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ICT – Computer Play and Children's Development of Skills in Science

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Abstract—**Play is a powerful mediator for learning throughout a person's life, while ICT (Information and Communication Technologies or digital tools or computers) packages are often presented in a playful manner. This paper aims to explore the link between ICT and play, as well as the contribution of ICT-play on children's development of different skills in science. It initially presents common features-characteristics of children's traditional play and ICT-computer play. Such characteristics include the active involvement of the children, self-motivation, decision making, experimentation with new and different situations and the players' high levels of engagement. Within the context of science education, ICT-computer play and children's development of various skills are discussed. Examples of such skills include, technical-computer skills, numeracy skills, problem solving skills, abstract thinking, higher order cognitive skills, creativity, imagination and attention concentration. As children learn through play, some objectives could be more informal, so as to facilitate the development of skills within science lessons.**

Index Terms— **Computer, Education, ICT, Play, Science.**

I. Introduction

Today's children interact with a wide range of technology in their everyday lives, and become competent users of devices, such as computers, mobile phones, video game consoles, digital video and communication-based devices, without any formal instruction [1]-[2]-[3]. The technological resources available in the home and other informal environments are increasingly widespread, while many homes possess more sophisticated resources than do schools. These children also referred to as "digital natives" [4] are growing up with different and diverse experiences to their parents and teachers. As children are exposed to new technological experiences on a daily basis, these experiences are likely to influence their competency and skills in using new technological tools. The computer, in particular, supports and extends children's learning and development, as they use computers to explore, play, solve problems, do puzzles and manipulate objects on the screen [5]. In parallel, much traditional childhood play is being replaced by time spent on computer play, and often at a very early age [6]. In discussing computer use in school classes, the phrase 'playing with the computer' is often used by teachers and children. This phrase designates a series of qualitatively different activities (associated with different types of software, including computer games) in which children may, for example, engage in exercise control, play or create.

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Some specific terms used in this paper will be briefly explained. Initially, the term information and communication technology (ICT) was used synonymously with the terms computer, digital tools and technology. The definitions of technologies vary, and many of the areas where play and ICT appear to function harmoniously rely on a definition of ICT that reaches beyond the desktop computer [7]. The phrases computer play and ICT play denote the process of children using computers-ICT, through which they can achieve different goals, such as familiarity with numeracy and literacy and the acquisition/ development of different skills. Computer-ICT play is not restricted to computer games; rather, it includes everyday electronic objects and toys that generate a response when stimulated by the child [8]. Finally, the words children, pupils and students denote school age children, with age range 7-18.

II. Play and ICT - Computer Play

A. Learning about and with ICT

Many national curricula contain specific requirement that children are taught ICT (a) as a discrete subject and (b) as a mean for learning other subjects (literature, science, mathematics, etc.) across the curriculum. The curricula do not specify particular technologies; however, the teachers can decide for themselves what technological/ digital tools to provide to children.

Of course, children do not only learn to use ICT in school. The technological resources available in homes and other informal environments are increasingly widespread. Other affordances arise from the human and cultural resources available to support activity: the willingness and ability of parents and friends to help as well as professional contacts. Children, in general, have a positive attitude towards ICT and most take the opportunity to develop their technical/ ICT capability. Both adults and children make sense of new programs and digital tools by playing with them, to find out what they can do, how they can do it and what uses can be made of them. 'Playful discovery' is a used strategy for learning, and children enjoy activities where they can set their own goals [1]. A spirit of exploration and self-sufficiency characterizes the use of ICT to achieve important goals. Pupils with computers at home often indicate that they are far more independent in their learning. This independence has implications for learning, both about and with ICT. In school, such demands are usually seen as 'boring work', whereas in games contexts out of school, pupils respond to cognitive challenges as 'fun'. The view of play as a continuum of activities accepts that non-playful or work-like behaviours can contribute to learning, especially when they also contain dispositions such as engagement with task and active involvement.

B. Common features of children's traditional play and ICT-computer play

Play has been identified as essential for children's development and as a key element in effective learning [9]. While freely engaging in play, children acquire various skills such as self-reflection and abstract thinking, communication skills, learn to manage their emotions and explore the roles and rules of functioning in society. The research has shown that play does assist in children's development and learning in many ways, depending on the educational and social frameworks where the play occurs [10]. Play can be described as informal (it is typically given a higher value in preschool curricula) when initiated by the children themselves, and as formal when organised by the teachers [11]. The research has also identified various characteristics that distinguish play from other human activities [12]. Play has been characterised as spontaneous, pleasant, child led and voluntary (freely chosen), opportunistic, creative, focused on the activity and process rather than the product, low risk and highly engaging [13] – [14]. Furthermore, children's play has been connected to terms such as creativity, adaptation, experimentation, learning, communication and socialisation [15] – [16].

