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Influence of Game Application Usage on Spatial Skills by Preschool Children

Vliv herní aplikace na prostorové dovednosti dětí předškolního věku

Disertační práce

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Abstract

The work focuses on the analysis of the influence of educational multimedia applications and the possibility of support and development of spatial skills in pre-school children. To date, only a limited number of ICT research studies have been conducted on pre-school education. Therefor in the interest of this research, the ADAM educational game application was developed which content is focused on the development of cognitive areas - namely spatial skills in pre-school children. Spatial ability and skills are the basis for mathematical thinking and for the whole STEM area that is gaining worldwide importance in society. Based on data obtained from pilot study, it seems the use of ICT might be an appropriate means to develop these skills already in early years.

The theoretical part analyses the basic concepts and theories on which the definition and description of spatial skills and abilities are based. Further areas are described, such as language and speech, gender differences that also affect spatial skills.

Firstly, the methodological part presents the results of preliminary and pilot studies, which were conducted with pre-school children from 4 to 6,5 years. The introduction of main research conducted as a quantitative experimental study and discussion of results follow in next chapters. In the chapter conclusion there are the benefits of the study described and further are also proposed possibilities of next research.

Keywords

Spatial skills, preschool education, ICT, educational application

Abstrakt

Práce se zaměřuje na analýzu vlivu vzdělávací multimediální aplikace ADAM na rozvoj prostorových dovedností u dětí předškolního věku. Do současné doby nebylo provedeno mnoho výzkumů zabývající se vlivem ICT na oblast předškolního vzdělávání. V rámci předkládaného výzkumu byla proto vytvořena vzdělávací herní aplikace ADAM, jejíž obsah je zaměřen na rozvoj kognitivních oblastí - konkrétně prostorových dovedností právě u dětí předškolního věku. Prostorové schopnosti a dovednosti představují základ pro matematické myšlení a celou oblast STEM, která získává celosvětově na společenském významu. Využívání ICT se jeví jako vhodný prostředek pro rozvoj těchto dovedností již u dětí raného věku.

Teoretická část analyzuje základní pojmy a teorie, ze kterých vychází definování a popis prostorových schopností a dovedností. Následně jsou popsány další oblasti, jako je jazyk a řeč, gendrové rozdíly, které prostorové dovednosti ovlivňují.

Metodologická část nejprve popisuje předběžnou a pilotní studii, obě provedené s dětmi v předškolním věku od 4 do 6,5 let. Následuje představení hlavního výzkumu, provedeného jako kvantitativní experimentální studie, a diskuze získaných výsledků. Závěr je věnován přínosům provedeného výzkumu a možnostem jeho pokračování.

Klíčová slova

Prostorové dovednosti, předškolní vzdělávání, ICT, vzdělávací aplikace

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List of Abbreviations

EF	Executive Function
ICT	Information and Communitation Technology
ECE	Early Childhood Education
NAEYC	National Association for the Education of Young Children
NCTM	National Council of Teachers of Mathematics
NCATE	National Council for Accreditation of Teacher Education
PCM	Progressive Coloured Matrices
RNC	Research National Council
STEM	Science, Technology, Enginnering and Math
SON-R	Intelligence Test Battery
RVP PV	Rámcový vzdělávací program pro předškolní vzdělávání

Declaration

I declare that this work entitled “Influence of Game Application Usage on Spatial Skills by Preschool Children“ is my own work based on my personal efforts and data collection through an experimental study. The content of this dissertation is original and written by the undersigned author, apart from the review of previous research, which quotes the relevant material and all references to original work have been cited.

Simona Pekárková

10.12.2018, Velká Dobrá

Dedication

First of all, I would like to express my thanks to my supervisor, prof. RNDr. Eva Milková, Ph.D., for her valuable advice, patience and inspiring leadership in scientific work throughout my studies. Furthermore, I want to thank my husband and children for their support and for creating good environment for my study. Finally, I want to give many thanks to my friend and colleague Dr. Muhammad Azim for his professional attitude and support of my work.

Introduction

Over the last decade, tablets and other kinds of new technology have appeared and rapidly become widespread. Many researchers have suggested the need to take this new technology into account and to try to employ it in the service of children's education in an efficient way (Leslie, Couse, Chen, 2014, Vernadakis at al., 2005). Plowman (2011) and others argue that the necessity of expanding the debate about the use of various technologies in early childhood education (ECE) should not be overlooked. Recent research projects have mostly concluded that young children access digital technologies from a very young age at home, but that the early years of childhood education are not yet able to meaningfully participate in their digital experiences and incorporate the relevant tools and content into ECE (Palaiologou, 2014).

Specifically, spatial ability has recently been recognized as a crucial area in children's education, one which might have a broad positive or negative impact on the further learning, education and even future career of a child (Gustafsson, J., 1988, Lohman 1988, Guttman, L., 1990, Diezmann M.C., Watters J.J.2000). We must also take into account certain important external factors which have an influence on the development of spatial ability through other developments such as language (Millar, Patterson, Simmering, 2015, Pruden, Lewine, Huttenlocher, 2011, Loewenstein, Gentner, 2005), choice of toys and games (Uttal, Miller, Newcombe, 2013, Caldera at al., 1999, Jirout, Newcombe, 2015), motor activities (Newcombe, Frick, 2010) or sex differences (Kail at al., 1979, Gur at al., 2000, Vogel at al., 2003, Hier, Crowley, 1982). It is already known that the spatial skills exhibited by small children are a strong predictor of later achievements in mathematics (Clements, D.H., and Battista, M.T., 1992, Stewart, R. at al., 1997, Van Nes, F. & De Lange, J., 2007, Cheng YL and Mix KS., 2012, Gunderson, E. A. at al., 2012, Farmer, G. at al. 2013, Crollen, V. at al. 2015). Moreover, spatial skills are closely related not only to mathematical skills but also the entire STEM field (Wai, J. at al. 20O9, Wai, J. at al. 2010, Uttal, D.H., Cohen C.A., 2012).

Furthermore, in our review of the literature we also describe a new attitude towards spatial skills and how they are taught in ways which can help prevent children from being left behind. In this context, Information and Communications Technology (ICT) is also considered to provide new learning opportunities in the field (Postholm, May, 2007). In order to analyse the benefits and impact of ICT, the ADAM educational game application was created as a story-based game. The ADAM game application is based on psychological and special pedagogical knowledge about the development and needs of preschool children and its description is also a part of this dissertation.

New educational curricula which stress the development of spatial skills have already begun to appear worldwide. Educational authorities have drawn the attention of teachers and educational institutions to this area which can no longer be overlooked, as it may well play a crucial role in the further education of children.

In the Czech educational system, a new educational curriculum for all education levels (including preschool education) is being prepared, one which also points to the role of spatial abilities and spatial skills. In the past few years, the focus on using modern technology in pre-school education has significantly increased (McCarrick, K., & Xiaoming, L., 2007, O'Hara, M., 2008, Couse, L. J., & Chen, D. W., 2010, Neumann, M. M., & Neumann, D. L., 2013, Kerckaert, S., Vanderlinde, R., Van Braak, J., 2015). The results of current research findings are that ICT can increase children's motivation, interest and engagement in literacy and learning (Shuker & Terrini, 2013) and can be beneficial when combined with new attitudes to learning.

Nevertheless, ICT is still relatively rarely promoted in pre-school education, due to the lack of professional work assessing the impact and benefits of ICT in pre-school children. There has as of yet been no significant body of research conducted on preschool children's usage of digital technologies, or how to create participatory learning environments alongside other activities (Palaiologou, 2014). However, there is a growing need to analyse whether applications for the development of intellectual skills are appropriate technological resources in pre-school education. For these reasons we decided to pursue this research to explore the possibilities for the game application we developed to influence the spatial skills of preschool children.

1. Current State of the Field

Recent research is providing new evidence concerning links between domains of human thinking and new interdisciplinary research is identifying and demonstrating the relations between education, neuroscience, psychology and neurophysiology. This is a move from the previous approach, which considered cognitive skills to be innate and inherited and instead includes the notion that skills are based on ability, and can be trained and improved using appropriate tools and tasks throughout the child's life. There is also the new concept that spatial competency and mathematical competence are associated with changes in social life.

1.1. Terminology

There is a need to define ability, skills and competencies and put these three terms into a hierarchy, although to some extent it must be admitted that they overlap.

Ability

Ability is the union of a native process within humans and content inferred from relatively permanent changes in behaviour. Abilities are the products of maturation and learning. Thus, possessing a particular ability facilitates further learning. Ability can be defined as one's potential for learning or knowledge that supports cognitive performance (Mayer, 2003). Another simpler and clearer definition is that ability is the level of aptitude one is either born with or is trained to perform.

Skills

These are gained during life and they are based on abilities as their potentials. Skills are sets of trainable mental abilities which can be developed, and which underpin successful learning and performance (Lohman, 1988, Sternberg, 2003). A skill is a type of work or activity which requires special training and knowledge (Collins dictionary).

Competency

Some scholars have pointed out that a key feature concerning the concept of competency is its stronger relation to "real life" (e.g. Bandura, 1990). He summarizes that "there is a marked difference between possessing knowledge and skills and being able to use them well under diverse circumstances." Furthermore, other authors, e.g. Connell, Sheridan and Gardner (2003) are particularly concise in describing competency as "realized abilities". Simonton (2003) characterizes competency as "any acquired skill or knowledge that constitutes an essential component for performance or achievement in a given domain". Competency is defined as a complex quality which may be cultivated though an educational process (NRC, 2006). In other words, a competency is not limited to cognitive elements and competency is therefore a broader concept that comprises skills as well as attitudes and knowledge.

Spatial ability

Previously researchers used "spatial ability" as a term which was strongly defined as a part of intelligence and which was inherited. Gardner (1983) states that spatial ability is defined as the neuro-psychological capacity to perceive form in objects as they are encountered in the environment (Gardner, 1983). According to Carrol (1997), spatial ability signifies the ability to manipulate patterns as indicated by the level of difficulty and complexity of the visual stimuli which can be handled successfully; without regard to the speed tasks are solved at. He sees visual-spatial thinking capacity as one of the three most compelling intellectual abilities that control and process information working within general intelligence (in Woolfolk, 2007). Lohman (1988) stated that "Spatial ability may be defined as the ability to generate, retain, retrieve and transform well-structured visual images. It is not a unitary construct. There are, in fact, several spatial abilities, each emphasizing different aspects of the process of image generation, storage, retrieval, and transformation".

Spatial skills

Later psychologists started using the term spatial skills to convey the idea that it may be possible to train these skills to some extent. S.A. Sorby (1999) underlines the difference in the meaning of the terms "spatial ability" and "spatial skills". The first term refers to an ability that is innate and whose level is determined. The second term "spatial skills" simply means skills that can be trained and improved by dint of various exercises and training. Another term that appears in other work is "spatial visualization". (Linn, Petersen, 1985).

Spatial competence

Includes thinking about distance, shape, order, frames, and different relations including two and three dimensional degrees, and in addition utilizing graphs, models, and common language to describe this information. Spatial competence is a key to numerous fields, areas and real aptitudes. Fields as geography and astronomy and skills for example as map reading and navigation include spatial relations of items in the surrounding. Fields, for example, mechanics and natural science include understanding the spatial relations between parts of things and their dynamic interaction. Likewise, spatial representations are associated with very high state of numerical comprehension, and in understanding the outlines and data visualizations normally utilized in numerous disciplines (Ferguson, Forbus, 1999). Seitinger (2008) also pointed to the importance of representations, but mentioned a further second domain that interacts with space: the capacity to move through a space physically or virtually and act upon an environment.

Based on the previous definitions, we can present a concept and terminology for spatial skills, which will be used in this research and in the presented results of the preliminary study, pilot study and main study. The researchers assume spatial skills can be trained and influenced by environmental conditions and the goal is also to determine the influence of the ADAM educational game application on spatial skills in small children. This game application was specifically developed for the purposes of this research study. In this review of the current literature, the terminology used in previous papers and works will be not changed, so depending on the source, the terms “spatial ability” and “spatial skills” will be preserved according to the authors cited.

1.2. Spatial Ability and Spatial Skills

1.2.1. Historical Background

The first mention in some way related to the later term spatial ability was made by Francis Galton in 1880. He defined, based on his own experiments, “mental imagery” as a part of intelligence. (Mohler, 2008). Nevertheless, publications with a focus on spatial imagery did not emerge until the 1920s. During the next century various research was carried out, new theories and new methods emerged through which the scientists and researchers attempted to specify these dimensions of human intelligence and attempted to clarify the specific characteristics and features of spatial intelligence. Following is an overview of the approaches in regards to spatial ability, see Table 1.

Table 1: Chronology of approaches in regards to spatial ability and spatial skills (Mohler, 2008)

1880 - 1940	Acknowledgement of a spatial factor separate from general intelligence through psychometric studies
1940 - 1960	Acknowledgement of multiple spatial factors through psychometric studies, emergence of myriad spatial assessments
1960 - 1980	Psychometric studies into cognitive issues, emergence of developmental and differential research
1980 -	Effect of technology on measurement, examination and improvement, emergence of information processing research

One of the first concepts of intelligence, the so-called “two-factor theory”, was expressed by Charles Spearman in the 1920s, nearly a half century before H. Gardner defined his concept. Spearman was focusing on intelligence as a single factor called the “g factor”, which was considered to be the main component or mental attribute used to perform any mental test. Importantly, he also stated that along with the g factor, other specific cognitive skills exist such as spatial ability, which he called the “s factor”, complimenting his main „g factor” (in Guttman, 1990).

The first paper to acknowledge the concept of spatial ability was published by L.E. Thorndike in 1921. Thorndike could be taken as a starting point for the following published research on spatial ability.

His definition of “mechanical intelligence” was crucial in regards to the factor of spatial ability. He described this part of intelligence as the ability to visualize relationships between objects and understand how the physical world works (Thordike in Mohler, 2008). Next, the goal of specifying and defining spatial ability was pursued further in the later work of El Koussy (1935) and Kelley (1928). El Koussy examined spatial intelligence and contributed to the methods for its measure. Subsequently he was the first to define the term “k factor“, which he described as the ability to obtain and utilize visual spatial imagery. In contrast to Spearman, Kelley claimed the “g” factor had much less importance and established his own pattern of intelligence. He defined verbal, numerical, rote memory, spatial and speed factors at each level. Furthermore, Kelley identified a new distinct factor within spatial ability, which was the manipulation of spatial relations (Mohler, 2008).

Further work was conducted by Thurstone (1950), Cattel (1971) and Guilford (1967). All of them worked on the structural hierarchical model of intelligence which is represented by the general factor “g” and other cognitive skills which are placed at lower levels underneath the “g factor”. Thurstone (1938) recommended that essential mental capacities fall into seven classifications and included spatial relations as one of the seven classifications. He presumed that the total of these classifications creates human intelligence. The new statistical techniques of multiple-factor analysis-developed by Thurstone provided the necessary tools for his most enduring contribution to psychology: The Theory of Primary Mental Abilities (Thurstone, 1938). Employing his new way to deal with factor analysis, Thurstone found that intelligence does not emerge from a general factor, yet rather rises up out of seven free factors that he called primary abilities: word fluency, verbal comprehension, spatial visualization, number facility, associative memory, reasoning, and perceptual speed (Thurstone, 1934).

Afterwards, Thurstone (1938) continued his study of primary mental abilities. First of all, he worked on defining a so-called “space” factor. This factor represented the ability to mentally manipulate spatial or visual images. (1938). Furthermore, Thurstone (1950) divided spatial ability in to three main visual/mental capacities. The first capacity is the ability to recognize the identity of an object when seen from different angles. The second capacity is the ability to imagine displacement among the parts of an object. The third ability represents the spatial orientation of an object in reference to the observer (Gardner, 1983).

To sum up, in the time period before 1940, the most significant result of research and these new theories, was a new view of spatial ability as a capacity separate from the general intelligence factor (g) defined by Spearman.

In the next two decades from 1940-1960, researchers conducted various research aimed at defining what spatial ability represents. Many researchers however considered this ability unimportant. Others considered spatial ability to be a “lower ability”. The undervaluation of spatial ability and the confusion within the increasingly contradictory results of the researches, which pointed to the importance of spatial ability, created additional difficulties (D’ Oliveira, 2004, Lohman, 1979a). Many researchers adopted contradictory names and definitions for spatial factors (Cooper, Mumaw, 1985). In spite of this sceptical attitude, Guilford – with his large-scale assessment conducted in the Army Air Forces – laid down the basic foundations for further spatial testing. (Guilford, 1947). As a result, the existing doubts concerning spatial ability as an equivalent component of intelligence were dispelled. At the end of this two decade-period, around 1960, several spatial tests were available and there was a consensus among researchers that the spatial ability was not unitary (Eliot, Smith, 1983).

From the 1960s onward, new, highly-influential attitudes emerged. Many intelligence theories belong this time-period, all of which concluded that spatial ability was a part of the mental ability of human beings. A notable theorist of this period was Cattell (1963), who developed the concepts of fluid and crystallized intelligence (abbreviated Gf and Gc, respectively) where spatial ability tasks would draw on both (Mohler, 2008). Another researcher in this time-period, M. Smith (1964), introduced his hierarchical view of the structure of human abilities, where he also clarified the position of spatial abilities. He further suggested distinguishing so-called “specific factors” from spatial factors such as spatial relations, spatial orientation and spatial visualization (Mohler, 2008).

In the time-period following 1980, other psychologists such as Gardner (1983) and Guilford (1988) avoided the concept of the ”g factor” and insisted there are at least eight, perhaps more. In other words, they claimed that multiple intelligences comprise human intelligence as a whole. In this model, spatial ability is considered a unique, separate intelligence altogether, rather than an ability operating and directed under the control of “g.” Gardner claimed that, according to his research, spatial intelligence includes the ability to perceive and represent the visual- spatial world accurately and to form and manipulate mental images (Gardner, 1983). He claimed that each part of intelligence, as well as spatial intelligence, reaches four different stages throughout one’s lifespan (Gardner, 1993). H. Gardner defines spatial ability as a separate factor of human intelligence that can also be empirically tested and evaluated. Gardner considers all factors of intelligence to be of equal importance. As a result, his theory describes intelligence as composed of multiple factors. According to this theory, intelligence arises from the combination of a person’s genetic heritage and the conditions of life in a given culture and area. In other words, intelligence is neither fully static nor innate. According to Gardner, spatial intelligence describes the potential to recognize and manipulate patterns in open space, as well as patterns within a confined area (Gardner, 1983).

Later, theories began to emerge describing intelligence as non-static and something that can be changed. R. Sternberg (1988) postulated that intelligence may be changed or influenced by many meta-components, and also by the environment. In Sternberg's view, intelligence revolves around the interchange between the analytical, practical and creative aspects of the mind. He claims that what most IQ tests measure is only the componential/analytical part of intelligence. He states that what makes the difference when determining if someone is smart, depends on how they utilize and balance their mental aptitudes. According to Sternberg (1988), spatial ability involves the visualization of shapes, rotation of objects and figuring out how pieces of a puzzle fit together.

In this time-period (1970-1990), a lot of research focused not only on demonstrating that the factor of spatial ability exists and is a part of intelligence, but there was also a lot of differential research. The aim was to target areas of difference between spatial ability, particularly on differences between genders. Thanks to the diversity of attitudes and different approaches during this period, knowledge concerning the development and differentiation of spatial ability increased dramatically. Thanks to Mohler (2008), further steps in conducting research on spatial ability focused on the impact of technology on the measurement, examination and improvement of spatial ability.

The previous paragraphs were a concentrated recapitulation of the emergence of the factor of spatial ability from the concept of general intelligence. Further attention will be directed towards the specific stratification of spatial ability. Since the 1920s, the use of factor analysis has enabled further distinguishing not only the differences between subtypes of intellectual ability, but significant effort was also undertaken on a detailed description of spatial ability. (El-Khoussy, 1935, Murphy, 1936). Research done in the 1940s and 1950s suggested two possible spatial factors: spatial orientation and spatial visualization (Michal, Guilford, Fruchger, Zimmerman, 1957, Michael, Zimmerman and Guilford, 1950). Subsequently, later studies based on factor analytic methods resulted in a large collection of articles where the terminology was often confusing and each article presenting its own definitions of spatial subfactors (Guttman at al., 1990).

