Technology Education: Innovations in Practice*, *18*, 61–85, http://dx.doi.org/10.28945/440510.28945/4405.

Makhaeva, J., Frauenberg, C., & Spiel, K. (2016). Creating creative spaces for co-designing with autistic children: the concept of a handlungsspielraum. In *Proceedings of the 14th biennial participatory design conference* (pp. 51–60). ACM.

Mazzone, E., Iivari, N., Tikkanen, R., Read, J. C., & Beale, R. (2010). Considering context, content, management, and engagement in design activities with children. In *Proceedings of the 9th international conference on interaction design and children* (pp. 108–117). Barcelona, Spain: http://dx.doi.org/10.1145/1810543.1810556.

Mercer, N. (1994). The quality of talk in children's joint activity at the computer. *Journal of Computer-Assisted Learning*, *10*, http://dx.doi.org/10.1111/j.1365-2729.1994.tb00279.x.

Nousiainen, T., Kangas, M., Rikala, J., & Vesisenabo, M. (2016). Teacher competencies in game-based pedagogy. *Teaching and Teacher Education*, *74*, 85–97.

Nousiainen, T., Vesisenabo, M., & Eskelinen, P. (2015). Let's do this together and see what we can come up with!: Teachers' views on applying game-based pedagogy in meaningful ways. *ELearning Papers*, *44*, 74–84.

Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2019). Exploring children's learning experience in constructionism-based coding activities through design-based research. *Computers in Human Behavior*, *99*, 415–427.

Papert, S. (1989). *Mindstorms: children, computers, and powerful ideas*. New York: Basic Books, Inc.

Perrotta, C., Featherstone, G., Astib, H., & Houghton, E. (2013). Game-based learning: latest evidence and future directions. Slough: NFER. *Evidence for Excellence in Education*.

Pesare, E., Roselli, T., & Corriero (2016). Game-based learning and gamification to promote engagement and motivation in medical learning contexts. *Smart Learning Environment*, *3*, 5. http://dx.doi.org/10.1186/s40561-016-0028-0.

Samaha, M., & Hawi, N. S. (2016). Relationships among smartphone addiction, stress, academic performance, and satisfaction with life. *Computers in Human Behavior*, *57*, 321–325. http://dx.doi.org/10.1016/j.chb.2015.12.045.

Sánchez, J., & Olivares, R. (2011). Problem solving and collaboration using mobile serious games. *Computers & Education*, *57*(3), 1943–1952.

Sanders, E. B., & Stappers, P. J. (2014). From designing to co-designing to collective dreaming: three slices in time. *Interactions*, *21*(6), 24–33. http://dx.doi.org/10.1145/2670616.

Schilhab, T. (2017). Adaptive smart technology use: the need for meta-self-regulation. *Frontiers in Psychology*, *8*, 298. http://dx.doi.org/10.3389/fpsyg.2017.00298.

Schmidt, J. A. (2011). Flow in learning. In S. Järvelä (Ed.), *Social and emotional aspects of learning* (pp. 28–34). Oxford, UK: Elsevier, http://dx.doi.org/10.1016/B978-0-08-044894-7.00608-4.

Spector, J. M. (2014). Conceptualizing the emerging field of smart learning environments. *Smart Learning Environments*, *1*(1), 5–10. http://dx.doi.org/10.1186/s40561-014-0002-7.

Sung, H-Y., & Hwang, G-J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education*, *63*, 43–51.

Triantafyllakos, G., Palaigeorgiou, G., & Tsoukalas, I. A. (2011). Designing educational software with students through collaborative design games: the we!design & play framework. *Computers & Education*, *56*(1), 227–242.

van Leeuwen, T. (2005). *Introducing social semiotics*. London: Routledge.

Vos, N., van der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education*, *56*(1), 127–137, 8.

Winograd, T. (2001). Architectures for context. *Human-Computer Interaction*, *16*(2), 401–419. http://dx.doi.org/10.1207/S15327051HCI16234_18.

Wu, M. L. (2018). Making sense of digital game-based learning: A learning theory-based typology useful for teachers. *Journal of Studies in Education*, *8*(4), 1–14. http://dx.doi.org/10.5296/jse.v8i4.13022.

Yannier, N., Hudson, S. E., Wiese, E. S., & Koedinger, K. R. (2016). Adding physical objects to an interactive game improves learning and enjoyment: evidence from earthshake. *ACM Transactions on Computer-Human Interaction*, *2*(4), http://dx.doi.org/10.1145/2934668.