At the same time, learning to use the computer may be characterised by the active involvement of the children in interacting with the software, investigation and experimentation, and focusing on the discovery process rather than the product [17]. For example, children's sign-making extends to computer screens and keypads, showing that the children transform the content of the meanings of the signs they make, whether on screen or on paper, through playful manipulation. Many different kinds of educational software have been presented in the form of play in order to make them attractive to young children [18] – [6]. Verenikina and her co-authors [6] have identified features of children's traditional play that can be supported and further enhanced by different kinds of computer play. Common characteristics between children's traditional play and computer play include, for example, the active engagement/ involvement of the children, self-motivation, experimentation with new and different situations and the players' high levels of engagement (see Table 1). Table 1 also shows the indicative procedure in the computer environment: when children work on the computer, very often, the choice and the order of activities is decided by the children, they decide on the pace of their work, they have the possibility to experiment and investigate new situations, as well as they work for the joy of the whole process (e.g., navigation without specific purpose). Additionally, appropriate and pedagogically designed programs offer the opportunity for fruitful feedback and for the development of children's creativity.

Table 1.

Common characteristics between traditional play and "ICT-computer play", and indicative procedure in the ICT-computer environment

Common characteristics	Indicative procedure in the ICT-computer environment
Active engagement/ involvement of children	Choice of computer activities by the child, the child is in control as s/he interacts with the software (e.g., which activities to be performed)
Children play at their own pace, without external pressure	The children decide on the pace/ rhythm, according to their knowledge, skills and interests
High levels of children's engagement, self-motivation to continue to play	When children work on the computer they are often self-concentrated
Exploration, experimentation with new situations	Possibility to investigate and experiment with various situations
Development of creativity and imagination	Pedagogically designed educational programs offer opportunities for creativity
Play regards more the process, rather than the product	Engagement with ICT may take place for the joy of the whole process

Playing with ICT involves much representation or symbolic activity and emphasizes meaning making. These play experiences can be crucial in allowing pupils to develop decision making, control over their own actions and abstract thought. Play situations also allow others to assist a child in the performance of these higher order skills in order to improve their competence. The interaction among people during play was particularly important for Vygotsky [16], whose views on play and learning are powerful and influential throughout different cultures.

III. ICT IN SCIENCE EDUCATION

The distinction between teaching ICT (or computers, or Information Technology) as a discrete subject and teaching different subjects with/via the use of ICT is widely known and has been mentioned in the previous section. This paper regards the latter case, and more specifically, the ICT use/ integration in science lessons. Pupils can use ICT in science lessons in order to look up ideas and information, to perform scientific procedures or experiments, to study natural phenomena through simulations, to process and analyze data and to practice skills and procedures [19]. ICT can support pupil-centered inquiry-based learning, can trigger enthusiasm and motivation for learning, and enable pupils to learn at their own pace.

Research findings suggest that ICT in secondary science, particularly in the form of simulations or animations of processes, provides a range of affordances for learning science [20]. Computer science software allows pupils to visualize and understand phenomena that cannot be easily observed or allows pupils in constructing and interpreting graphs (e.g., of speed over time). For example, research has shown that through using simulations, pupils gained understanding of physical phenomena involving interacting variables, enabled pupils to perform at higher cognitive levels and promoted conceptual change [17]. Cox and Nikolopoulou [21] showed that computer based data analysis software helped 13-14 year old pupils to perform a range of intellectually advanced/ complex data analysis tasks, such as classifying data according to different criteria. Ünlü and Dökme [22] reported that pupils stated as more enjoyable and interesting those science lessons which combined computer simulations with lab activities.

Webb [23] argued that science teachers need to learn how to relate the affordances of specific ICT applications for science education, such as modeling, simulations and data logging devices, to pupils' alternative conceptions of specific science concepts in order to be able to incorporate the ICT applications in concrete learning activities. It is emphasized that when ICT is used in science lessons there are various factors (beyond the scope of this paper) that impact on pupils' learning such as, the type of the software, the pedagogical practices, classroom interactions (e.g., collaborative learning), pupils' ICT competence and the teachers' beliefs, skills, knowledge, competencies (technological, pedagogic) and confidence. For example, Skryabin and co-authors [24] indicated that pupils' ICT competence (individual ICT usage) was a significant positive predictor for individual academic performance in science. Regarding teachers, Voogt [25] indicated that extensive ICT-using science teachers appeared more confident about their ICT competencies. Others [26] found that the fewer the years of teaching experience and the higher the teachers' computer self-efficacy, the stronger was the view that ICT play is not just free play. Teachers' beliefs and confidence affect their classroom practices and, consequently, the children's learning.