Further ambitions to clarify the distinctions between the different spatial factors emerged. Wilson, De Fries, McClearn (1975), McGee (1979) proposed a "single spatial visualization factor". In contrast, Lohman (1988) listed ten spatial factors with a specific test. He provided a wealth of evidence, based on factor analysis, showing that a detailed definition of spatial ability as the main domain of intelligence is needed.

As already mentioned, in 1950 Thurstone divided spatial ability into three main visual/mental capacities. The first capacity described was defined as mental rotation (S1), the second was defined as spatial visualization (S2) and the third spatial perception (S3). Spatial perception emerged as the ability to use one's bodily orientation to relate to questions regarding spatial orientation (Smith 1964).

Gardner (1983) listed several operations of spatial ability which all are connected. The first operation is the ability to recognize instances of the same element (similar to visual perception). The second operation is to recognize a transformation of the object or elements. Then the third operation is to generate mental imagery (close to visualization). These three capacities come together to aid the observer in many different aspects of everyday life. They are important for locating oneself in different places. They are important for the recognition of objects and scenery and their modifications. In contrast, Lohman (1988) came with a proposal for slightly different names for the three categories noted above – spatial orientation, spatial relations and spatial visualization. Nevertheless, some researchers even tried to reduce them to only two factors: spatial relations and visualization (Clements & Battista, 1992).

The debate about the more or less important factors of spatial skills continues today. The primary factors of spatial skills have varied over the last several decades. Lohman and Carrol's meta-analysis is often cited in the literature as encouraging the appearance of three main factors – spatial orientation, spatial relations and spatial visualization.

Following is an overview of the variations in spatial factors over time, see Figure 1.

		Spatial Ability Factors					
Year	Authors	Visualization	Spatial relations	Spatial orientation	Spatial perception	Mental rotation	Later factors
1950	Thurstone, L.L.	•	•	•			
1951	French, J.W.	•		•			
1956	Guilford, J.P.	•		•			
1977	Rost, D.H.	•		•			
1979	Lohman, D.F.	•	•	•			
1979	McGee, M.G.	•		•			
1985	Linn, M.C. Peterson, A.C.	•			•	•	

1988	Lohmann, D.F.	•	•	•			Flexibility of Closure Spatial Scanning Perceptual Speed Serial Integration Visual Memory Kinaesthetic
1993	Carrol, J.B.	•	•				Closure Speed Closure Flexibility Perceptual Speed Serial Pictorial Integration Spatial Scanning Imagery Length Estimation
1994	Maier, H.P.	•	•	•	•	•	

Figure 1: Overview of the factors of spatial ability according to different authors (Ilič, M., Dukic,A., 2017)

Based on the previous argumentation, the structure according to Lohman (1988) has been chosen. He describes three basic spatial ability factors as follows:

Spatial Relations

This factor appeared only when the same or highly similar tests were included in the same test battery. Although mental rotation is the common element, this factor probably does not represent the speed of mental rotation. Rather, it represents the ability to solve such problems quickly (Carroll, 1993).

Other authors such as Guilford, Lacey (in Carrol, 1993) described spatial relations as different stimuli being related to different responses which are arranged in a spatial order. Pawlik (in Cattel 1987) defined spatial relations as the identification of an object when seen from different angles. In Pawlik's other definitions, the main criterion defined was recognizing objects from different angles and the ability to rotate and manipulate a presented object. Carroll (1993) integrated this factor into the three main factors which establish spatial ability.

Spatial Orientation

According to Lohman this factor appears to involve the ability to imagine how a stimulus will appear from another perspective. In the true spatial orientation test, the subject must imagine being reoriented in space, and then make some judgment about the situation. There is often a left-right discrimination component to these tasks, but this discrimination must be made from the imagined perspective. However, the factor is difficult to measure since tests designed to discern it are often solved by mentally rotating the stimulus rather than by reorienting an imagined self (Carroll, 1993).

Generally speaking, spatial orientation is the second factor which the researcher agreed to define as one of the three main factors of spatial ability. Other authors (French, 1951 in Carrol,1993) described spatial orientation as the ability which helps us to remain unconfused by the varying orientations in which a spatial pattern may be presented. He described this factor as an ability to comprehend the nature of the arrangement of elements within a visual stimulus pattern with respect to the examinee's body as the frame of reference. He added that it was related to perception of the position and configuration of objects in space.

Pawlik (in Cattel 1987) defined the spatial orientation of the observer's body as an essential part of the problem. Ekstrom (in Carrol 1993) presented this factor as the ability to perceive spatial patterns or to maintain spatial orientation with respect to objects in space.

Spatial Visualization

This factor is represented by a wide variety of tests such as Paper Folding, Form Board, WAIS Block Design, Hidden Figures, Copying, etc. In addition to their spatial-figural content, the tests that load on this factor share two important features: (a) all are administered under relatively unspeeded conditions, and (b) most are much more complex than the corresponding tests that load on the more peripheral factors. Tests designed to measure this factor are often quite close to tests of Spearman's "g", such as Raven Matrices or Figure Classification (in Carroll, 1993).

One of the first descriptions focused on the factor of spatial visualization was suggested by Guilford, Lacey (in Carrol, 1993). They described this domain as the ability to imagine the rotation of objects, the folding or unfolding of flat patterns, relative changes in the position of objects in space. Michael at al. (1957) further stressed that this factor of spatial visualization is a part of high mental functioning. In particular, spatial visualisation is the mental manipulation of a highly complex stimulus pattern. Smith (1964) gave more information about the process of visualization which he saw closely connected to memory and visual discrimination. He defined visualization as the ability to perceive, retain and recognize a whole configuration (discrimination between shapes).

Recent researchers agree that spatial ability is not a unitary construct, but they've failed to come to any agreement on the number of components the construct of spatial ability consists of. It could be claimed to represent a collection of skills, and some authors believe the collection may be infinite in number (Gardner, 1983; Lohman, 1988). Guttman (1990) stated that:" these studies have not resulted in a theoretical framework for the structure of spatial abilities because the factor names are often for vague and overlapping concepts." Although many distinct components of spatial skills can be identified, since the early part of the 20th century, researchers have generally divided spatial ability into at most two or three main categories – Spatial Visualization, Spatial Orientation, Spatial Relations.

Concepts of the structure of spatial ability

It is clear that research conducted so far relies on various terms. It usually attempts to arrange the interrelation of terms associated with spatial ability in a partly hierarchical, partly radial structure.
The following descriptions are three examples of conceptual schemes relating to spatial ability. The first model on Figure 2 represents the attitudes of the researchers who argued that spatial ability should be minimized to two main sub-factors such as Spatial Visualization and Orientation (Michal, Guilford, Fruchger, Zimmerman, 1957, Michael, Zimmerman and Guilford, 1950):

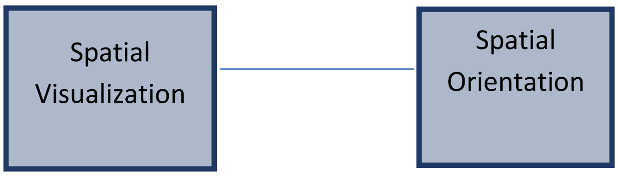


Figure 2: The concept of the structure of spatial ability according to Guilford, 1950

For purposes of comparison, the following figure 3 shows the basic concepts proposed by Tartre (1990) who suggests the following classification scheme:

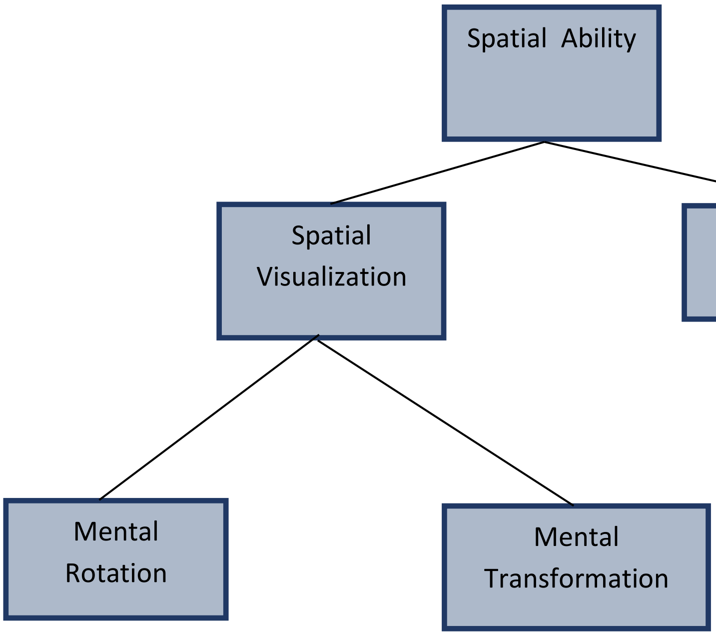


Figure 3: The concept of the structure of spatial ability according to Tartre, 1990

He considers "mental rotation" to be a part of "spatial visualization" and understands "spatial relations" in the context of "spatial orientation". He sees the difference between mental rotations and mental transformations in the fact that when it comes to a mental rotation, the whole object is in space in our mind while r otating, but mental transformation relates only to the part of the object that is somehow altered or transformed.

Another attempt to structure and clarify the concept was undertaken by Maier (Maier, P.H., 1994 in Sorby 1999), who proposed five main components (see Figure 4) that together form the spatial ability, however, as he himself admits, they overlap each other in certain aspects:

Figure 4: Five components of spatial ability according to Maier, 1994

As Hagarty and Waller (2005) stated, the most comprehensive review of factor-analytic studies of spatial ability was conducted by John Carroll in 1993. Carroll (1993) analysed more than 140 datasets and detected five major clusters: Visualization (Vz), Spatial Relations (SR), Closure Speed (CS), Flexibility of Closure (CF) and Perceptual Speed (P). Carroll's (1993) definition of the Vz factor does not differ from that of the other researchers cited above. The Spatial Relations factor may be considered just another name for the Speeded Rotation factor defined by Lohman (1988) for three-dimensional objects.

Hierarchy and terminology used within this research:

The concept of the structure of Spatial ability which will be used in this research is based on the structure defined by Lohman (1988), (see Figure 5):

Figure 5: The concept of the structure of spatial ability

Following is a brief reminder of the concept of the structure of spatial skills used in this study, based on the professional literature:

Spatial visualization involves mental patterns and the visualization of their movement, turning over and rotating in ones' mind.

Spatial orientation includes images of one's own motion within a stable environment.

Spatial relations are associated with understanding and interpreting one's relations towards other people or the relations between other people and the objects around them.

This definition and clarification of the structure of spatial skills was also necessary when designing the content of the ADAM game application (see the section 3.1.2 thereinafter), where different tasks were chosen, based on the current knowledge concerning spatial ability and spatial skills.

The structure of spatial skills that we chose, as mentioned above, is taken into account in the tasks of the game application we developed. Some examples of tasks and their descriptions are provided.

Spatial Relations are covered within the "Rotation", "Mistake" and "Construction" tasks in the developed game app. Children will face these tasks when they rotate the subjects (houses) in order to recognize which pattern matches with the pattern provided in the instructions. In the "Construct" task, objects are divided into several parts and some parts are further divided into even smaller pieces. Objects are combined according to specific patterns. The child has to figure out which subjects must be built and which pieces belong together in order to construct the desired object.

Spatial Orientation is involved in the "Maze, Missing Tops, Select" tasks. For instance, in the "Maze" task, children need to find the right way out of the maze, have to follow voice instructions (a series of commands, left-right orientation, understanding prepositions) to the goal.

Spatial Visualization is covered by the "Shelf", "Pairs" and "Shadow" tasks. For instance, in the "Shelf" task, 3 or more objects are presented on a shelf. After a few second the presented objects disappear and the child is supposed to try to recreate the same order of objects. In the "Pairs" task, the child has to determine which pair of subjects are the same and which are different in detail, position, mirror position or vertical and horizontal position.

The main stratification of spatial ability has been defined in the previous paragraphs. As part of the framing of this research the stratification of spatial skills should be considered the same, because spatial skills derive from spatial ability. In terms of the developed Game Application, the researcher has covered all of the three categories of spatial skills with different tasks, whose contents corresponds with the domain descriptions for Spatial Visualization, Spatial Orientation and Spatial Relations.

1.2.2. Cognitive Development of Spatial Ability and Spatial Skills

Gardner claimed that each part of intelligence, including spatial intelligence, reached four various stages throughout one's lifespan (Gardner 1993). H. Gardner proposes that there is a natural four-stage development trajectory for each intelligence. The trajectory of development involves the recognition of differences, described by a system of symbols that provides an initial insight into particular domains, and development is almost complete when that particular intelligence is expressed in adolescence and adulthood through vocational and avocational pursuits. For example, a student who is interested in music may become a professional musician or simply pursue an interest in music through concert attendance (Gardner, 1993).

In the same way, Piaget and Inhelder (1971) also focused on the development of and changes in spatial ability from childhood to adulthood. According to them, spatial ability develops in three stages. For instance, in the first stage children acquire topological ideas which are primarily two-dimensional, and are usually understood as such by children aged 3–5 years. Thanks to these abilities, children are able to recognize the mutual proximity of objects, their ranking within a group and their isolation or integration within the wider environment. Children who are for example able to solve puzzles, have already acquired skills including understanding the topology of two-dimensional relations. Hejný (1990) underlined that a limited age-range close to Piaget's stage above that is the first major period for the development of spatial skills. It is said that there are certain age periods which are favourable to the development of spatial visualization, especially the age span between five and six years old. Later research is also in agreement with this result. The conclusion of Heckman (2006), is that a focus on spatial skills will also likely begin in the first 5 years, presenting evidence that early education generally provides the largest benefits for later achievement (in Newcombe and Frick, 2010).

In contrast to Piaget's view, which is in opposition to the gradual unfolding of spatial skills over the course of development, recent evidence shows that infants are able to code spatial information concerning objects, shapes, distances, locations, and spatial relations without reaching the stage defined by Piaget. Some researchers argue that this early emergence of spatial skills is consistent with an evolutionary perspective which emphasizes the adaptive importance of navigation for all mobile species (e.g., Newcombe and Huttenlocher, 2000, 2006; Wang and Spelke, 2002).

The abovementioned arguments lead us to think that the most suitable childhood age which we should concentrate on in our research is children from 5 to 6 years of age. When preparing all our tasks, we considered this age-range, and took into account the developmental stages of visual discrimination, spatial perception, (pre)mathematic skills and visuo-spatial memory in preschool children from the ages of 4 to 6½ years. The tasks and difficulty levels in the developed game application focus on this age group.

Previous research has provided evidence for the malleability of spatial intelligence (speaking in Gardner's terminology) (Newcombe 2002, Terlecki at al.,2008). Evidence for malleability is quite encouraging and research focusing on this issue has repeatedly confirmed similar outcomes, meaning that it is possible to enhance and support this cognitive factor with training and specific tasks (Terlecki at al.,2008). Most of these studies have involved adults, secondary school or university students. The studies involving preschool children are rare and mostly focus on finding which subfactor of spatial ability appears in infants and how, if ever, they are able to use this ability at any particular age (Newcombe, Frick, 2010).

The development of spatial skills is not only affected by the age periods a child goes through. Many studies demonstrate the importance of the role of language, which is essential for the formation of spatial skills in children. Language is a tool that can magnify and strengthen cognition and have many crucial effects on the overall development of thinking (Vygotsky). Recently, a body of research has been focused on the relations between language and spatial ability within development. There are many new indications that providing relevant verbal instructions while children perform spatial tasks can boost their performance in specific spatial tasks (Loewenstein, Gentner, 2005). Very clear evidence concerning children's spatial language and their relationship towards their spatial skills has been provided (Pruden, Levin, Huttenlocher, 2011). Furthermore, there is other research which has shown that spatial language in the context of spatial tasks can promote the spatial performance of preschool-aged children (Loewenstein, Gentner, 2005, Shusterman et al., 2011). Dessalegn and Landau (2008) conducted research with 4-year-olds and provided some evidence that combining spatial tasks with visual features (colour) improved memory and performance in tasks. Other scientists included even younger children to provide some evidence for the extent spatial skills can be influenced in toddlers. Jeffrey Loewenstein and Dedre Gentner (2005) conducted an experiment with small children, which showed that three-year-old children have difficulties finding and remembering objects if these are shown by their parents using a limited vocabulary ("over there, over here, this way). Children who were provided with appropriate spatial descriptions, were clearly more successful in searching for various objects. Shannon, Pruden, (2011) published similar results concerning 52 toddlers aged 1 to 4 years old. A rich vocabulary and advanced language used to describe space probably encourages children to focus more attention on the spatial information they encounter. Furthermore, Levine at al. (2012) argued that children might learn best when combining challenging spatial toys with language.

Children's spatial skills are related to their own spatial language which is influenced by the spatial language they hear (Pruden, Levine, Huttenlocher, 2011). Although many researchers support the theory that language has broad effects on spatial skills (Hermer-Vazguez et al., 2001, Pyers at al. 2010 in Miller at al., 2016), Hermer-Vazguez (2001) and Pruden at al. (2011) argue that children's ability to produce spatial language predicts their spatial skills. When children are able to use words such as "left, right, middle", this was positively associated with performance in spatial tasks which depend on these spatial relations. Additionally, it has been also shown that the number of spatial words children use during free play correlates longitudinally with their spatial skills (Pruden at al., 2011). The aforementioned research results are interpreted as evidence that spatial language enables children to verbally encode task-relevant spatial information, thereby improving spatial task performance (Miller at al. 2016).

Based on previous research, the influence of language on the development of spatial skills is undoubtable. These recent results lead us to include specific features in the game application. A narrated guide in the game app talks to the child while playing and gives them instructions on where to move to next task in the game, where to find the things they should take (in space, in a room or on top of various shelves as part of some task in the game). The narrated guide uses words for different directions, prepositions and can include multiple instructions in a single command.

The effects of training on spatial skills have not been clear in previous years. For instance, Sorby (2009) found that a semester of a spatial training course improved spatial skills in students, and gains exceeded 1 standard deviation or roughly +15 IQ points. In contrast, other researchers have claimed that training effects are small or nonsignificant and do not transfer to other, non-trained tasks (Sims & Mayer, 2002). Because of these diverging conclusions Uttal et al. 2013 conducted an exhaustive search of the literature on spatial training. They examined more than 2,500 relevant articles reporting studies on spatial training. It has been shown that the overall effect size of training was 0.47 standard deviations or roughly +7 IQ points. This is considered a moderate effect size and indicates that spatial skills are malleable. Many different training methods (e.g., playing video games, practicing spatial tests, or taking an engineering graphics courses) improved spatial skills. A variety of training methods can substantially improve spatial skills. Due to the results of the research of Uttal et al., spatial training is considered persistent. Although most studies (67%) measured spatial skills only immediately after training, some studies measured spatial skills weeks or months after training. In these longitudinal studies, training effects persisted despite delays of up to 4 months (e.g., Feng, Spence, & Pratt, 2007). Of course, those researchers may have used particularly intensive training, because they knew that participants would be tested after a long delay. Nevertheless, those studies show that well-designed, intensive training can have lasting benefits (Uttal, 2013). Miller and Halpern found that 12 hours of Sorby's (2009) training improved grades by approximately 0.4 standard deviations. These findings are particularly impressive. Students' gains in science learning were evident up to 2.5 months after training, although they did not last 8 to 10 months after training. As a whole, the available evidence indicates that spatial instruction can improve STEM learning in some instances (Sanchez, 2012; Stransky, Wilcox, & Dubrowski, 2010).

It seems that spatial skills can be improved through environmental conditions. Previous studies provide a lot of evidence of the enhancement of these skills through coursework, PC tools, programs and training. Nevertheless, research including preschool children is still rare. Therefore, there is still scant evidence on whether the use of ICT technology can also improve spatial skills at the preschool age or whether it is more beneficial to go with "traditional" toys and games.

Several studies and research dealing with activities and games for high school students with well-developed spatial skills demonstrated the positive impact of visual-motor activities on the development of spatial skills. Activities which develop spatial orientation mainly included: 1) boxes of bricks, construction games 2) playing 3D computer games, 3) partaking in certain sports 4) well-developed mathematical skills (Sheryl A. Sorby, 1999). In the literature, there are several studies concerning the development of spatial ability over different ages, from young learners to adults. Some studies focused on younger children from 6 to 10 years old (Connor, Schackman, & Serbin, 1978, Lisi & Wolford, 2002), some investigated school-age students (Ben-Chaim, Lappan, & Houang, 1988, Olkun, 2003). Some research was also conducted with university students (Alias, Black, & Gray, 2002, Battista et al.,1982) while yet further researchers engaged adults in their studies (Salthouse, Babcock, Skovronek, 2002). In several research studies different instructional programs, specific materials, manipulatives, visual treatments, sketching activities, technologies, computer-aided design courses, and toys have been found to be effective tools in improving individuals' spatial ability. (Alias et al., 2002, Battista et al., 1982, Bishop,1980, Okagaki & Frensch, 1994, Rafi et al., 2005, Newcombe, Frick, 2010). Most of these research studies indicated that if effective instruction were provided, individuals' spatial abilities could be enhanced. (Alias et al, 2002, Battista et al., 1982, 1978, Olkun, 2003a, Rafi et al., 2005, Clements,1998).

Based on previous argumentation and evidence concerning language, tools and training, we decided to design our own tool – a game application named ADAM. Language, with chosen wordings for narrated instructions, is also the part of this game application. There are many narrated tasks where a child needs to listen and understand spatial terms and sequences of instructions which contain spatial terms. The game application will be used repeatedly which means that it includes training over a specific time period, after which the results will be analysed.

The further goal in finding effective methods and including them in the support of spatial ability is that they also reduce gender differences and socioeconomic status (Levin, Vasilyeva, Lourenco, Newcombe, Huttenlocher, 2005 in Newcombe and Frick, 2010). It has been shown that lower spatial ability could also have a negative impact on number representation and on accuracy of the mental number line and its left to right orientation for children with learning disabilities (Crollen, Vanderclausen, Allaire, Pollaris, Noel, 2015).

Gender differences in spatial ability and skills have been analysed and well described by many researchers (e.g. Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005). Early researchers in this area have often reported better results for males over females on standard tests of spatial ability (Maccoby & Jacklin, 1974). Recent research has to some extent showed that gender differences also emerge when children are of preschool age or starting first grade. Levine, Huttenlocher, Taylor, and Langrock (1999) found that, on average, preschool boys are more accurate than girls at spatial tasks. They concluded that gender differences in favour of boys are present for spatial tasks by the age of 4½.

Recent studies with infants have demonstrated that at as soon as 3–5 months, gender differences in mental rotation could be detected (Moore & Johnson, 2008; Quinn & Liben, 2008). Quinn and Liben (2008) used a rotated two-dimensional figure and reflections of the figure in the mirror. Similarly, Moore and Johnson (2008) demonstrated gender differences with 5-month-old infants using two-dimensional objects representing three-dimensional objects. The male infants discriminated better compared to female infants who treated both objects similarly. This research concluded that gender differences in mental rotation appear as soon as during infancy. Nevertheless, it was recommended to explore techniques which may be able to minimize these differences. In the study by Tzuriel (2010), researchers focused on gender differences with mental rotation and transformation of perceptual stimuli and training to see them from different perspectives. They found out that the improvement of boys and girls showed that girls' improvement in the experimental group was greater than that of boys and that the girls were able to close the initial gap. Moreover, in the post-intervention phase, girls in the experimental group showed higher performance than the boys in the control group; this improvement occurred for both tests. They suggest that "early, deliberate, instructional training programs might help to bridge the gender gap in spatial ability, whether or not the differences in ability are attributed to biological mechanisms" (Tzuriel D. and Egozi G., 2010). These findings strengthen the claim that strategy-oriented interventions can overcome gender differences.

In the previous paragraphs we discussed the possibility of the positive influence of spatial skills as one of the cognitive components of general intelligence. Broad research has shown that in spite of some negative results, enhancement of spatial skills has been demonstrated in most of the studies. We moved outside of the scope of these research results which were mostly for students and adults, and tried to find out if spatial skills are significantly malleable in children with the help of our game application. Because of the importance of language, which is crucial for the positive development of spatial skills, we also included the particular vocabularies and instructions which refer to those skills.

1.2.4 Measurement of the Spatial Skills of preschool children

With the new findings of recent research, evidence supporting the importance of spatial ability and skills has been gradually increasing. Most of the new tools for assessing the different domains of spatial ability were created in the last 5 years. Before that time there was a lack of instruments capable of assessing these skills in small children. This new awareness means that the sooner we can assess small children, the better we can support and train their specific skills and help them avoid being left behind in later school years. Following is an overview of the tools which are currently being used for the measurement of particular components of spatial ability and spatial skills. Unfortunately, many tools only focus on particular domains and the tools are not wide enough in scope to cover spatial ability and skills generally. Many of the new tools have already been computerized. Digital technology allows us to make use of new and efficient means of assessment and carry out precise diagnostics of particular cognitive skills.

- **Mental Folding Test for Children (MFTC):**

This multiple-choice test requires children to mentally fold 2D shapes. It is aimed at a target population of children aged 4–6 years old (Harris, J. Hirsh-Pasek, K., Newcombe, N.S., 2013).

- **Cross Slicing, Penetrative Thinking**

This measure uses 3D objects sliced with a cardboard "plane". Children are asked to select which of four 2D options would result from cutting the 3D figure at the given plane and looking at the "cross section". The test is aimed at children aged 5–9 (Ping, R. M. et al. 2012).

- **Animal Mental Rotation**

This computerized test uses line drawings of animals, rotated in the picture plane. The child must also distinguish between pairs of identical vs. mirror-image animals. It is aimed at children aged 4–6 years old. (Wiedenbauer, 2008).

- **Children's Mental Transformation Task (CMTT)**

The task requires children to choose which shape would be created by moving two separate pieces together (Ehrlich, S. et al. 2006).

- **Ghost puzzle**

The children have to choose which one of two puzzle pieces would fit into a hole on a board. The development of mental rotation leads to improvement of perceiving of shapes of subjects in space in 3 – 5 years old children (Frick, Hansen, Newcombe, 2013).

- **Perspective-Taking Test for Children (PTT-C)**

Children (4–8 years) view scenes of toy photographers taking pictures of the layout of objects from different angles. The children are then asked to choose out of four pictures, the one which could have been taken from a specific viewpoint (Frick, Moering, Newcombe, 2014).

- **Spatial Scaling Test SST**

Children are asked to locate targets in a two-dimensional spatial layout (fields) using information from a second spatial representation (map). The test is designed for children 3–6 years old, 2012.

- **Test of Spatial Ability TOSA**

The test assesses the spatial skills of 3-year-olds to capture individual differences and study their relationship with early mathematics. Early results suggest that the test performs well in predicting later spatial skills at ages 4 and 5. There are concerns about ceiling effects when the test is used at an age of 48 months or older. (Verdine et al., 2013).

- **Standardized IQ test batteries**

The test batteries such as WPPSI-IV, Stanford-Binet Test, SON-R, RPM (Raven) and its subtests reflect visuo-spatial ability and are also often chosen for its assessment (Wechsler, 2012, Raven 1986, Roid 2003).

It has been shown that the field of spatial skills is very broad. Nevertheless, new assessment tools have appeared in the last 5 years. Some of these tests utilise computers and are already including further technology. Many test for small children have been designed as computer games or computer tasks. The computer tests make use of 2D and 3D models, rotations, with frequent assembly and decomposition of various objects. For these, as well as other reasons, we incorporated similar tasks which we found important and necessary concerning psychological development and educational milestones into our educational application.

1.2.5 Using technology in kindergartens

Digital technology, computers and tablets are intrinsically compelling to young children because the sounds and images are quick to gain children's attention. Children become interested since they are able to make things happen with the devices. Developmentally appropriate software engages children in creative play, mastery learning, problem solving. Children can regulate the pace of their activities, they can be in control of the learning situation. They also can repeat an activity as often as they like and experiment with different variations. They can collaborate in making decisions and share their discoveries and creations with others (Haugland, Shade, 1990).

Some authors have seen ICT as a threat to playful learning and children's development (Cordes and Miller 2000; Healy 2003). They claim that ICT use leads to lack of exercise, social isolation, poor concentration, impaired language development, etc. At the same time, other authors have been promoting the use of technology and argue that new technologies are useful learning tools (Bolstad 2004; Hatzigianni and Margetts 2012).

According to Hatzigianni and Margetts (2012), ICT presents young children with a new space for exploration and discovery, offers challenging activities and responds to children's curiosity. Bolstad (2004) indicates that ICT already has an effect on the people and environments surrounding young children's education and, as such, these technologies offer new opportunities to strengthen many aspects of early childhood educational practice. They can stimulate creativity and play, cognitive development, social interaction, etc.).

Moreover, the DeSeCo elaborates that competence is not limited to cognitive elements; it also encompasses functional aspects (involving technical skills) as well as interpersonal attributes (social or organisational skills), values and ethics, attitudes, emotions, and motivation (Rychen and Salganik, 2003.; CEDEFOP, 2008.). There is a clear new attitude which attempts to define competence as an “attribute of participation in an activity system” (Gresalfi et al. 2009; Greeno, 2006.; Lemke, 1990.). This highlights the social and cooperative aspects of mathematical competence. The competency labelled “the ability to use technology interactively” has been defined as a key competency for the 21st century by the OECD. The interactive use of technology requires an awareness of new ways in which individuals can use technologies in their daily lives. Information and communication technology has the potential to transform the way people work together, access information, think and build new knowledge. As with other tools, technology can be used interactively and beneficially if we understand its nature and reflect on its potential.

The possibilities of ICT

Various authors give an overview of the possibilities of ICT for young children. These possibilities can be listed in five broad categories as follows:

1. ICT can add an extra dimension to the play activities of young children (Bolstad 2004). Children can use ICT in realistic and imaginative socio-dramatic role-play, while learning the correct vocabulary and learning to use different forms of ICT.

2. ICT can contribute to both the language development and mathematical thinking of young children, through easy transitions between words and pictures, and practice software, drawing programmes or computer manipulatives (Bolstad 2004; Kalas 2010).

3. ICT can provide unique opportunities for scaffolding and supporting children with special learning needs, or children from culturally or linguistically diverse backgrounds (Bolstad 2004; Kalas 2010).

4. If ICT is used in spontaneous learning and play in the classroom, it can be a catalyst for social interaction (Clements and Sarama 2003), although adult guidance is often needed to gain the most from ICT environments (Kalas 2010; Siraj-Blatchford and Siraj-Blatchford 2005).

5. Wood et al. (2008) acknowledge the motivational aspects of ICT. Children find the rapid movements, colours, dynamic presentation and instant feedback attractive. This illustrates the fact that ICT offers multiple possibilities and can be embedded in early childhood education in many divergent ways.

Teuwens (2011) shows that pre-schoolers regularly have their first involvement with the Internet at home. In an examination in the UK (Marsh et al. 2005) parents disclose that 53% of children in the age to six utilize a PC at home every day. As McKenney and Voogt (2010) state: 'There is little question that today, children are utilizing ICT even before they realize how to read and write’. Unexpectedly, there is as of now very little data accessible on the real utilization of ICT in early childhood education.

ICT and free play

Plowman and Stephen (2005, 2006) show that there are ‘cultural’ contrasts between learning in the preschool area and learning in grade schools. The educational modules are less prescriptive in kindergartens and there are distinctive standards of expert practice. There is more focus on learning through play and less reference to formal and teacher coordinated educating. Along these lines, implementing ICT into the early childhood educational programs can mean something totally unique in relation to incorporating ICT into grades of primary and secondary school (Campbell and Scotellaro 2009). Though in formal education, it is accepted that ICT can make instruction more child-focused, early childhood education is as of now to a substantial degree controlled by this. In Plowman and Stephen's investigation (2005), this kid centeredness in early childhood education converts into the utilization of the PC as one of numerous activities in free play.

During the time of free play, pre-schoolers can pick when they have interest to play with the computer. While teachers give bolster in different exercises and arrange guided exercises, this does not occur in exercises with technology, as educators appear to be resistant to give excessively guidance, and so disadvantage the child-centred pedagogy (Plowman and Stephen 2006).

In an investigation of Morgan (2010), there is proof that the utilization of an interactive whiteboard does not really support playful or interactive learning encounters. The teacher is in charge and the technological innovation is mostly utilized for instruction. The two examinations demonstrate that, when utilizing ICT, educators should know about their role in managing and leading the youngsters. At the point when ICT is utilized by the educator, it dangers supporting a more instructionist type of teaching method, while hurting the child-centered pedagogy (Morgan 2010). At the point when ICT is just utilized as a free option for activity, children will in general get disappointed and immediately continue to another activity (Plowman and Stephen 2006). As Terreni (2010) states:” Free play does not guarantee effective or creative engagement or development and there is still need to support and guide children’s interactions in informed ways.”

Kindergarten teachers’ attitudes to ICT

The efficiency and beneficial use of ICT depends on certain aspects of teachers’ attitudes and personal and professional characteristics. It would be misleading to think that it is enough to provide kindergartens with tablets and think the main work has been done. Below we list the primary variables of the teaching profession which crucially influenced the use of ICT and the benefits children might gain from it. The teacher’s role is critical, they need to make judgements about what is appropriate in light of the principles of development and learning. Choosing appropriate software is similar to choosing appropriate books or other tools. Teachers should look for ways to use ICT technology and digital devices to support development and learning (NAEYC, 1992).

Grade being taught

A few authors call attention to the significance of the idea of „developmental appropriateness“ (Bolstad 2004; Kalas 2010; Siraj-Blatchford and Siraj-Blatchford 2000). This idea alludes to the possibility that the utilization of ICT ought to be fitting inside the extent of child’s development. This implies experiences with technology ought to be challenging, yet additionally achievable for most children of a specific age (Siraj-Blatchford and Siraj-Blatchford 2000). Educators are in charge of looking at which types of the utilization are fitting for a specific age and and certain child.

Teachers’ experience in education

Age is as often as possible referenced as a factor identified with ICT reconciliation (Hermans et al. 2008, in Kerckaert et al., 2015). Inan and Lowther (2010) incorporate both age and length of education in their study and infer that these socioeconomics adversely influence the integration of ICT by teachers.

Innovativeness

Van Braak (2001) shows innovativeness as a moderately steady, socially developed and innovation-dependent feature that demonstrates a person's ability to change his or her common routine and practices. Innovativeness appears to apply an effect on ICT use in the classroom (van Braak 2001; van Braak, Tondeur, and Valcke 2004). These discoveries support the role of innovativeness as a critical determinant in clarifying the utilization of PCs in classrooms (Tondeur, Valcke, and van Braak 2008 in Kerckaert et al., 2015).

Teacher self-efficacy

Tschannen-Moran and Woolfolk Hoy (2001) characterize educator self-efficacy as 'an educator’s judgment of his or her abilities to achieve wanted results of child’s commitment and engagement, even among those children who might be troublesome or unmotivated. As per Sang et al. (2010) educator self- efficacy is identified with the utilization of ICT, the frames of mind towards ICT and the educators’ ICT competences.

ICT-related teacher characteristics

Educators' ICT capabilities. Self- perceived ICT skills mirror a person's convictions about his or her abilities to utilize ICT (Compeau, Higgins, and Fit 1999 in Kerckaert et al., 2015). Hew and Brush (2007) show that an absence of knowledge and aptitudes has been recognized as a noteworthy obstruction to ICT incorporation.

ICT professional development

Vanderlinde and van Braak (2010) define ICT professional development and education as a crucial procedure that cultivates ICT integration. As indicated by Galanouli, Murphy, and Gardner (2004), different methodologies have been utilized. In an investigation of van Braak, Tondeur, and Valcke (2004), the measure of preparing taken by educators was essentially related to the utilization of the PC in the classroom.

Experience with ICT at home and at school

Both van Braak (2001) and Hermans et al. (2008) reason that involvement with ICT at home and at school is a critical factor in clarifying the classroom utilization of ICT. Van Braak (2001) led his investigation in secondary education, while Hermans et al. (2008) utilized educators in primary education. Tsitouridou and Vryzas (2004) found comparable outcomes in early childhood education.

Teachers´ attitudes towards ICT in the classroom

A few authors (e.g. van Braak, Tondeur, and Valcke 2004; Inan and Lowther 2010; Mueller et al. 2008; Sang et al. 2010) incorporate frames of mind towards ICT in their endeavor to explain the utilization of ICT in the classroom and analyse certain relation. As per Inan and Lowther (2010) educators' attitude towards ICT comprises of ' view of innovation's effect on student learning and accomplishment. Concentrate by Kerckaert et al., 2015 recommends that ICT proficient advancement is a critical factor in enhancing ICT use in early childhood education. He recommends that preschool educators should be tested to consider the role that ICT can have in their classroom practice. The educators think that utilization of ICT as an instructive device is predictable with ICT utilize supporting substance and individual learning needs (Kerckaert et al., 2015).

Overall, previous research has mostly agreed that digital technology, computers and tablets are intrinsically compelling to young children. They can actively create, discover and select, not only what they want to do, but also which solution they want to try now and which later. This new technology allows them to interact with it. Furthermore, children are in control of the situation and have to take responsibility for the results and for their decisions when solving tasks, e.g. when using a tablet or computer. Children are able to control the pace and choice of actions and they can take a leading role in the learning situation. They can also repeat the activity as often as they like and experiment with variations. Technology makes it possible to support motivational traits. Still, little research has been done on this topic with small preschool children.

1.2.6 Spatial skills attitudes in kindergartens

The teachers in kindergartens usually plan activities for children for every single day. The children are offered a wide rank of activities for their organized activity time and for free play time also. Educational offers are compulsory for the kindergarten teachers working with pre-schoolers according to Framework of Educational Plan for Preschool children (RVP PV). The teachers have to use tools, toys, activities recommended to reach the expected outputs in children´s education. Furthermore, the expected outputs are also defined in the document Framework of Educational Plan for Preschool children prepared by the Ministry of Education of the Czech Republic.

The control group received the treatment and care according to educational plan for pre-schoolers. While the sessions when the experimental group was using the application ADAM, the children of the control group were playing activities planned by teachers who planned them in agreement with this official document RVP PV. The translation of the educational offers is provided below.

Chosen educational offers of activities related to Spatial skills according to Framework of Educational Plan for Preschool children prepared by the Ministry of Education of the Czech Republic.

- Motivated manipulation of objects, operations (sorting, assignment, arrangement, estimation, comparison, etc.) with materials
- Sensory games, various activities focused on development and exercises of perception, visual and auditory memory, concentration and so on.
- Theme games and activities various games supporting creativity, imagination and fantasy (cognitive, imaginative, artistic, constructive, musical, dance or dramatic activities)
- Games and activities solving both mental and practical problems, searching for different options and variants
- Games and activities aimed at exercising different forms of memory (mechanical and logical, figurative and conceptual)
- Activities aimed at creating (understanding) concepts and learning (explanation, clarification, answers to questions, work with a book, with visual material, media, etc.)
- Activities aimed at identifying simple figurative character systems (letters, digits, pictograms, symbols, symbols, shapes)
- Games and practical activities practicing orientation both in space and in the plane the activities of initiating the child into the time concepts and relations related to the daily order

As next we show the outputs expected (requested skills of a child which performs them at the end of the preschool) and defined in the Framework of Educational Plan for Preschool children prepared by the Ministry of Education of the Czech Republic.

Chosen educational outputs related to Spatial skills and defined in the Framework of Educational Plan for Preschool children prepared by the Ministry of Education of the Czech Republic.