IV. ICT, PLAY AND DEVELOPMENT OF PUPILS' SKILLS

The play component of children's ICT tools / digital tools/ software should not be seen as appropriate solely for recreational or fun purposes. Play is a powerful mediator for learning throughout a person's life. In schools, learning activities are generally considered to be work rather than play. However, research suggests that aspects of the situation influence the way we feel about being involved with them. Pupils can develop various skills through 'playful learning', both about and with ICT. Competencies with digital technologies will be necessary to ensure future employability and economic effectiveness. When play is not seen as a peripheral activity, it can be a medium to support learning in elementary and in secondary education.

A number of studies illustrated the advantages of using computers/ ICT and play, mainly in elementary education [27] – [28] – [29] – [1]. Computer games can be useful in enhancing memory capacity, in concentration of attention and in the problem solving strategies of children, which can affect their academic achievement. Cassell and Ryokai [27] described a computer based environment that can enhance advanced forms of children's collaborative storytelling. Pillay [28] explored the transfer of cognitive and meta-cognitive skills developed in recreational computer games to high school children's subsequent performance on computer based educational tasks. Skills such as generating alternative solutions, information organization and navigation were examined. Ko [29] showed similar results, where the strategies of logical thinking used in computer games were analyzed. Morgan and Kennewell [1] described a project carried out in a number of informal learning situations. The children developed competence in using unfamiliar hardware and software and they learned in a loosely structured learning environment. Groups of children were left to 'play' with the software in order to explore the possibilities and discover new features. Their evidence indicated that the influence of self-efficacy may be more important in gaining success than previous experience with technology. Thus, the research studies associate ICT-computer play with the development of different skills.

A. Examples of playful computer activities in science lessons

Exploring pupils' ICT-play activities demands attention in context in which the engagement occurs (the form of activity etc.). Within the context of an educational environment, with its discourse of play as a medium for learning, digital /ICT technologies have been thought of as an educational tool by educators, policy makers and researchers.

There is a range of ways that computers might contribute into pupils' learning. Complex processes and techniques can be learned through informal methods: unfocused exploration, creative invention, trial-and-error, cooperation with friends and asking people who are more experienced. As children learn through play, a number of learning objectives could be more informal and various skills might be developed within science lessons as well.

Activities such as exploration and enquiry-learning could be carried out informally, offering significant cognitive challenges with specific goals, materials and strategies. The design of a project structured around computers and telecommunications, supported by specially selected software as well as making use of the internet, may take place within science lessons. In such contexts, learning is not only fun, but pupils actively construct their own meanings and make sense of the world in their own ways.

Talib et al. [30] found a positive connection between positive experiences gained through playful and creative science-based activities and the development of interest in science. Through a collaborative creative project, primary school pupils were encouraged to create stories (script writing, creating models, taking digital images to produce an animation etc.) on their own based on the exploration and understanding of science concepts. Their findings indicated that the project has enabled pupils to explore science concepts through play and increased their motivation.

Computer software that allows pupils to engage in play tends to be open-ended and does not simply require the pupil to press the button in order to get a response. Complex 'play' can be considered as a 'high yield' cognitive activity. New digital tools (e.g., virtual reality tools) may provide experiences that go beyond those possible with traditional materials. For example, pupils may construct a virtual world or investigate the reasons of an earthquake or simulate the consequences of a volcano's eruption. Augmented-reality applications use a link between a tablet or smart-phone and, typically, a set of interactive characteristics, with the device providing a screen through which a real scientific phenomenon is viewed.

Pupils using science simulations have the opportunity to try 'what if' scenarios in order to develop hypotheses, make decisions and also develop computational thinking. For example, 'what will happen if' they change the values of variables of a physical phenomenon.

As new forms of technology/ ICT are developed, with sensors and computer chips embedded into a wide range of devices, such developments are likely to simulate the more imaginative and exploratory aspects of pupils' play. The interactivity offered by several ICT tools may well provide motivation for pupils' learning.

V. Concluding Remarks

Over the last years the ICT / computer software targeted at children has significantly increased. Digital tools and software range from educational software, designed to enhance literacy and numeracy skills, to commercial applications, produced for recreational purposes only. To make the educational content of these ICT packages more attractive to children, such software is often presented in a playful manner. There is a potential learning value of ICT play designed for the purposes of children's recreation and entertainment. There is a potential in further exploration, for example, of the affordances of ICT-computer play in the development of children's higher order skills. Future research is interesting to investigate the ways in which digital/ ICT resources are incorporated into play. The merging of the physical and digital words are made possible with the new ICT. The new ICT/ digital tools and the activities associated with them have the potential to extend learning in new and more informal/ playful ways.

Given the time and opportunities children of today have for engaging with ICT or computers (or digital tools), it is essential that ICT designers understand the learning potential of their products. It is also essential that teachers (and parents) are able to make informed decisions on the purchase of such products on the basis of educational value.

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