- Consciously use all senses, deliberately observe, perceive, notice (new, altered, missing)
- Deliberate focus on activity and attention □ think, conduct simple reflections and also express what it thinks and thinks about
- To focus on what is important from a cognitive point of view (to reveal the essential features, the properties of the objects, to find common features, the form and the difference, the characteristic features of the objects or phenomena and the interrelationship between them)
- Follow and learn according to instructions
- To understand the basic numerical and mathematical concepts, elementary mathematical contexts and to use them (compare, arrange and classify sets of objects according to a rule, orient them in elementary numbers to about six, understand the numerical series in the range of the top ten, know more, less, first, last, etc.)
- To understand spatial concepts (right, left, bottom, top, middle, behind, below, above, u, beside, etc.), elementary time concepts (now today, yesterday, tomorrow morning, evening, spring, autumn, winter, year), orientation in space and plane, partial orientation in time
- To solve problems, tasks and situations, thinking creatively, submitting "ideas" - find new solutions or alternatives to common ones

Summary

According to our recent experience only few kindergarten´s teachers in the kindergarten participating in our activities have had experience with tablets so far. Most of those teachers with whom we cooperated during the research were not familiar with technics and needed help and support with use of the tablets. Some of the teachers claimed that they already using PC and modern technics in their classes and are familiar with this type of work. But in our point of view practical use of technics of those teachers was not satisfactory. They mostly switched the computer on only and let the children choose some game (mixing colours, choosing some objects). The children often played chaotically and lost interest in playing games soon. If a teacher helped the children structure some game activity, explained instruction and the goal of a game, the children came again and showed interest to fulfil tasks.

The knowledge and competency of some teachers still are on low level. Some of them are not aware yet what the proper use of technics should be provided. The use of tablets with App game in the kindergartens, where we conducted the researches, was mostly assigned to one teacher which was not afraid of use of tablets. This teacher than organised the activities and motivated other teachers to use tablets.

To sum up, most of the teachers with whom we worked in the research needed technical support how to use ICT in their work. Furthermore, they need to have the overview of the possibilities of efficient and useful software for small children and they need to be guided how to implement this new type of work in the curriculum of the educational plan instead of using this activity as random spending of time.

2. Research Objectives

The main objective of this research is to investigate and analyse the influence of ADAM, a specially developed educational game application, on the development of children's spatial skills. The secondary objective is a comparison of performance in specific domains between boys and girls. We also aim to analyse if there are any correlations within the three specific subtests which are aimed at measuring spatial skills.

To reach our objectives, the following steps are to be made:

1. To design the ADAM educational application aimed at supporting spatial skills in preschool children.
2. To prepare and conduct a preliminary study to investigate if all features in the game application are suitable for these children and to make sure they actually want to play the game.
3. To choose standardized psychological tests as well as suitable subtests for the measuring spatial skills, choose a standardized test.
4. To organise a meeting with teachers and inform them about procedures and ethical rules.
5. To conduct a pilot study with the developed ADAM game application.
6. To analyse data from the pilot study and make the necessary adjustments in procedures.
7. To conduct the main research study.
8. To analyse data from the main research study.

Assumptions:

Based on the literature review there are several primary assumptions which must be taken into account, based on these we will set up our further hypotheses.

1. For the assessment of spatial skills in preschool children the SON-R Test Battery is widely used in different countries. There are three subtasks: Mosaics, Puzzles and Patterns which, according to the authors and psychological theories, reflect the level of spatial ability and skills in children from 2½ to 7 years old. *The first assumption is that by using these three subtasks of the standardized SON-R Test Battery aimed at the spatial skills of small children, these results will be measurable in pretest as well as posttest.*

2. Much research focusing on the malleability of spatial skills has been conducted with secondary students, college students or adult men and women. Most of this research provided results showing that spatial skills were improved for the groups involved in the experiment. Sorby (2009) provided

evidence that spatial training brought a gain of roughly +15 IQ points (Sorby, 2009). Utal at al. 2013 also showed in their study that the effect size of training was roughly +7 IQ points. Other research has provided information on the kinds of toys or PC games that may influence spatial skills positively for children of primary school age. *The second assumption is that training and playing an educational game app focusing on spatial skills will have a positive effect on capability even for preschool children.*

3. Research has also shown that improvements of the same intensity were observed in both girls and boys. To some extent girls made even greater improvements than boys (Tzuriel D and Egozi G., 2010). *Based on these previous outcomes it is expected that there will be similar results in this research concerning boys and girls.*

Hypothesis:

Based on the objectives above, the following hypotheses have been formulated:

H01: No significant difference exists in pretest and posttest scores for the Mosaics task between the control and the experimental group.

HA1: A significant difference exists in pretest and posttest scores for the Mosaics task between the control and the experimental group.

H02: No significant difference exists in pretest and posttest scores for the Puzzles task between the control and the experimental group.

HA2: A significant difference exists in pretest and posttest scores for the Puzzles task between the control and the experimental group.

H03: No significant difference exists in pretest and posttest scores for the Patterns task between the control and the experimental group.

HA3: A significant difference exists in pretest and posttest scores for the Patterns task between the control and the experimental group.

H04: No significant effect exists between boys and girls in achieved test scores for spatial skills.

HA4: A significant effect exists between boys and girls in achieved test scores for spatial skills.

Research variables:

There are three (3) different dependent variables, namely (1) Mosaics – spatial skills, (2) Puzzles – spatial skills and (3) Patterns – spatial skills, which will be measured with the help of standardized and previously validated quantitative tools (SON-R). The tasks of the treatment tool, the ADAM Game Application, are an independent variable in this study.

3. Research Methodology

In the subchapters below, individual steps within the research methodology and a description of the research teaching/learning process are introduced. The research will be conducted as a quantitative experimental study with pretest, application treatment, and posttest phases. Two groups of preschool children were involved in the research. The first control group of children used activities according to the Educational Framework for Preschool Education (see chapter 1.2.6). The second, i.e. experimental, group used the ADAM Game Application in planned sessions. The research has three different dependent variables, which can be considered measurable with the help of standardized or previously validated quantitative tools (SON-R).

3.1. Research Instruments

In the main research study, as well as in the conducted pilot study, the same standardized psychological test batteries were used. This standardized test was chosen based on its subtests, which are aimed at assessing the level of spatial skills. Furthermore, the developed game application is part of the instruments in this research.

3.1.1 Standardized Psychological Test

SON-R 2.5–7

This test is used to measure general intelligence in children. The SON-R test is suitable for all children between the ages of 2½ to 7 years old. The fact that it doesn't require written or spoken language during testing makes it particularly suited for all children. The sub-tests measure abstract and concrete reasoning, spatial ability and visual perception. The sub-tests are grouped into two types: reasoning tests (Categories, Analogies and Situations) and spatial performance tests (Mosaics, Puzzles and Patterns). In the reasoning tests the correct solution is chosen from several provided alternatives. However, perceptual, spatial and reasoning ability play a role in all of the sub-tests. The performance sub-tests can be found in a similar form in other intelligence tests, although in these other tests they require verbal instructions.

Standardization of the SON-R Test

Norm tables for monthly age-groups make it possible to transform the raw subtest scores into normalized standard scores with a mean of 10 and standard deviation of 3. The total test results are represented as IQ-scores (with an 80 % interval), as a percentile score, and as a reference age.

Reliability

The reliability of the subtests is on average .72. The reliability of the IQ-score increases somewhat with age and is on average .90. The stability of the IQ-score (correlation test-retest) over an interval of three to four months is .79.

Validity

The SON-R 2.5-7 test has been compared to a large number of intelligence- and language-development tests, among which are K-ABC, WPPSI-R, TONI-2, RAKIT, Bayley, DTVP-2, Peabody, etc.

3.1.2 ADAM Game Application

This is a game application tool that was used in the pilot study and was developed by the author of the study with the cooperation of a software specialist. The ADAM game application (see chapter 3.2.2) was used as a study tool by children in the time between the pretest and posttest.

The ADAM Game Application was developed using the instructional design model (Passerini, Granger, 2000) which is a sequential model where each phase (Analysis, Design, Development, Evaluation, Delivery) is constantly revised and modified according to feedback obtained from evaluations from testers (children, teachers, parents). The game application is running on touch-screen devices, tablets, PCs and interactive boards.

The game is designed as a complete story that a child can participate in through their play and help fulfil the main task of the primary character. The story has its own development, and as the child plays, they move through the story from one task to another. Discovery, curiosity and emotional engagement have been included throughout the story (Pekarkova, Milkova 2017).

Structure of the ADAM Game Application

The game is divided into 13 tasks which contain a broad variation of subtasks to keep children playing for as long as they are interested. Each task has subtasks which are divided into low, middle and high difficulty levels according to the selected difficulty criteria. The number of subtasks in every task is 70 different variants at the low level, in the middle over 400 and over 1000 variants for the high level of each task.

The entire story is framed by a narrative guide who provides the child with instruction, tells them the result of their solution for each task and provides the child with feedback of the correct solution. If a child fails at some task, the correct solution is given and the child can observe it on the device's screen. Throughout the story the guide uses terms which match with spatial skills and with early mathematical skills (seriation of order, directions, prepositions, use of the terms bigger / smaller / equal / nothing, item order, comparisons etc.). Very clear evidence concerning children´s spatial language and their relations towards their spatial skills and thus mathematical skills has been provided (Pruden, Levin, Huttenlocher, 2011, Loewenstein, Gentner, 2005, Shusterman et al., 2011, Dessalegn and Landau, 2008).

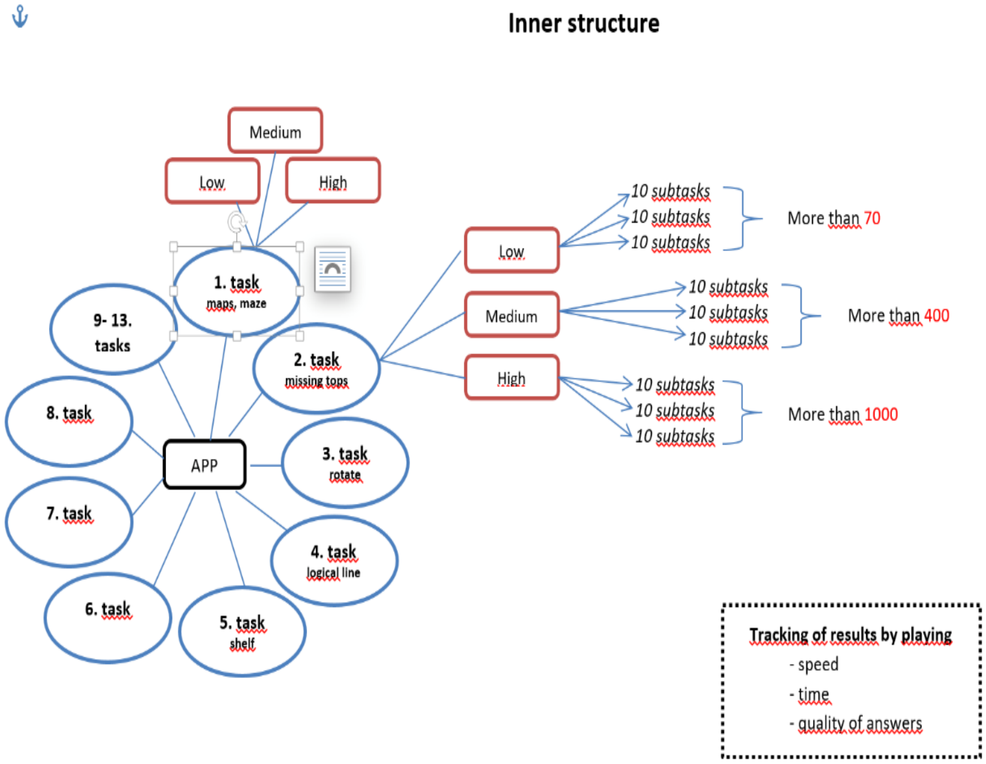


Figure 6: Inner structure of the ADAM Game Application

A full and detailed description of the ADAM Game Application, its tasks and the instructions provided for the low, middle and high levels are available in Appendix IV.

Algorithm for data collection from play

The application collects and evaluates data on the level attained in each task in addition to providing useful information about a child’s achievements in these tasks. An individual profile was saved for every child in the application, to allow the monitoring and evaluation of their success and performance at various times, or even to identify the area with the highest number of wrong solutions. Data concerning the time spent solving each task was collected. Further data about the solution speed was also collected. Last but not at least, the types of wrong/correct solutions in every task and subtask were noted.

Setting difficulty levels

The educational application estimates the appropriate level of difficulty for a child based on the previous results achieved. The application collects and evaluates data on the level attained in each task. A task is divided into three levels of difficulty – low, medium and high. Ten random subtasks from each task are shown to a child in gradually increasing difficulty. The difficulty level a child plays on depends on their previous game results. When a child plays for the first time they start on the low difficulty level and then progress forward. The tasks in the low difficulty contain approximately more than 70 combinations, in the middle difficulty the number of variations increase to over 400 combinations, in the high level the number of variations may reach over 1000 variations of a single task.

Varied subtasks can maintain a child´s level of attention, motivation and the app game can be played for a comparatively long time-period. For example, there are 20 different objects in the task "Logical Lines" which have to be put in line in specific patterns – aaaa, ababab, aaabbb, aabaab abcabc, aabbcc etc. – this means that the game system enables the creation of several hundred combinations for this task. Analogical criteria are considered by each task in order to create and generate enough combinations to avoid the child getting bored with the same task.

Feedback for children

Much attention is paid to feedback and working with incorrect solutions. Children are motivated to search for the solution, which is offered at the right time. In the following tasks the children can correct their solutions and strategies. The game application estimates the appropriate level of difficulty based on the previous results achieved. The idea is to start at an adequate level which corresponds to the child´s current capabilities, so that they can solve tasks without fear of failure. Significant attention is also paid to the internal construction of difficulty, as its level must always provide a manageable challenge. According to research conducted on the relations between language, spatial terms and the positive influence of spatial skills, the speaking guide uses language which includes spatial terms profusely (especially in the subtasks focusing on navigation, maps, mistakes, tasks focusing on the relations between objects).

According to goal setting theory, learners' motivation and learning can be promoted when the goals are specific and moderately challenging (Locke & Latham, 1990). Moreover, when immediate feedback is provided to learners during the learning process, learners are more likely to achieve the expected outcome (Schunk, 1990). In many games for small children, points and badges are often used to guide learners in setting up reasonable goals and direct their attention to important activities. The feedback in this game application uses no badges, hints, stars or leader boards as tools to motivate the children. In terms of intrinsic motivation, this could be merely to enjoy playing a game and to be satisfied by achieving something. Intrinsic motivation occurs when we act without any obvious external rewards. We simply enjoy an activity or see it as an opportunity to explore, learn, and actualize our potentials." (Coon & Mitterer, 2010)." Intrinsic motivation refers to the reason why we perform certain activities for inherent satisfaction or pleasure." (Brown, 2007). There is the review of feedbacks according to a type of motivation (see Table 4).

Table 2: Feedback for extrinsic motivation not used in the app and feedback for intrinsic motivation incorporated into the game application.

Extrinsic motivation	**Intrinsic motivation**
Badges	A completed story
Hints	Feedback – correctly administered
Leader boards	Signal of "a job well done"
Collecting stars	Visualisation of the correct solutions
Points gain and loss	Helping out the guide – Mr. Mouse

Learning principles included in the app game

Some critical new approaches in learning were included in the game-based educational application and the design of the "game" was developed according to the chosen learning approaches.

In terms of new methods, many aspects of microlearning are used in order to maximize the positive effects of using new technologies (Hug, T., Lindner, M., Bruck, A.P.,2005). Microlearning mostly happens during the informal learning which this educational application provides. Content is divided into small units which can be practiced repeatedly. This means learning using small, repeated and increasing steps. With this approach the educational content is offered for short durations (which can be combined to make them longer). Applications designed in this way are based on the fact that people learn better when they engage in short, focused sessions, because of their limited attention spans.

Such educational applications are designed and developed according to the characteristics of Game-Based Learning (Meihua Qian, Karen R. Clark, 2016). The story is important in these applications, in order to actively engage children with the game. The goal when including a story, is that while playing the game, children experience the pleasure of being immersed in a ”play mode” where they can explore a new environment and contribute to achieving the target of the game. Game-based learning makes educational applications more engaging, because children can easily transfer their experience from the game task to a real world environment. Children can adjust their achievements according to immediate feedback in response to their mistakes. Thanks to the content of the tasks, which has a gradually rising difficulty, the pace of learning is tailored to each individual child.

The aspects mentioned next relate to the area of Adaptive Learning. The educational applications in this research endeavour to transform a child from a passive receiver of information into an active collaborator in their own educational process (Murray, M. C., & Pérez, J., 2015). According to the child’s skill, the application always selects a suitable level for further practice. As practice of these skills proceeds, the application offers and opens up new and more narrow ranges of tasks with a higher difficulty.

According to a child’s results, the game displays a subtask of adequate level. A scoring algorithm has been implemented, which either switches to a more difficult level or decreases the level if the child fails a few times. The principle of adequate challenge should help keep a child motivated to try each subsequent and more demanding task.

Affective Learning aimed at motivations and feelings is also incorporated in the app game. The level of a child´s motivation and their emotional state must also be considered. These two aspects are crucial in accomplishing a task once it has been started. It is generally accepted that affect plays a part in conditioning behaviour and influences learning (Oatley & Jenkins, 1996, Grawemeyer, B. at al. 2017). There is a strong relation between affect and cognition, in other words affect influences a child´s attitude towards learning and their learning methods. This application for young children was tailored to the appropriate age (4–7 years) by using suitable graphics, animations and illustrations and a talking guide, using pauses in the game with mini stories where the child can relax and play freely with the newly added details. These aspects can have a positive influence on motivation and the emotional state of the child while playing the educational application.

3.2. Preliminary Study

The aim of the preliminary study was to verify whether or not children would refuse a game application with atypical motivational features

Two questions were set up in the preliminary study:

1) Is the proposed game-based design model without typical extrinsic motivational elements interesting to play for young children?

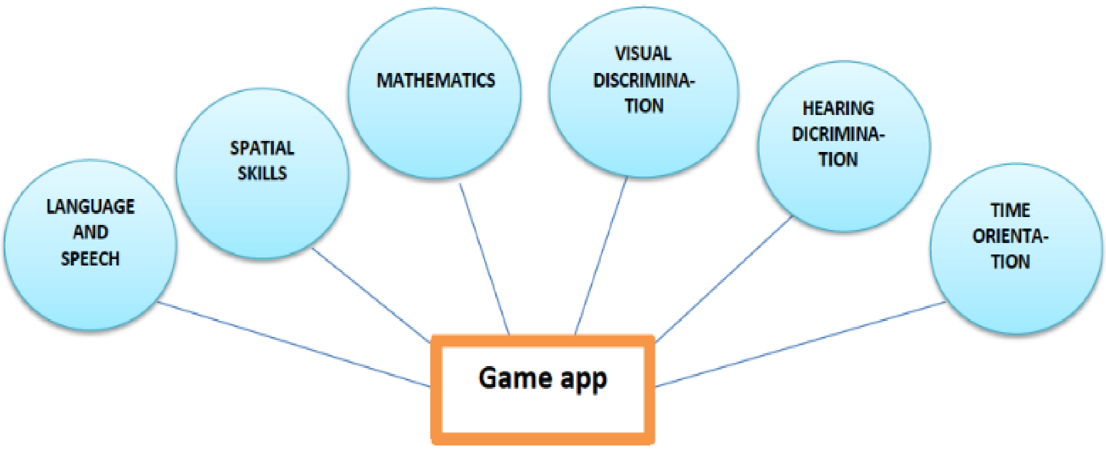
2) Do the children want to play the higher difficulty settings without receiving typical rewards (stars, hints, badges etc.)?

Three tools were used in the preliminary study:

1. The specially developed educational game application “I´m going to school”.
2. Similar tasks were available in printed form in worksheets.
3. A questionnaire for teachers.

The application “I´m going to school”, the previous version of the ADAM application, was used in this preliminary research. The application named “ADAM” (aimed at spatial skills) was used in the following main research study. Both of these applications were designed and created with the same features and based on the same methods and learning principles that follow.

The structure of the app game used in the preliminary study “I´m going to school” was divided into



small units focusing on specific topics from 6 areas as represented in this picture.

Figure 7: The structure of task areas in the “I´m going to school” game application used in the preliminary study

The application consisted of well-planned short episodes, together creating a complete story. The educational application had a talking guide (Mr. Mouse Adam) who explained instructions to the player and showed examples of tasks. After each single task was completed, the guide provided clear feedback on the correctness of answers. The educational application estimated a suitable level of difficulty based on the player´s previous results (if the level were either too easy or too hard, this could demotivate the player).

The questionnaire for teachers consisted of 23 questions. The selected questions were based on previous teacher interviews. After analysing the teachers´ statements, 3 categories of motivational domains were recognised: pleasure/joy, persistence, goal orientation. Then the teachers were individually asked about the influence of ICT on the daily schedule in their classrooms, about their attitude towards ICT in ECE.

Participants in the preliminary study were preschool children in three preschools in the Czech Republic. The study of the design of the educational experiment was conducted in 2/2017. The children were of ages from 4 to 7 years old. 45 children were included in the target group. The kindergartens were supplied with all necessary ICT devices – tablets with the app game installed, chargers, headphones. Profiles for the children were created on the tablets. A training workshop for teachers was organised and the teachers were given instructions and rules on how to use the tablets in class. Multiple data collection tools were adopted in this study, such as survey questionnaires and interviews. The results provided the following data (see table 3).

Table 3: The results in three chosen motivational domains of Pleasure/Joy, Persistence, Goal Orientation.

Over **65 %** of children wanted to play and **help** the main hero.
Nearly **70 %** of children felt that **learning** while playing with the app was **fun**.
Teachers observed that more than **63 %** of all children showed significantly longer **persistence** when searching for a correct solution and **completing** their tasks in comparison with work on worksheets.
More than **75 %** of children were doing **more difficult** tasks using the application compared with worksheets.
Around **84 %** of children showed a higher **ability to focus** on their chosen tasks.
More than **31 %** of all children were **interested** in tasks in which they had **failed at** previously when working with the worksheets

The game-based application with feedback based on intrinsic motivation showed that 63 % of the group of children were motivated to a greater degree and for a longer time period than with regular work consisting of worksheets or other materials. According to the responses, the app supported 75 % of all children when they worked with tasks with a higher difficulty. And the children did not give up on harder tasks when working with the application. A very important outcome is that children with SEN (special educational needs) are included in this percentage result. According to the teachers’ answers, the biggest motivational aspect (70 %) was fun (enjoyment) from playing the game. Although the children did not get any badges, hints or other extrinsic incentives, they enjoyed the game and 75 % of them wanted to continue with more difficult tasks, while more than 60 % of all children also showed longer persistence and wanted to help the game hero.

We conclude that an educational application can increase the level of intrinsic motivation of pre-school children. An educational app can enhance the interest, persistence and goal-orientation of pre-schoolers in learning. Badges, points and hints are not a critical point for the motivation of preschool children (Pekarkova at al. 2017). Children are able to overcome various obstacles without losing interest in tasks that have higher difficulty.

3.3. Pilot Study

The pilot study was conducted to verify the treatment tool as well as the entire process of conducting research in a kindergarten among small children. The kindergarten is a specific environment where many rules must be followed including a specific daily schedule with planned routines. The aim was to test the developed treatment tool and also test the planned procedure.

3.3.1 Pilot Study Objectives:

The following hypotheses also postulated for the main research study, have been tested in this pilot study:

H01: No significant difference exists in pretest and posttest scores for the Mosaics task between the control and the experimental group.

H02: No significant difference exists in pretest and posttest scores for the Puzzles task between the control and the experimental group.

H03: No significant difference exists in pretest and posttest scores for the Patterns task between the control and the experimental group.

3.3.2 Sample of the Pilot Study

The target population of this study were children from the Czech Republic – Královéhradecký region. The accessible population of this study were preschool children from 4y 10m to 6y 10m old in the kindergarten MŠ Kratonohy. There was one experimental and one control group which consisted of 16 and 13 children respectively.

3.3.3 Pilot Study Measurement Tools

Test Battery SON-R 2.5–7

Assessments of spatial skills in the pilot study were conducted with the help of 3 subtests of the previously described standardized psychological test battery SON-R 2.5–7. All these subtests –

Mosaics, Puzzles and Patterns – are among subtests which reflect the level of spatial relations and spatial skills (see chapter 3.2.1).

3.3.4 Pilot Study Data Collection

Quantitative data were collected twice. The first data collection was conducted during the pretest and the level of spatial skills of the preschool children was measured. The second data collection was conducted after four months of the children using the ADAM game application. The same test battery was used as in the pretest. The data were collected during personal researcher visits. Before research and data collection started, general parental consent for children who were to take part in the research was collected. The parents were informed about the ethical rules of the planned research. An introductory workshop was prepared for the headteacher and teachers in order for them to get to know and to provide experience with the ADAM application and to agree on the settings for playing the game. 20 tablets, chargers and headphones were provided to the kindergarten. All of the children's profiles were prepared, record sheets for teachers were provided in order to allow them to make notes on which child played on which day.

Before the treatment phase started, the classroom environment was prepared and teachers were informed about the training. The training consisted of information about the application and its content. Teachers were given information on how to use and how to manipulate the devices. The schedule of playing sessions was discussed and clarified with the teachers. The teachers then provided a name list for the children. After randomization of the sample, each child was given their own profile in the tablet under their name and always played under this profile. This enabled the researchers to evaluate a child's results during play and their performance in the game. An updated version of the game was downloaded onto each tablet. Each child had approximately 26 play sessions altogether. The experimental group used the app game during a time suitable for the regular schedule of the classroom.

3.3.5 Pilot Study Results

The design of the pilot study is quantitative. For this reason, the researcher used the latest version of SPSS to analyse the quantitative data. The data were analysed using descriptive statistics. A further, independent sample t-test and paired sample t-test were used to assess the existence of a significant difference in scores among groups. The assumptions (assumption of normality, assumption of equality of variances, no outliers, random samples) for the analysis were fulfilled with the help of a t-test. The tables for the assumption of normality and assumption of equality of variance are shown in Appendix I.

Further data from the descriptive statistics are shown in following two tables. Then, a summary of the results of the data analysis with the help of the t-test in the pilot study is presented. Detailed tables containing all the data are to be seen in Appendix II.

Descriptive Statistics

Table 4: Gender-wise distribution of participants in pilot study

Gender	Control Group	Experiemtal Group	Total
Male	8	11	**19**
Female	6	5	**11**
Total	**14**	**16**	**30**

The table (4) above highlights the distribution of children according to their gender differences. A total of nineteen (19) children (63 %) were males and eleven (11) (37 %) were females. Both males and females were distributed into both control and treatment groups as described in the table above. The table below (Table 5) shows the distribution of the participant´s age in the pretest and posttest. The posttest was conducted 4 months after the pretest which is why there is a difference in ages.

Table 5: Age distribution of participants in the pretest and posttest

	N	M	Min	Max	Range	SD
Pretest-Age	30	63.77	49	73	24	7.63
Posttest-Age	28	69.17	53	78	25	7.56

N: Number of participants *M: Mean age in months among participants*
Min: Minimum age in months of a participant *Max: Maximum age in months of a participant*
Range: Age difference between the youngest and oldest participant *SD: Standard deviation*

Summary of the data analysis results with the help of t-tests

Table 6: Summary of the independent sample t-test (Pretest)

Independent Sample t-test (Pretest)							
Tasks	**Groups**	**N**	**M ean**	**SD**	***Df***	**t-value**	**Sig**
Mosaics	Control	14	8.143	2.627	28	-.421	.677**
	Exp	16	8.563	2.804			
Puzzles	Control	14	9.214	2.992	28	-.816	.421**
	Exp	16	10.125	3.096			
Patterns	Control	14	9.214	3.725	28	.826	.416**
	Exp	16	8.188	3.082			

**p > 0.05 (Non-Significant)

The results in the table above show that there were only non-significant differences between the Control and Experimental groups in all three variables (Mosaics, Puzzles, Patterns). It is evident from the P-values (.677, .421, .416) that the results are non-significant because all figures are higher than the significance level (0.05). The results clearly show that participants from both the Control and Experimental groups had a similar level of spatial skills when dealing with Mosaics, Puzzles and Patterns tasks in the pretest study.

Table 7: Summary of the independent sample t-test (Posttest)

Independent Sample t-test (Posttest)							
Tasks	**Groups**	**N**	**Mean**	**SD**	***Df***	**t-value**	**Sig**
Mosaics	Control	14	8.571	2.243	28	-3.817	.001*
	Exp	16	12.125	2.778			
Puzzles	Control	14	9.50	2.710	28	-3.479	.002*
	Exp	16	12.75	2.408			
Patterns	Control	14	8.857	3.634	28	-2.239	.033*
	Exp	16	11.625	3.138			

*$p < 0.05$ (Significant)

The results in this table are evidence that a significant difference exists between the Control group and Experimental group in all three variables, with P-values of .001, .002 and .033, all figures fall below the significance level (0.05). These results showed that children from the Control and Experimental groups had significantly different levels of spatial skills when dealing with tasks in the posttest. This is also evidence that the aforementioned change occurred as a result of the treatment provided, based on the ADAM game application.

Table 8: Summary of the paired sample t-test (Control Group)

Paired Sample t-test (Control Group)							
Tasks	**Pre/Post**	**M**	**SD**	**Std. Error Mean**	**Df**	**t-value**	**Sig.**
Mosaics	Pre-Post	-.429	.852	.228	13	-1.883	.082**
Puzzles	Pre-Post	-.286	1.138	.304	13	-.939	.365**
Patterns	Pre-Post	.357	1.150	.308	13	1.161	.266**

**p > 0.05 (Non-Significant)

As shown in the table above, a paired sample t-test was applied to compare pretest and posttest scores of participants for all tasks (Mosaics, Puzzles and Patterns). It was found that there was no significant difference between respondents' responses in pretest and posttest scores where P-values .082, .365, .266 are higher than the assumed significance level (0.05). The results of the paired sample t-test above suggest that the development observed in the children was not significant. No difference was observed in the performance of the control group after comparing its pretest and posttest scores.

Table 9: Summary of the paired sample t-test (Experimental Group)

Paired Sample t-test (Experimental Group)							
Tasks	**Pre/Post**	**M**	**SD**	**Std. Error Mean**	**Df**	**t-value**	**Sig.**
Mosaics	Pre-Post	-3.562	2.032	.508	15	-7.013	.001*
Puzzles	Pre-Post	-2.625	1.258	.314	15	-8.345	.001*
Patterns	Pre-Post	-3.438	1.460	.365	15	-9.423	.001*

*p < 0.05 (Significant)

As shown in this table, a paired sample t-test was applied to compare the pretest and posttest scores of participants for all three tasks (Mosaics, Puzzles and Patterns). It was found that there was a significant difference between responses given by respondents in pretest and posttest scores, with the P-values for all of the tasks being lower than the assumed significance level (0.05). The results of the above paired sample t-test suggest that some development was observed in the children while playing with Mosaics, Puzzles and Patterns tasks under the influence of the treatment given to experimental groups. A noteworthy difference was observed in their performance after comparing their pretest and posttest scores together.

Based on the evidence from abovementioned analysis results:

we **reject H01**: No significant difference exists in pretest and posttest scores for the Mosaics task between the control and the experimental group, further

we **reject H02**: No significant difference exists in pretest and posttest scores for the Puzzles task between the control and the experimental group, and

we **reject H03**: No significant difference exists in pretest and posttest scores for the Patterns task between the control and the experimental group.

Summary:

The pretest and posttest results were analysed with the help of SPSS. Analysis of the data has shown that there is a significant difference between the level of spatial skills for the control and the experimental group. The experimental group achieved better results in posttest phase in all three subtests Mosaics, Puzzles and Patterns and scored significantly higher. We have therefore rejected hypotheses H01, H02 and H03. From the pilot study we obtained evidence that an educational application aimed at the development of spatial skills is worth using even by preschool children and that cognitive skills can be improved using the chosen treatment method, an educational game application. The ADAM game application was shown to have some influence on the level of children´s spatial skills in the pilot study.

3.4. Main Research Study

The processes of the main research study and the detailed planning of the following procedures were adjusted according to the results and findings of the pilot study. The time requirement for the assessment of a child was verified and the researchers discovered that more time is needed to finish a test of the required quality. The schedule was reworked in order to assess every child adequately during the main research study.

3.4.1 Main Research Data Collection

The preparation of the space in the kindergarten, which was to be used by the researcher and children for assessments, was checked and adjusted. Some conditions had to be followed and kept for the main research, for example having a quiet place with suitable furniture, a place from which the child and the researcher can easily reach the teacher or the main group, etc.

Before the treatment phase started, the classroom environments were prepared and the teachers were provided with training. The training consisted of information about the application and about its content. Teachers were given information on how to use and manipulate the devices. The schedules of playing sessions were discussed and clarified with the teachers. The correct version of the game was downloaded onto all the tablets.

The number of play sessions for the main research study was adjusted according to the results in the pilot study. For the main research the ethical rules and parental consent were adjusted based on some recommendations and requirements from parents and teachers.

3.4.2 Research Sample

The sample for this study included children from 4 to 6 years old enrolled in kindergarten. The participants were 70 children aged from 4 to 6, from three classes in the main study. Children were assigned randomly to experimental and control groups. They were chosen from kindergartens located in the town Pardubice. A random sampling strategy was used to create randomized experimental and control groups with a similar number of participating children. The research and its results are valid for this specific region. These results cannot be generalized to other regions in the Czech Republic.

The control group in the experiment did not receive the treatment from researcher and was later used as a benchmark to measure how the other test subjects behaved. The control group did not use the tablets. But instead of the treatment they carried out the suggested activities planned by their teachers.

The research instruments of the main study are described in chapter 3.1.

3.4.3 Research Results

The design of the main research is quantitative, just as the pilot study was. Therefore, the researcher used the latest SPSS version for the analysis of quantitative data. The obtained data were analysed using descriptive statistics. An independent sample t-test and a paired sample t-test were used to assess whether or not a significant difference exists in pretest scores among all groups.

Three different statistical tools were used to analyse the data, including an independent samples t-test, a paired samples t-test and crosstabs. The independent samples t-test was implemented in order to compare the means of the two independent groups. The condition for the use of this test, i.e. requiring two different groups, was fulfilled. It enabled a comparison of whether the associated population means are significantly different from each other or not. The data collected from both the experimental and control groups separately for the pretest and posttest scores were analysed. Thus, in the case of our research the scores of respondents from two different groups (experimental/control) were analysed with the help of independent sample t-tests.

We used the paired sample t-test because it enables the comparison of two population means where we have two samples in which observations in one sample can be paired with observations in the second sample. Therefore, data collected twice from the same group i.e. experimental (Pretest) and experimental (Posttest) were compared. In this case, we analysed data within the same group with two different observations based on their pretest and posttest scores.

In addition to this, we used a crosstabs query to see how the scores of the pretest and posttest data react to the given treatment based on the ADAM game application. Crosstabs gives us a general view of how the combination of the two variables under investigation relate towards each other.

Assumptions for the use of sample t-tests in the main research

- There are some assumptions which must be fulfilled when analysing data with the help of a paired sample t-test and an independent sample t-test. The first requirement is the assumption of normality which must be held, otherwise it is impossible to draw accurate and reliable conclusions about reality. For this purpose, the Shapiro-Wilk test was used, which is based on the correlation between the data and the corresponding normal scores. The Shapiro-Wilk Test is also appropriate for small sample sizes (< 50 samples). For more details, see Appendix III.
- The second assumption which must be fulfilled is the equality of variances (homogeneity of variance). The independent t-test assumes the variances of the two groups being measured are equal in the population. The Levene test can be used to verify that assumption. The tables for these assumptions are shown in Appendix III.

- The next assumption is that there are no significant outliers in the research samples.

All assumptions were fulfilled up to the expectations and it was possible to carry out analysis with the help of t-tests. Following are tables with the data analysed. The results are described under each table.

Table 10: Gender-wise comparison of respondents

Gender	Control Group	Experiemtal Group	Total
Male	13	20	**33**
Female	22	15	**37**
Total	**35**	**35**	**70**

In Table 10 above, the results of a gender-wise comparison of respondents are presented, showing that 13 (37.13 %) boys and 22 (62.85 %) girls participated in the control group. In the experimental group the gender of 20 (57.14 %) children were male and the remaining 15 (42.85 %) children were female.

Table 11: Pretest and posttest age of respondents

Age Level	N	Mean	Minimum	Maximum	Range
Pretest-Age	70	62.83	53	74	21
Posttest-Age	70	66.21	55	77	22

The results in the table above show that a total of 70 children participated in the pretest study where the minimum, maximum and mean age were 53, 74 and 62.83 respectively. The same number of children participated in the posttest study where the minimum and maximum age were 53 and 74 respectively and the average age of the children was 66.21.

Table 12: Independent sample t-test for Mosaics tasks [pretest]

Groups	**N**	**Mean**	**SD**	***Df***	**t-value**	**Sig**
Control	35	8.74	2.020	68	.943	.349**
Experimental	35	8.29	2.037			

**p > 0.05

The results in Table 12 show that there was a non-significant difference between the control (*M*=8.74, *SD*=2.020) and the experimental group (*M*=8.29, *SD*=2.037). It is evident from the P-value (.349) that the results are non-significant because the P-value is higher than the assumed significance level (0.05). The results clearly show that the participants from both the Control and Experimental groups demonstrated a similar level of spatial skills when dealing with the Mosaics task in the pretest study.

Table 13: Independent sample t-test for Puzzles tasks [pretest]

Groups	**N**	**Mean**	**SD**	***Df***	**t-value**	**Sig**
Control	35	7.89	2.011	68	.657	.513**
Experimental	35	7.57	1.989			

**p > 0.05

The calculated values of the independent sample t-test show that there was a non-significant difference between the control group (*M*=7.89, *SD*=2.011) and the experimental group (*M*=7.57, *SD*=1.989), where $t(68) = .657$. It is clear from the P-value (.513) that the results are insignificant. The analysed results in the table above clearly show that the participants in both groups demonstrated a similar level of spatial skills when dealing with the Puzzles task in the pretest study.

Table 14: Independent sample t-test for Patterns [pretest]

Groups	**N**	**Mean**	**SD**	***df***	**t-value**	**Sig**
Control	35	6.91	1.721	68	1.021	.311**
Experimental	35	6.49	1.788			

**p > 0.05

The independent sample t-test as calculated above demonstrates that there was a non-significant difference between the control group (*M*=6.91, *SD*=1.721) and the experimental group (*M*=6.49, *SD*=1.788), where t (68) = 1.021. The calculated P-value (1.021), which is less than the assumed significance level i.e. 0.05, shows a non-significant difference between the groups. Thus, the analysed results show that the participants of both groups demonstrated a similar level of spatial skills when dealing with the Patterns task while collecting data in the pretest study.

Table 15: Independent sample t-test for Mosaics tasks [posttest]

Groups	**N**	**Mean**	**SD**	***df***	**t-value**	**Sig**
Control	35	9.17	1.723	68	-4.609	.001*
Experimental	35	11.26	2.049			

*p < 0.05

The results in Table 15 explore the significant difference that existed between the Control (*M*=9.17, *SD*=1.723) and the Experimental (*M=11.26*, *SD*=2.049) groups, where t(68) = -4.609, and the P-value is p=.001 < 0.05. These results show that children in the Control and Experimental groups achieved a different level of spatial skills when dealing with Mosaics tasks in the posttest. This result also supports the conclusion that the aforementioned changes in the level of spatial skills achieved in Mosaics occurred due to the treatment provided based on the ADAM game application. The same evidence is presented later with the help of a paired sample t-test, which was used to clarify whether the changes in achievement level had a significant or non-significant impact on the overall responses of the participants.

Table 16: Independent sample t-test for Puzzles tasks [posttest]

Groups	N	Mean	SD	*Df*	t-value	Sig
Control	35	8.20	1.762	68	-5.690	.001*
Experimental	35	10.69	1.891			

*p < 0.05

The calculated values of the independent sample t-test reveal that a significant difference was found between the Control (*M*=8.20, *SD*=1.762) and Experimental (*M*=10.69, *SD*=1.891) groups, where t(68) = -5.690 and the same is also confirmed with the help of the calculated P-value (.001), which is less than the assumed level of significance (0.05). The analysed results further reflect that the participants in both groups had comparatively distinguished levels of spatial skills when dealing with Puzzles tasks in the posttest and the same has been presented later in Table 38 with the help of a paired sample t-test.

Table 17: Independent sample t-test for Patterns tasks [posttest]

Groups	N	Mean	SD	*df*	t-value	Sig
Control	35	7.37	2.102	68	-4.032	.001*
Experimental	35	9.80	2.878			

*p < 0.05

An independent sample t-test was calculated and the results are that a significant difference exists between the Control group (*M*=7.37, *SD*=2.102) and the Experimental group (*M*=9.80, *SD*=2.878), where t(68) = -4.032. The calculated P-value (0.001) also shows the significant difference between both groups as it falls under the assumed significance level. The analysed results in the table also show that the participants in both groups achieved significantly different levels of spatial skills when dealing with Patterns tasks in the posttest. The same evidence is presented in Table 39 with the help of a paired sample t-test to analyse whether the difference between pretest and posttest data is significant or not.

Table 18: Pretest-posttest paired sample t-statistics for Mosaics tasks [control group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	35	8.74	2.020	.341
Posttest	35	9.17	1.723	.291

Paired Sample t-statistics

Groups	**Paired Differences**			***Df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-.429	1.267	.214	34	-2.001	.053**

**p > 0.05 (2-tailed)

As shown in Table 18 above, a paired sample t-test was used to compare the pretest and posttest scores of participants for Mosaics tasks. It was found that there was an insignificant difference between the responses given by respondents in the pretest (M=8.74, SD=2.020) and posttest scores (M=9.17, SD=1.723) where t(34) = -2.001, and since p=0.053, the significance is still higher than the assumed significance level (0.05). The results of the paired sample t-test above show that a noteworthy difference was observed in performance after comparing the pretest and posttest scores together.

Table 19: Pretest-posttest paired sample t-statistics for Puzzles tasks [control group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	35	7.89	2.011	.340
Posttest	35	8.20	1.762	.298

Paired Sample t-statistics

Groups	**Paired Differences**			***Df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-.314	1.105	.187	34	-1.682	.102**

**p > 0.05 (2-tailed)

As shown in Table 19 above, the paired sample t-test was applied to compare pretest and posttest scores of participants for Puzzles tasks. It was found that there was an insignificant difference between the responses given by respondents in both pretest (M=7.89, SD=2.011) and posttest scores (M=8.20, SD=1.762) where t(34) = -1.682, p=.102. The results of the paired sample t-test above show that no significant change occurred in the level of spatial skills in the children when dealing with Puzzles tasks in the pretest and posttest data.

Table 20: Pretest-posttest paired sample t-statistics for Patterns tasks [control group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	35	6.91	1.721	.291
Posttest	35	7.37	2.102	.355

Paired Sample t-statistics

Groups	**Paired Differences**			***df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-.457	1.633	.276	34	-1.656	.107**

**p > 0.05 (2-tailed)

As shown in Table 20 above, a paired sample t-test was applied to compare the pretest and posttest scores of participants for Patterns tasks. It was found that there was an insignificant difference between the responses given by respondents in both pretest (M=6.91 SD=1.721) and posttest scores (M=7.37, SD=2.102) where t(34) = -1.611, p=0.107. The results of the paired sample t-test above sugests that since no treatment was applied to children in the control group, only an insignificant difference was observed when comparing their pretest and posttest scores.

Table 21: Pretest-posttest paired sample t-statistics for Mosaics tasks [experimental group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	35	8.29	2.037	.344
Posttest	35	11.26	2.049	.346

Paired Sample t-statistics						
Groups	**Paired Differences**			***df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-2.971	2.107	.356	34	-8.342	.001*

*p < 0.05 (2-tailed)

As shown in Table 21 above, a paired sample t-test was applied to compare the pretest and posttest scores of children in the experimental group. It was found that a significant difference exists between the level of children´s spatial skills when dealing with the Mosaics tasks between both the pretest (M=8.29, SD=2.037) and the posttest (M=11.26, SD=2.049) where t(34) = -8.342. The calculated P-value (p=0.001) also shows a significant difference between both groups. Thus, the abovementioned results suggest that the treatment provided to the experimental group helped the children perform better in comparison with the pretest. Certainly, this confirms that if children are given the chance to play with the ADAM game application, it can positively influence their achievements.

Table 22: Pretest-posttest paired sample t-statistics for Puzzles tasks [experimental group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	35	7.57	1.989	.336
Posttest	35	10.69	1.891	.320

Paired Sample t-statistics						
Groups	**Paired Differences**			**df**	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-3.114	1.345	.227	34	-13.694	.001*

*p < 0.05 (2-tailed)

As shown in Table 22 above, a paired sample t-test was applied to compare pretest and posttest scores of children in the experimental group. It was found that there was a significant difference between the level of children's´ spatial skills when dealing with Puzzles tasks in both pretest (M=7.57, SD=1.989) and posttest scores (M=10.69, SD=1.891) where t(34) = -13.694. The calculated P-value (0.001) also shows the significant difference between both groups. Therefore, the abovementioned results confirmed that the treatment given to the experimental group helped the children perform better in comparison to how they performed in pretest.

Table 23: Pretest-posttest paired sample t-statistics for Patterns tasks [experimental group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	35	6.49	1.788	.302
Posttest	35	9.80	2.878	.486

Paired Sample t-statistics

Groups	**Paired Differences**			***df***	**t-value**	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-3.314	2.166	.366	34	-9.052	.001*

*p < 0.05 (2-tailed)

As shown in Table 23 above, a paired sample t-test was applied to compare the pretest and posttest scores of children in the experimental group. It was found that there was a significant difference between the level of children's spatial skills when dealing with Patterns tasks in both the pretest (M=6.49, SD=1.788) and posttest scores (M=9.80, SD=2.878) where t(34) = -9.052. The calculated P-value (p=0.001) also shows a significant difference between both groups. Thus, the above results suggest that treatment provided to the experimental group supported the children in performing better than they performed in the pretest. This is also evidence that playing the ADAM game application can provide a positive influence on the level of children's achievements.

Table 24: Cross comparison according to student achievement level in Mosaics tasks in both pretest and posttest [experimental group]

		Achievement Level [Posttest]			
		Low	Average	High	Total
Achievement Level [Pretest]	Low	1	15	4	20
	Average	0	5	9	14
	High	0	0	1	1
	Total	1	23	11	35

In Table 24 above, a cross comparison between the results of the pretest and posttest is presented in a way that shows how the children's achievement level shifted towards improvement as a result of the treatment provided to the experimental group of children. The same results can be observed in the table above, where pretest data shows that a majority of the children, according to their performance in Mosaics tasks, fell under low (20, 57.14 %) and average (14, 40 %) achievers. Later on, they became average (23, 65.71 %) and high (11, 31.24 %) achievers and the change which occurred in their achievement scores appears largely a result of the treatment provided based on the ADAM game application, which is evidence to show it was helpful in positively affecting the children's performance.

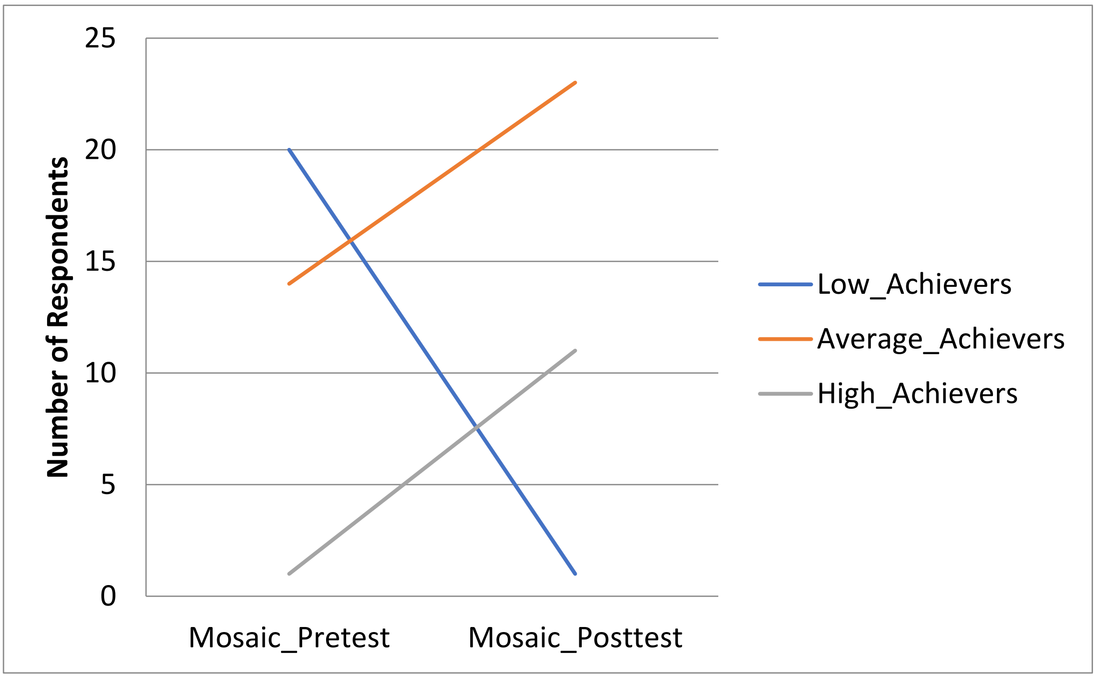


Figure 8: Cross comparison of student achievement level in Mosaics tasks in both pretest and posttest [experimental group]

Table 25: Cross comparison according to student achievement level in Puzzles tasks in both pretest and posttest [experimental group]

		Achievement Level [Posttest]			
		Low	Average	High	Total
Achievement Level [Pretest]	Low	7	16	4	27
	Average	0	0	5	5
	High	0	0	3	3
	Total	7	16	12	35

In Table 25 above, a cross comparison between the results of the pretest and posttest is presented to show the level of achievement of children in the experimental group who were provided with the treatment. Most of these children were low achievers when dealing with Puzzles tasks, while later they performed better and reached average as well as high levels. The same effect can be observed in the table above, where pretest data shows that a majority of the children, according to their performance in Puzzles tasks, fall under low (27, 77.14 %) and average (5, 14.28 %) achievers. Later on they became average (16, 45.71 %) and high (12, 34.28 %) achievers and this change occurred as a significant result of the treatment provided, based on the ADAM game application. This shows that the application had a positive effect on children’s performance.

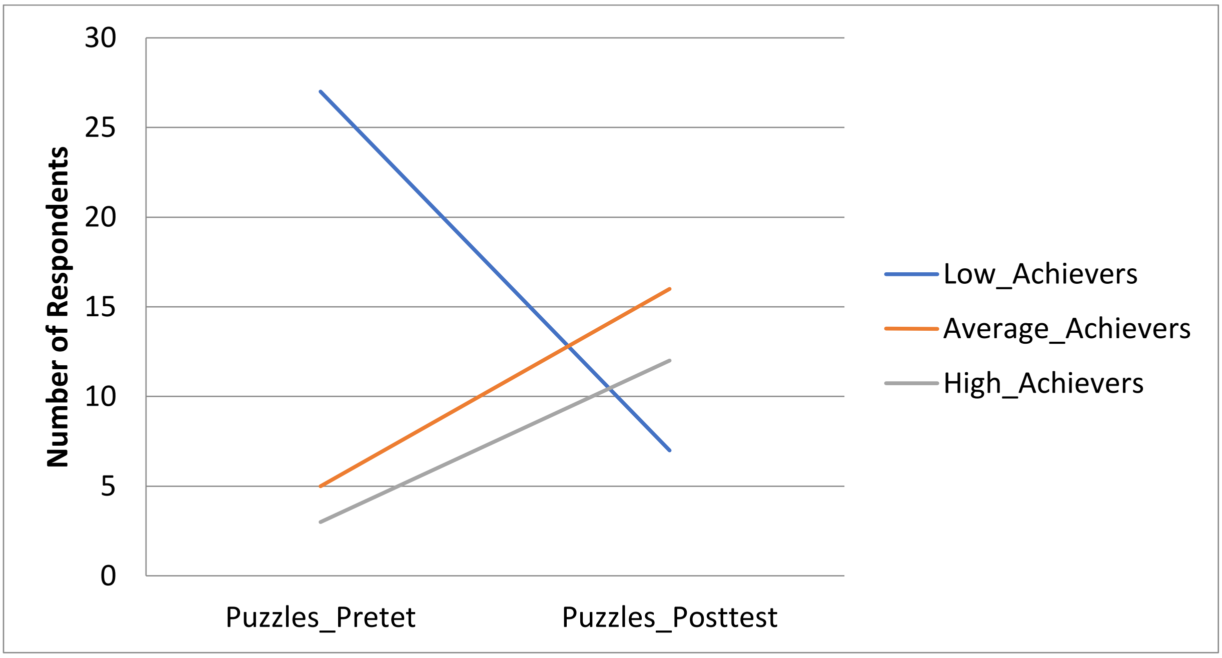


Figure 9: Cross comparison of student achievement level in Puzzles tasks in both pretest and posttest [experimental group]

Table 26: Cross comparison according to student achievement level in Patterns tasks in both pretest and posttest [experimental group]

		Achievement Level [Posttest]			
		Low	**Average**	**High**	**Total**
Achievement Level [Pretest]	**Low**	17	12	4	**33**
	Average	0	0	2	**2**
	High	0	0	0	**0**
	Total	**17**	**12**	**6**	**35**

In Table 26 above, a cross comparison between the results of the pretest and posttest is presented, reflecting the level of achievement of the children in the experimental group, who were provided with the treatment. Most of these children were low achievers when dealing with Patterns tasks, but they performed comparatively better and reached average as well as high level results. The same effect can be observed in the table above, where pretest data shows that a majority of these children, according to their performance in Patterns tasks, fall under low (33, 94.28 %) and average (2, 5.7 %) achievers. Later on, they became average (12, 34.28 %) and high (6, 17.14 %) achievers and this change appears to have occurred largely due to the treatment provided based on the ADAM game application, which is evidence that the application was helpful in positively affecting the children's performance.

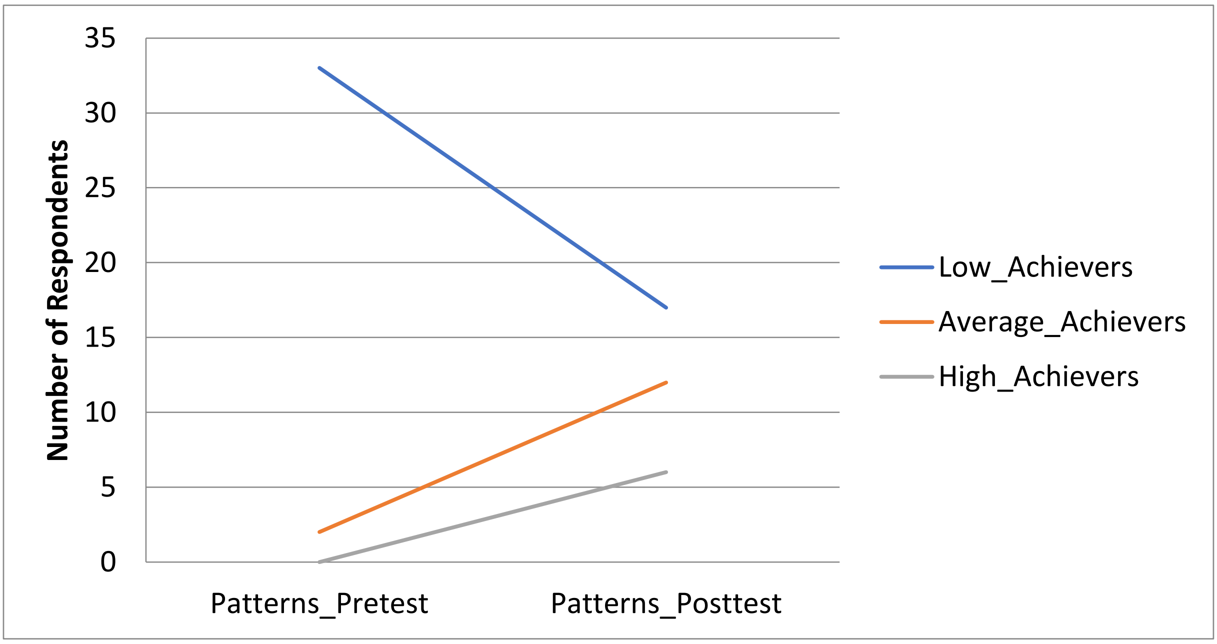


Figure 10: Cross comparison of student achievement level in Patterns tasks in both pretest and posttest [experimental group]

Table 27: Mean differences between boys and girls in pretest score

Groups	N	Mean	SD	*Df*	t-value	Sig
Male	33	7.59	1.455	68	-.339	.735**
Females	37	7.70	1.422			

**p > 0.05

The calculated values of the independent sample t-test show that only a non-significant difference was found between the performance of males (*M*=7.59, *SD*=1.455) and females (*M*=7.70, *SD*=1.422), where *t*(68) = -.339. The calculated P-value (.735) is also higher than the assumed level of significance of 0.05 needed to support the argument made previously. The analysed results in the table above show that participants of both genders demonstrated a similar level of spatial skills based on gender differences in the pretest data.

Table 28: Mean differences between boys and girls in posttest scores

Groups	N	Mean	SD	*df*	t-value	Sig
Male	33	9.66	1.912	68	1.014	.314**
Females	37	9.20	1.865			

**p > 0.05

The calculated values of the independent sample t-test shows that there is only a non-significant difference between males (*M*=9.66, *SD*=1.912) and females (*M*=9.20, *SD*=11.865), where *t*(68) = 1.014. The observed P-value (.314) > 0.05 was further evidence that the differences in results were insignificant between both genders. Thus, the analysed results in the table above also make it clear that participants demonstrated a similar level of spatial skills, regardless of gender differences. Moreover, the mean scores in the table above also show no prominent difference. Current results fail to show any significant changes based on gender difference in the posttest data.

Based on abovementioned evidence from the results we first of all reject **H01**: No significant difference exists in pretest and posttest scores for the Mosaics task between the control and the experimental group.

Secondly, we conclude that we reject **H02**: No significant difference exists in pretest and posttest scores for the Puzzles task between the control and the experimental group.

Finally, based on the results provided by the analysis, we reject **H03**: No significant difference exists in pretest and posttest scores for the Patterns task between the control and the experimental group.

Based on these results we accept the last hypothesis **H04**: No significant effect exists between boys and girls in achieved test scores for spatial skills.

To sum up we have obtained evidence from the main study to show that the educational application “ADAM”, aimed at the development of spatial skills, is worth using by preschool children and that their cognitive skills can be improved by applying the chosen treatment – an educational game application.

4. Conclusion

Spatial skills are a cognitive ability that can be used in everyday life, in the workplace and in science, to structure problems, find answers and express solutions using the properties of space. They can be learnt and taught formally to students using appropriately designed tools, technologies, and curricula (National Research Council, 2006). There is still a lack of specific knowledge concerning how spatial skills may be best spread across curricula and how to optimally incorporate new technologies in order to provide better results for children (Newcombe, Frick, 2010). Nevertheless, educational authorities are aware of the necessity in supporting teachers and the educational system in understanding the growing role of spatial skills and thus, the introduction of new aspects of curricula concerning the integration of spatial skills with concrete teaching contents is on the rise. Some educational systems have already started deliberately focusing on the development of spatial ability.

Executive Functions

Even though the research was not primarily aimed at executive functions, during the research and play sessions the researcher and teachers were able to observe differences when using the new tools and how such tools may influence some level of executive function. Children with signs of weak attention or impulsivity (signs of ADHD) were able to work for a longer period of time, concentrate on achieving a certain result and finishing their task. The differences observed while these children worked with the application and without it were markedly visible, according to some kindergarten teachers. These children were spontaneously motivated to start doing something and to finish their work. In general, they behaved more passionately when solving the tasks provided. The ability to focus on a single task and remain patient is also a skill which needs to be trained and supported. Children with ADHD were able to focus more on the interactive game on their tablet and were more goal-orientated when completing a task.

The authors of Grissmer et al., 2013; Gunderson et al., 2012; Verdine et al., 2014 state that executive function skills make a significant contribution to young learners' mathematical performance in later years. According to the results of the preliminary study, around 84 % of children included in the preliminary study showed a higher ability to focus on a chosen task. More than 75 % of the children were willing to try and complete more difficult tasks while using the application compared to a worksheet.

Later findings of the significant impact of spatial skills on early mathematical skills stressed the importance of including more spatial skills into new early mathematical competencies for educational curricula. Young children's mathematical development has become an important predictor of later labour market success (Ritchie & Bates, 2013; Rose, 2006). It has been clearly shown that spatial skills are critical for mathematical performance (Verdine et al. 2014, Uttal, 2013). Mix and Cheng (2012) state that "The relation between the spatial ability and mathematics is so well established that it no longer makes sense to ask whether they are related."

The reality of preschool education and its lack of focus on spatial skills is unsatisfactory. There are few concepts of how to support such skills, which remain largely hidden at a preschool age. Preschool teachers aren't always able to recognise where a child's level of spatial skills is. The result of our research has clearly shown that supporting spatial skills with the help of game applications is more effective than following the current educational possibilities provided by the Educational Framework (see chapter 1.2.6). Training with the help of ICT seems to be faster. There may be several reasons:

1) Educational applications are able to display environments in 3D. The entire area a child needs to move within, according the instructions provided, is shown on the screen and the child is able to observe the various movements and directions. It is a new experience compared to moving oneself in space (which must be the first natural experience and activity of a child). At the age of 6, children are able to perceive and understand things from a different perspective.
2) There are rotations of a subject, which the child can observe and combine repeatedly. They can also try new combinations.
3) The tasks are often connected to the narrated instructions. Voices and instructions are linked with movements inside the space of the game.
4) Children are solving multiple logical sequences and playing out the individual steps of a solution in their logical order. In an ordinary game the possibilities of those tasks are very limited and children learn repeating patterns relatively fast. The variation of tasks in this game is a significant benefit.
5) Children are able to perceive the concept of spatial orientation and perception thanks to different play environments in the game.
6) In the narrated instructions concerning spatial skills, there are many abstract words referring to time and space, and which are related to mathematics.

A factor analysis by Mix, Levine, Cheng, Young (2016) found that the significant spatial predictor of mathematical ability changes across Kindergarten, 3rd and 6th grades. One explanation would be, that the acquisition of different mathematical skills across grades relies on different types of spatial expertise (Mix, Levine, Cheng, Young, 2016). Gollinkoff (2016) states that the strengthening of spatial-mathematical links with age is consistent with a causal chain of events whereby spatial skills provide a foundation for mathematical learning. Gollinkoff further states that there are also links between spatial skills and magnitude comparisons, which suggest the link between spatial and mathematical skills may operate as early as preschool.

The abovementioned “causal of chain of events” is the core of many tasks in the ADAM Application. Naturally, in the real world children need to absorb and repeat their everyday life experiences. Nevertheless, it has been observed that children don’t need just real physical experiences in space, but also probably need to see themselves in some specific game space and think about “where I’m going, what I’m doing” while following instructions. The opportunity to zoom in and out inside a 3D reality might be a very necessary experience at this age.

A growing body of research has demonstrated that further abilities not traditionally viewed as ”mathematical skills”, such as spatial skills and executive function skills, make significant contributions to young learners’ performance in mathematics. (Grissmer et al., 2013; Gunderson et al., 2012; Verdine et al., 2014). Spatial ability is necessary for success in the domains of science, technology, engineering and math (STEM) (Uttal, Cohen, 2012 in Jirout J.J., Newcombe S.N., 2015). Recent research indicates that spatial skills play a unique role in predicting which students pursue STEM-related careers. In a large nationally representative sample (n ~ 400,000), Wai, Lubinski, and Benbow (2009) found that spatial skills assessed in high school predicted which students would enter a STEM career 11 years later. Spatial representation is indeed core to the STEM field. The ability to interpret spatial representations allows people to grasp STEM concepts more quickly (Uttal,2012).

From above-mentioned research, it is evident how much of a crucial impact spatial skills may have on mathematical skills during the later school years. Currently, based on our observations, the focus is on whether preschool children count up to 6 or 10 and whether they can recognize certain numbers and their magnitude. The first criterion (counting up to 6) doesn´t predict much concerning later maths results, but it is easy for preschool teachers to see and assess if a child can count or not. In reality, they would need to concentrate on assessing the level of spatial skills to be able to estimate the level of a child´s ability in this area, because these spatial skills specifically create a stable and adequate base for maths skills. This game application can help the teachers briefly recognise which areas a child needs help with or which tasks they may try to avoid. The Application also provides data on solution times, correct results as well as which areas are preferred and which are skipped.

It is necessary to mention some issues which might have a negative impact on the use of ICT in education:

1) The quality of the devices. It seems inadvisable to buy lower-quality ICT devices for kindergarten children. There are issues with charging the tablets.

2) Sometimes children need to use headphones to listen to the narrated instructions. They need to have good headphones and sensitive volume control on their tablets. In that case the children are able to cope without trouble.
3) The app games don't include other real objects for rotation and manipulation in conjunction with real objects in tasks which would be associated with the use of ICT.

Although there are some withdrawbacks of use ICT, as it was mentioned above, positive benefits of use of tablets overweigh those withdrawbacks. The most important thing is to find the optimal and efficient way for using tablets and smart software in education of preschool children whose needs and conditions are different from children attending the school already.

There is the statement from the kindergarten headteacher who was included into research: *"This is the first year all our preschoolers (except one) are able to understand prepositions, directions on either side and to combine direction instructions. Although we've tried to train this and repeat many of these words such as 'left/right, first on the right, second on the left' and others every time we go outside for a walk, I've just realized that we have never had such positive results. I don't want to let them (the children) play just any application, but I think the combination of a different reality and new perspectives was beneficial and sped up some of the learning process."* (*M. Brožová,* headteacher at Kindergarten Kratonohy).

4.1. Significance of the Study

This study may be useful for kindergarten teachers, special educational teachers, teachers´ assistants, educational psychologists, government officials, policy makers and non-governmental officials looking to know more about how to incorporate digital technology in the educational system to increase the learning benefits for children. This study can also help headteachers and government institutions understand the positive or negative effects of the use of digital technologies by preschool children for the development of specific cognitive skills – in this case spatial skills, which are strongly related to early mathematical skills. This research will contribute its conclusions on the effects of digital technology on spatial ability and the assessment of necessary features needed to increase children´s interest.

It will also contribute to the discussion on newly arising pilot curricula in early childhood education which tends to incorporate the positive aspects of new technologies in education. This experience may be used for the preparation of appropriate teacher´s training and define the primary criteria and skills teachers need to cope with incorporating digital technologies. The study will contribute to the growing body of research on the use of digital technologies in early childhood education, which is still small. If the results prevail in showing more positive outcomes, it could become a more permanent piece of evidence of the effects of ICT and the possibilities for its use in early childhood education.

4.2 Future Work

Based on the results in our previous studies we want to focus on further discovering of efficient use of tablets in early childhood education and its analysing. In our next work we are planning to combine ICT (using tablets and educational applications) with the tools which enable tactile experience. The tactile experience is one of the most important aspect in development and education of small children. The next work will be aimed on supporting more cognitive areas such as visual memory, visual perception, spatial and time orientation, mathematical skills and informatics thinking.

We also aim to conduct some researches in abroad and analyse how the system can work in the other countries and among the children of different culture.

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Appendix Content

Appendix I: Assumptions of T-test for the Pilot study

Table 29: Normality of Distribution

	Shapiro-Wilk		
Mozaics_Pretest	.942	30	.106**
Mozaics_Posttest	.968	30	.487**
Puzzles_Pretest	.940	30	.088**
Puzzles_Posttest	.948	30	.150**
Patterns_Pretest	.933	30	.061**
Patterns_Posttest	.977	30	.733**

**p > 0.05

Table 30: Test for Equality of Variances

	Levene's Test for Equality of Variances	
	F	Sig.
Mosaics_Pretest	.498	.486**
Mosaics_Posttest	.716	.405**
Puzzles_Pretest	.001	.979**
Puzzles_Posttest	.356	.556**
Patterns_Pretest	.213	.648**
Patterns_Posttest	.040	.844**

**p > 0.05

Appendix II: Pilot Study's Data Analysis

Table 31: Independent sample t-test for Mosaics tasks [pretest]

Groups	**N**	**Mean**	**SD**	***Df***	**t-value**	**Sig**
Control	14	8.143	2.627	28	-.421	.677**
Experimental	16	8.563	2.804			

**p > 0.05

The results of Table 31 explore that there was a non-significant difference between the Control (*M*=8.143, *SD*=2.627) and Experimental groups (*M*=8.563, *SD*=2.804), where $t(28) = -0.421$. It is evident from the P-value (.677) that the results are non-significant because it is higher than the assumed significance level (0.05). The results clearly show that participants from both the Control and Experimental groups have a similar level of spatial skills when dealing with Mosaics tasks in the pretest study.

Table 32: Independent sample t-test for Puzzles tasks [pretest]

Groups	N	Mean	SD	*Df*	t-value	Sig
Control	14	9.214	2.992	28	-.816	.421**
Experimental	16	10.125	3.096			

**p > 0.05

The calculated values of the independent sample t-test show that there was a non-significant difference between the Control (*M*=9.214, *SD*=2.9925) and Experimental groups (*M*=10.125, *SD*=3.096), where *t*(28) = -.816. It is clear from the P-value (.421) that the results are insignificant. The analysed results in the table above, plainly show that participants from both groups demonstrated a similar level of spatial skills when dealing with Puzzles tasks in the pretest study.

Table 33: Independent sample t-test for Patterns tasks [pretest]

Groups	N	Mean	SD	*Df*	t-value	Sig
Control	14	9.214	3.725	28	.826	.416**
Experimental	16	8.188	3.082			

**p > 0.05

The independent sample t-test calculated above demonstrates that there was a non-significant difference between the Control (*M*=9.214, *SD*=3.725) and Experimental groups (*M*=8.188, *SD*=3.082), where *t*(28) = .826. The calculated P-value (0.464), which is higher than the assumed significance level of 0.05 in the table above, shows a non-significant difference between the groups. The analysed results further show that participants of both groups have a similar level of spatial skills when dealing with Patterns tasks while collecting data in the pretest study.

Table 34: Independent sample t-test for Mosaics tasks [posttest]

Groups	**N**	**Mean**	**SD**	***df***	**t-value**	**Sig**
Control	14	8.571	2.243	28	-3.817	.001*
Experimental	16	12.125	2.778			

*p < 0.05

The results of Table 34 show that a significant difference exists between the Control (*M*=8.571, *SD*=2.243) and Experimental groups (*M=12.125*, *SD*=2.778), where *t*(28) = -3.817, and the P-value is p=.001 < 0.05. These results show that children in bo th the Control and Experimental groups were demonstrated to have significantly different levels of spatial skills when dealing with Mosaics tasks in the posttest. This is also evidence that the aforementioned change occurred as a result of the provided treatment based on the ADAM game application.

Table 35: Independent sample t-test for Puzzles tasks [posttest]

Groups	**N**	**Mean**	**SD**	***Df***	**t-value**	**Sig**
Control	14	9.50	2.710	28	-3.479	.002*
Experimental	16	12.75	2.408			

*p < 0.05

The calculated values of the independent sample t-test reveal that a significant difference was found between the Control (*M*=9.50, *SD*=2.710) and Experimental groups (*M*=12.75, *SD*=2.408), where *t*(28) = -3.479. The same is also confirmed with the help of the calculated P-value (.002), which is less than the assumed level of significance (0.05). The analysed results further show that participants of both groups have a relatively improved level of spatial skills when dealing with Puzzles tasks in the posttest.

Table 36: Independent sample t-test for Patterns tasks [posttest]

Groups	**N**	**Mean**	**SD**	***df***	**t-value**	**Sig**
Control	14	8.857	3.634	28	-2.239	.033*
Experimental	16	11.625	3.138			

*p < 0.05

The independent sample t-test was calculated showing that there was a significant difference between the Control (*M*=8.857, *SD*=3.634) and Experimental groups (*M*=11.625, *SD*=3.138), where *t*(28) = -2.239. The calculated P-value (0.033) in the table above also shows a significant difference between both groups, as it falls under the assumed significance level. The analysed results in the table also show that participants from both groups demonstrated different levels of spatial skills when dealing with Patterns tasks in the posttest.

Table 37: Pretest-posttest paired sample t-statistics for Mosaics tasks [Control group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	14	8.143	2.627	.702
Posttest	14	8.571	2.243	.600

Paired Sample t-statistics						
Groups	**Paired Differences**			***Df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-.429	.852	.228	13	-1.883	.082**

**p > 0.05 (2-tailed)

As shown in Table 37 above, paired sample t-statistics were used to compare the pretest and posttest scores of participants for Mosaics tasks. It was found that there was no significant difference between responses given by respondents in the pretest (M=8.143, SD=2.627) and posttest scores (M=8.571, SD=2.243) where t(13) = -1.883, and p=0.082 is higher than the assumed significance level (0.05). The results of the paired sample t-test above suggest that no significant development was observed in children while playing with Puzzles tasks. No difference was observed in the performance of the control group after comparing its pretest and posttest scores.

Table 38: Pretest-posttest paired sample t-statistics for Puzzles tasks [Control group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	14	9.214	2.992	.799
Posttest	14	9.5	2.710	.724

Paired Sample t-statistics						
Groups	**Paired Differences**			***df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-.286	1.138	.304	13	-.939	.365**

**p > 0.05 (2-tailed)

As shown in Table 38 above, paired sample t-statistics were applied to compare the pretest and posttest scores of participants for Puzzles tasks. It was found that there was no significant difference between the responses given by respondents in both the pretest (M=9.214, SD=2.992) and posttest scores (M=9.5, SD=2.710) where t(13) = -.939, p=0.365. The results of the paired sample t-test above suggest that no significant effect was observed on performance. No significant change was observed in the level of spatial skills when dealing with Puzzles tasks in the pretest and posttest data.

Table 39: Pretest-posttest paired sample t-statistics for Patterns tasks [Control group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	14	9.214	3.725	.995
Posttest	14	8.857	3.634	.971

Paired Sample t-statistics						
Groups	**Paired Differences**			***df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	.357	1.150	.308	13	1.161	.266**

**p > 0.05 (2-tailed)

As shown in Table 39 above, paired sample t-statistics were applied to compare the pretest and posttest scores of participants for Patterns tasks. It was found that there was no significant difference between the responses given by respondents in both the pretest (M=9.214, SD=3.725) and posttest scores (M=8.857, SD=3.634) where t(13) = -458, p=0.266. The results of the paired sample t-test above suggest that participants of the control group showed a similar level of spatial skills when dealing with Patterns tasks.

Table 40: Pretest-posttest paired sample t-statistics for Mosaics tasks [Experimental group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	16	8.562	2.804	.701
Posttest	16	12.125	2.777	.694

Paired Sample t-statistics						
Groups	**Paired Differences**			***Df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-3.562	2.032	.508	15	-7.013	.001*

*p < 0.05 (2-tailed)

As shown in Table 40 above, paired sample t-statistics were applied to compare the pretest and posttest scores of participants for Mosaics tasks. It was found that there was a significant difference between the responses given by respondents in the pretest (M=8.562, SD=2.804) and posttest scores (M=12.125, SD=2.777), where t(15) = -7.013, and p=0.001 is also lower than the assumed significance level (0.05). The results of the paired sample t-test above suggest, that development was observed in the children while playing with Puzzles tasks under the influence of treatment provided to experimental groups. A noteworthy difference was observed in their performance after comparing their pretest and posttest scores together.

Table 41: Pretest-posttest paired sample t-statistics for Puzzles tasks [Experimental group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	16	10.125	3.095	.774
Posttest	16	12.750	2.408	.602

Paired Sample t-statistics						
Groups	**Paired Differences**			***df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-2.625	1.258	.314	15	-8.345	.001*

*$p < 0.05$ (2-tailed)

As shown in Table 41 above, paired sample t-statistics were applied to compare the pretest and posttest scores of participants for Puzzles tasks. It was found that a significant difference exists between the responses given by respondents in both the pretest (M=10.125, SD=3.095) and posttest scores (M=12.750, SD=2.408), where t(15) = -8.345, p=0.001. The results of the paired sample t-test above suggest that a clear effect on the performance of children under the influence of the given treatment was observed. A significant change occurred in their level of spatial skills when dealing with Puzzles tasks in the pretest and posttest data.

Table 42: Pretest-posttest paired sample t-statistics for Patterns tasks [Experimental group]

Paired Sample Descriptive Statistics				
Groups	**N**	**Mean**	**SD**	**Std. Error Mean**
Pretest	16	8.188	3.082	.770
Posttest	16	11.625	3.138	.784

Paired Sample t-statistics						
Groups	**Paired Differences**			***df***	***t-value***	**Sig**
	M	**SD**	**Std. Error Mean**			
Pretest-Posttest	-3.438	1.460	.365	15	-9.423	.001*

*p < 0.05 (2-tailed)

As shown in Table 42 above, paired sample t-statistics were applied to compare the pretest and posttest scores of participants for Patterns tasks. It was found that a significant difference exists between the responses given by respondents in both the pretest (M=8.188, SD=3.082) and posttest scores (M=11.625, SD=3.138), where t(15) = -9.423, p=0.001. The results of the paired sample t-test above suggest, that the treatment applied to children from the experimental group therefore shows a significant difference after comparing their pretest and posttest scores.

Appendix III: Assumptions of the t-test for the main research

Table 43: Normality of Distribution

	Shapiro-Wilk		
	Statistic	df	Sig.
Mosaics_Pretest	.968	70	.068**
Mosaics_Posttest	.966	70	.056**
Puzzles_Pretest	.971	70	.099**
Puzzles_Posttest	.969	70	.078**
Patterns_Pretest	.968	70	.069**
Patterns_Posttest	.973	70	.137**

**p > 0.05

Table 44: Test for Equality of Variances

	Levene's Test for Equality of Variances	
	F	Sig.
Mosaics_Pretest	.437	.511
Mosaics_Posttest	.680	.413
Puzzles_Pretest	.276	.601
Puzzles_Posttest	.631	.430
Patterns_Pretest	.013	.911
Patterns_Posttest	2.935	.091

Appendix IV: Description of tasks in the ADAM game application

1. Voice Navigation Task

A child needs to find the right way out of a maze, they have to follow voice instructions telling them where to go. There is also a particular seriation of the commands. On the map are streets running in different directions and orientation points which a child must pay attention to in order to find their way according to the instructions provided and according to which orientation points are visible on the screen. The child comes to understand that positions and movements can be described. They have to concentrate on the position of certain objects in relation to other objects. There is also the experience of being provided instructions for a series of movements.

Instructions were prepared for the various directions, orientation points and combinations of further instructions. Instructions at the lower level are automatically part of the higher difficulty level. In the middle and high levels certain instructions are given, which occur only at this specific level.

Low level:

Instructions (examples)			**Sequence of instructions**	**Size of the town map**
Directions	**Orientation points**	**Further instructions**	1–2	7 x 7 squares/ 8 x 8 squares
Go forward	Go alongside the church	... and then go straight forward		
Turn right	Go alongside the fountain	..continue forward		
Turn left	Go alongside the chimney			

Voice navigation example from the task:
Go straight forward. Continue forward.

Middle level:

Instructions (examples)			Sequence of instructions	Size of the town map
Directions	**Orientation points**	**Further instructions**	**2**	10 x 10 squares
Turn back, then turn left/right	Go alongside the church and turn left	…then before you come to the bridge, turn left/right		
Take the first left, then the first right	After you pass the fountain, turn right	…next to the bus station, go right		
Continue left/right/forward	After you cross the bridge, turn right	….then go down the opposite street		

Voice navigation example from the task:

Turn right and go forward to the bridge.

After you cross the bridge, go down the first street on the left.

High level:

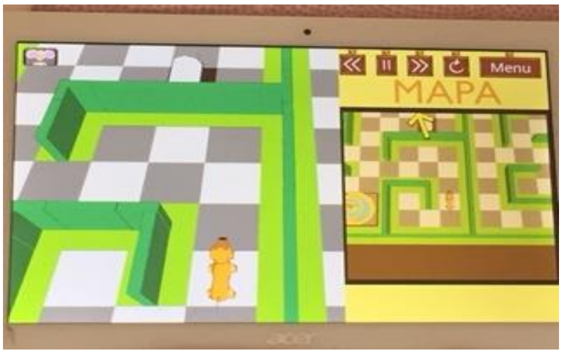
Instructions (examples)			Sequence of instructions	Size of the town map
Directions	**Orientation points**	**Further instructions**	**3**	12 x 12 up to 20 x 20 squares
All previous combinations	After you pass the bus station, turn left/right and go forward	…next to the bus station, go left and then turn right		
	Turn down the third street on the left/right, then go down the first street to the left/right.	…then go down the street which is opposite to the bridge		
	Turn down the first street left/right			

Voice navigation example from the task:

Turn right, go forward to the bridge and then turn right at the second street.

After you cross the bridge, go down the first street on the left and then go down the street which is opposite to the bridge.

2. Maze Navigation Task



The scene of this task is divided into two parts. The first part is a maze the child needs to find a way out of, the second part is a map given to them to help visualise their current position and find the right way out. The child can only see the whole maze on the map while at the same time they see only the particular part of the maze currently being navigated. This way one is motivated to use the map and look at the map from one’s current position. The map is stable and orientated independently of the child´s movements through the maze. The scene of the maze rotates according to the steps a child chooses through the maze. The child moves through that space looking for the correct destination. They perceive the different spatial structures and two types of navigation through space. One is independent of movements through the map, the second one on the left side usually rotates according to the movements and position of the child.

	Low level	**Middle level**	**High level**
Size of the map	5 x 5	10 x 10	20 x 20
Number of orientation objects in the maze	2–3 objects in the maze	4–5 objects in the maze	6–7 objects in the maze
Structure of the maze	simple inner structure	adjusted inner structure	challenging inner structure

Voice navigation example from the task:
Look at the map and find the way for the dog from the maze out.

3. Prepositions – Hoover Task

The child needs to find the correct object according to the voice instructions provided (e.g. find a cup up on the left hand side, find a star in the bottom middle, prepositions in space). There are different scenes, such as with objects placed in different rooms or objects placed on shelves. There are multiple identical objects and the child needs to listen and understand the instructions on which object needs to be chosen. The difficulty setting of the task was prepared according to developmental stages.

	Low level	**Middle level**	**High level**
Prepositions used in this level	on, in, in front of, near, behind, above, below, between	in the middle, the first, the last, right, left	top right, bottom right, top left, bottom left, in the middle, in the second row, the first one in the middle row
Objects used in this level	different objects, each object is in the scene only once	different objects, two of the same objects are in different places in the scene	two or three of the same objects are in the scene, different/similar objects in similar places

Voice navigation example from the task:

Find the flower on the shelf. Find the bottle of water behind the table.

Find the star which is left.

Find the cup which is top left on the shelf. Find the spoon which is in the second row.

4. Order Gallery Task

Cards with pictures will be offered to a child, who has to put all the cards in the right order. All of the cards present a small story or some specific situation. The child needs to decide how the story starts, how it carries on and how it ends up. The child learns that a specific order must be followed to get a meaningful result and that some logical rules must be considered. They come to understand that order is not created merely by coincidence. Time is linked to space and both of these aspects are closely tied to mathematical skills.

	Low level	Middle level	High level
Number of cards in a story	3 cards – a growing flower, an apple tree, etc.	4 cards – building a house, lighting a fire, a child´s development, etc.	4–6 cards – pizza, baking bread, a boy getting dressed, making a snowman, etc.
Strategy	The stories chosen are common and every child can see examples around them.	The stories chosen are such that the order of cards must be considered with higher precision.	Some of the chosen stories are uncommon, but can be solved according to the clues provided, which the child must be aware of.

Voice navigation example from the task:

Put the cards into the right order to create the story.

5. Select Row Task (logical lines)

There is a line of different objects placed in a particular pattern. The child must recognize the pattern and put the correct picture in the empty slot (mirror positions on the left and right sides of a row are also used).

A child is presented with a line of objects. One object in the line is missing and the child must choose one of the other objects offered under the task. The lines change according to different patterns described previously. The objects in line and those offered as a choice differ in shape, size, colour, details and the horizontal position of those details. The child also perceives each picture in a spatial manner and learns to observe each line from the beginning to the end and distinguish between the different positions of objects in the line and also the various positions of the missing objects. In order to choose the correct objects, they must pay attention to the relations between the remaining objects in the line.

The child looks for the right pattern, compares the positions of particular objects, is required to find where the right pattern begins and ends and finally to select the missing object. In order to distinguish between patterns, a child has to be able to count objects in a row. Moreover, objects on one side must be compared with objects on the other side.

	Low level	**Middle level**	**High level**
Number of objects in the line		5–6	7–8
Pattern of the line	Aaaa aabbcc aaabbb	abbabbabb abcabcabc	abbcabbc abcdabcd
Generation of different variants (example)	4–5 objects (two different types of trees) in an “abab” pattern	6–7 objects (cars and vehicles) in an “abcabcabc” pattern	8 objects (flowers, vehicles, etc.) the line is divided into left and right sections to create mirror patterns

Voice navigation example from the task:

Observe the row of objects, one object is missing. Find the right one and complete the row. according to the pattern of the objects.

6. Missing Top Tasks

There is a row of completed houses in the top row, in the bottom row there are incomplete houses whose components (roofs) are missing. In the middle there are various shapes of roof which are required, but these are also mixed up with shapes that do not belong on any of the houses. The child must choose the correct part of each house and complete it according to the pattern above. The objects in the line and objects offered for selection differ in shape, size, colour, detail and the horizontal position of details. More objects are added, requiring the child to reason and distinguish between multiple objects. They must look for the correct pattern, compare the position of a particular object and must always compare its appearance with the specific example of a house in the line above. Vertical position must be distinguished as well as mirror positions of some of the details of the objects. The child observes the houses and their details carefully. Some of them might have reversed colours or details which differ horizontally or vertically.

The player learns to observe details as well as the position of a particular object in line. Furthermore, they must also compare the closest house to the house which is not yet complete. The child has to find a sequence of patterns, add pieces to a different object and complete it. They must clearly understand how to complete the object and the group of objects.

	Low level	**Middle level**	**High level**
The number of types of object in a row	2	4–5	6–8
Number of missing types of parts	2	4	5
Number of other ”wrong” parts	1–2	3	**3–4**
Types of tops	chosen according to colour and position	chosen according to colour, position and shape	chosen according to colour and position or shape and detail

Voice navigation example from the task:

There is a row of completed houses in the top row. In the bottom row there are incomplete houses. In the middle there are various shapes of roof which are mixed up with shapes that do not belong on any of the houses. Choose the correct part of each house and complete it according to the pattern above.

7. Construction Tasks

The child has to build the correct house which matches the pattern, out of different geometric parts provided.

This includes the rotation of objects and the combination of different parts needed to build a house. The houses are divided into particular sections (floors). Some floors can only be built from a combination of other, smaller parts. In the higher difficulty level, at least two floors out of three must be built from two parts. Certain parts of the houses are similar in colour and the child must consider their choice carefully. There are also mirror positions and different vertical positions. Some of them may have colours in reversed positions, or multiple details which differ horizontally or vertically.

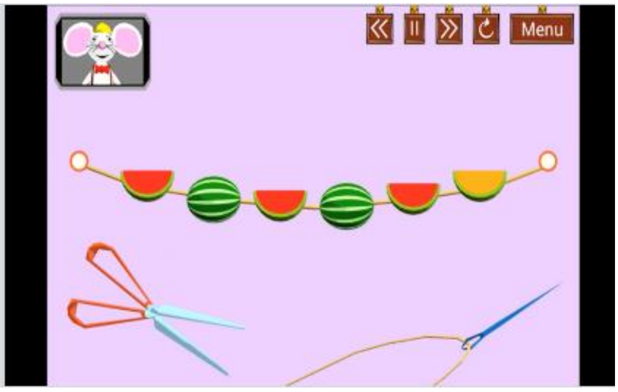
In this task the child needs to consider three (3) different aspects:

1) Look for the correct bricks and discover the relations between them. They must decide which brick will go first and which one follows.
2) Some bricks and some house floors must be combined from two parts.
3) The child must observe the pattern created by the houses and figure out which house is missing.

	Low level	**Middle level**	**High level**
The number of types of objects in a row	3	4–5	6–7
Number of missing types of parts	2	3	4–6
Number of other "wrong" parts	0–1	2–3	**4**
Types of models	• 1-floor house consisting of two parts • 2-floor house where a floor is made of a single brick	2–3 floors, one of these floors is built out of more parts than one	2–3 floors which are built from more blocks than one
Shapes	sphere, cube, rectangle	+ triangle, it is possible to construct a shape from two parts	it is possible to construct a shape from two parts and at least two floors are made out of two parts

Voice navigation example from the task:
You have to build the correct house, which matches the pattern, out of different geometric parts which are provided in row on the top. Please build a house and complete the row.

8. Mistake Row Tasks



The child has to find a mistakes among beads which are lined up in a row. There are also instructions concerning where the child should look (right/left). The child must find which bead is the mistake among the other beads. The narrative guide provides a clue concerning which side they should look to find the mistake. The discrimination of shapes, colours, sizes, patterns, positions, similarities and differences, vertical and horizontal positions is included. In the higher difficulty level, the shapes of numbers, letters and different patterns are included as new options. The line of "beads" is longer and patterns are included which the child needs to compare, determine the beginning and the end of a particular pattern and contrast the different positions of each object to find the inner structure of the pattern and then find the mistake. The child needs to compare different objects and the relations between then.

It is necessary to understand the voice instructions. The role of comprehension and language here is to provide a clue for a better and quicker solution to each task.

	Low level	**Middle level**	**High level**
The number of objects in each line	6	12	12–18
Patterns	Aaaa ababa	abbabb abbaabba	Abcabc aabbccaabbcc
Difference Criterion	criteria – colour, shapes	criteria – shape, size, colour	criteria – shape, size, detail, position/rotation
Type of models	fruit, geometric shapes	geometric shapes (beads with patterns and numbers)	the previous options + the shapes of letters and numbers

Voice navigation example from the task:
You need to find a mistakes among beads which are lined up in a row. Listen carefully to instructions which helps you to find a mistake fast. Than click on the objects which does not belong to the pattern.

9. Planet Tasks

The child has to sort out and select different objects according to the instructions given by the guide. The child needs to distinguish objects according to their size, amount and numbers. There are from three to five planets of different sizes and the child needs to use analogical reasoning to put the correct objects on the planets.

In these tasks the child must add or take away some objects from the planets according to the instructions. They must practice understanding terms such as “less/more, one less, two less, one more, two more, equal, nothing, the most, the least”. The child has to match numbers with a particular amount of a thing. Each group of objects must be assigned to a number when the child counts (1–8), learning that the last number defines the size of the set.

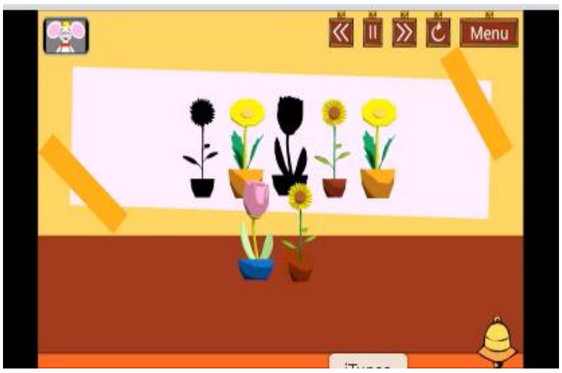
	Low level	Middle level	High level
Distinguishing criteria	big/small, all, a few, pairing up	less, more, the same, one more, one less	two more, two less
Sorting	shapes, colours	shapes, colours, sizes	colours, shapes, sizes, details

Voice Instructions (examples):

Divide the fruit according to the number on the planets and select the correct number for each amount of fruit.

Choose the right number according to the size of the planets.

10. Shadow Tasks



The child must match pictures with their shadows. They must also use their reasoning skills to see how to combine the pictures with their shadows, because sometimes two or three different objects go together. Furthermore, the child must consider shapes and colours, and the shapes of objects are often very similar. When 2 or 3 objects go together in one piece a child must manipulate and consider the correct order of objects. They must change their strategy while solving the task. The child needs to compare which objects are the same and what relationships there are between them. They must also use matching strategies to find out the correct position of the objects.

	Low level	Middle level	High level
The number of objects in each line	4	4–5 2–3 objects can be joined together into one piece	6–8 2–3 objects can be joined together into one piece
Colours	objects of the same colour, different colours of the same object	objects of the same colour, different colours of the same object	objects of the same colour, different colours of the same object
Shapes (objects)	flowers, fruit, animals	means of transport, balls, geometric shapes, similar objects	geometric shapes, similar animals, similar fruits (similarities among objects)

Voice navigation example from the task:
There are several objects and their shadows on the picture. Choose the correct object for each shadow and match them together.

11. Shelf Tasks (Difference Shelf Task, Same Shelf Task)

Different objects will be presented to a child. They must recognize which picture doesn't belong among the others, which one is different. There are various criteria which provide a clue for the child to distinguish differences – colours, shapes, positions and details. There are also pairs of objects which are either the same or differ in details or positions (mirror position, left/right position). Children learn to compare objects and relations such as "equal to" or "different from a group of things".

	Low level	Middle level	High level
Criteria	different colour, size, different picture in the row	difference in horizontal position or in details	difference in vertical position, in the mirror position of the pictures

Voice navigation example from the task:
Look at the objects in the row and find one of them which differs and does not match to others. Click on this different object and remove it from the shelf.

12. Memory Panorama Tasks

There are three (3) or more objects presented on a shelf. After a few seconds the objects disappear and the child has to try to create the same order of objects that they saw before. At the beginning the child needs to remember a combination of two objects, later the difficulty gradually increases and more objects will appear in different combinations, such as geometric shapes with different patterns. The child has to remember the sequences of objects. They may also use unitizing in order to code the number of objects which are the same and perceive the relationships between objects.

	Low level	**Middle level**	**High level**
Number of objects in one row	3–4	4–5 2–3 objects can go together in one piece	5–6
Shapes (objects)	different, no similarities (e.g. ducks, cups, trees…)	with similarities – cubes, geometric shapes	with similarities – cubes, geometric shapes, different or similar patterns on the shapes
Patterns	one different object in the row	multiple different objects in the row	multiple different objects in the row – geometric shapes, similar animals, similar fruits (similarities among objects)

Voice navigation example from the task:

There are several objects on a shelf. Remember how they are organised. After a few seconds the objects disappear and you have to try to create the same order of objects that you saw before.

Appendix V: Ethical Research Principles of the Study

The ethics of undertaking research activities will be strictly adhered to.

1) All participants, parents, teachers and headteachers will be aware that they are taking part in an investigation where data will be collected. The researcher will provide parents and teachers with any necessary information to ensure their full understanding of the research.
2) A research permit will be obtained from the kindergarten headteacher in order to conduct the study in a given kindergarten and in specific classrooms.
3) The researcher will explain to participants their right to withdraw from the research at any time. The researcher must attempt to ensure that all participants (including children) are aware of their right to withdraw. When testing children, avoidance of the testing situation may be taken as evidence of a lack of consent to the procedure and should be acknowledged.
4) Informed consent will also contain information about confidentiality. Participants in research including psychological outcomes have a right to expect that the information they provide will be treated as confidential and, if published, will not be identifiable as theirs.
5) Researchers have a primary responsibility to protect participants from physical and mental harm during the research. The risk of harm must not be higher than during everyday life.
6) If a research procedure might result in undesirable consequences for the participants, the researcher has the responsibility to detect and remove or correct these consequences.
7) In research involving children, the researcher must always be prepared and willing to discuss the results with parents, teachers or caregivers (acting in loco parentis).
8) Any observation must respect the privacy and psychological well-being of the children being studied. The observational part of the research is only acceptable in situations where those observed would expect to be observed by strangers.
9) If during research associated with the psychological field any result showing problems of a child is detected, the advice of parents and teachers must be solicited, concerning educational, personality, behavioural or health issues. If the issue is serious and the investigator is not qualified to offer assistance, the appropriate professional advice should be recommended.
10) The researcher shares responsibility for the ethical treatment of research participants with their collaborators, assistants and teachers.

    Consent letters will be provided to all parents whose children will be participating, to inform them about the study, the processes of information collection and the results.

Appendix VI: Parental Informed Consent

Introduction

Your child has been invited to join a research study to look at possibilities for the support of mathematical skills at an early age and to enable children to achieve the best results possible. Please, take whatever time you need to discuss the study with your family or anyone else you to wish to. The decision to let your child join, or not to join, is up to you.

In this research study, we are investigating the possibility of improving certain cognitive skills (spatial ability) through the use of a new educational application which might be beneficial for development of preschool children before they go to school.

What is involved in the study

The study will start in March 2017 and will last one school term until the end of June. Children who are to be involved in the study will have two initial sessions, each lasting 30 minutes, in which your child will be asked to play with cubes and pictures. Their spatial skills and visual perception will be noted. We think this will take them about 2 x 30 minutes. The session will be divided to enable the child to enjoy playing with the materials and so as not to get tired from the work.

After this initial session, your child will be playing with an educational tablet application which we believe may enhance some of the child´s cognitive skills and could be beneficial to the child´s development. The child will be playing 4 times a week for 30 minutes. The first half of the play session will be playing assigned tasks, after that they can chose tasks freely.

At the end of the school term, in June 2017, the child´s spatial skills will be checked once more during two sessions where the child will play with cubes and pictures again.

The investigator may stop the study or take child out of the study at any time if they judge it in your child´s best interest. They may also remove your child from the study for various other reasons. Your child can stop participating at any time. If your child decides to stop participating, they will lose no benefits.

Benefits of taking part in the study

It is reasonable to expect the following benefits from this research:

- A new learning experience with an educational tool.
- Supporting and training the chosen cognitive skills – mathematics skills.
- Supporting and training the chosen cognitive skills – spatial skills and visual perception.

- Enhancing interest, motivation, attention to more challenging tasks, overcoming obstacles by themselves.
- New types of social interactions and communication among classmates.

Confidentiality

Your child's name will not be used when data from this study are published. Every effort will be made to keep clinical records, research records, and other personal information confidential.

We will take the following steps to keep information confidential, and to protect it from unauthorized disclosure or damage: all information will be kept locked. Whether the information are saved in the computer, they will be kept under the password which the researcher knows. _Other people do not have any access to the information.

Confidentiality protection

All data files will be kept in locked cabinets. Data stored on a computer will require a password to access the system. Only a very limited number of people have access to the data, primarily the researcher. The researcher's assistant only has access for limited time periods. After the study is finished they have no right to access the data. Videotapes with recordings of the classroom and children will be kept in a locked cabinet, after the data is analysed the videotapes will be no longer be used.

Your rights as a research participant

Participation in this study is voluntary. Your child has the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which your child is entitled.

If your child decides to leave the study, the procedure is:

They will withdraw from the list of participants. Their user profile in the game application will be deleted, and alongside the profile all information collected in the application will also be deleted. The data collected from the initial play and assessment will not be used and will be deleted.

Permission for a Child to Participate in the Research

As parent or legal guardian, I authorize ________________________(child´s name) to become a participant in the research study described in this form.

Parental or Legal Guardian´s Signature: ________________ Date:___________________