PEDAGOGIC PRINCIPLES TO DEVELOP DESIGN STUDENTS' SPATIAL ABILITIES IN THE STUDY PROCESS

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Abstract

Spatial abilities of students are essential in order to understand interrelationship between knowledge acquired during the learning process and decision making on learning tasks.

Objective of the current study is to find out pedagogical possibilities for promotion of spatial abilities of design students applying principles of Universal Design for Learning (UDL) in learning process. In start-up phase of learning process students were tested by Santa Barbara Sense-Of- Direction Scale, Spatial Orientation Test, The Visual-Spatial/Auditory-Sequential Identifier. Testing was performed with 23 interior design students of the second and fourth year students. Results of tests demonstrated that students are diverse in their spatial abilities. It was found that there are differences in perception of space, spatial reasoning as well as in way of teaching.

Learning process according to UDL principles was organised diversifying ways of information presentation, involvement and possibility of task performance. Evaluation of intermediate phase tests and design project development during the learning process was done by involvement of students in discussions, varying the way of idea expression and presentation according to variety of students' presentation skills.

Assessment of spatial cognition was carried out according to the following criteria: navigation and mental rotation.

For evaluation of final design projects the following 5 spatial cognition criteria are used:

1. Disembedding (perceiving objects, paths, or spatial configurations amidst distracting background information)
2. Spatial Visualization (piecing together objects into more complex configurations or visualizing and mentally transforming objects, often from 2D to 3D or vice versa).
3. Mental rotation (rotating 2D or 3D objects)
4. Spatial Perception (understanding abstract spatial principles, such as horizontal invariance or verticality)
5. Perspective Taking.(visualizing an environment in its entirety from a different position)

Tests repeated in the closing phase of learning demonstrated essential increase and equalization of spatial abilities in comparison to those observed in the beginning of investigation and reflected in spatial solutions of control experiments (design projects).

Results of investigation demonstrated that implementation of UDL principles in learning process is helping to develop spatial abilities of interior design students.

Keywords: Universal design, spatial abilities.

1. INTRODUCTION

A historically essential and necessary competence for spatial designers (architects, interior designers) and representatives of the engineering professions is a set of skills and knowledge to be able to solve 3D tasks and implement the design solution. Spatial designers must be able to visualise the new spatial object in their imagination, understand the possibilities for its arrangement (placement) in a particular space, and be able to create two-dimensional drafts and drawings with the level of accuracy and quality to assure that the actually implemented idea corresponds to the project.

The Bologna Process, which started with the declaration signed by the European ministers of education in Bologna in 1999, marks conceptual changes in the formation of the environment of higher education in Europe. It is intended to achieve them by facilitating the comprehensibility and mutual comparability of the diverse European higher education systems in order to stimulate international cooperation in the field of education and creation of a common labour market. The Bologna Process can be viewed as a framework of a concrete action plan for a change of the paradigms in education from teaching to learning, from teacher-centred education to student-centred education, from process to result, by putting more emphasis on the result of the studies and assessment of the acquired competences. If the results of the studies describe the aims of the study programme or the process of education, then competences describe the assessment of the actual skills of the graduate. (Crosier, 2009).

2. SPATIAL THINKING

Our world exists in a space, and living in this world implies continuous interrelation between the space and the human. Creative development of new solutions requires higher mental spatial action. Spatial information contains data which describe the shape, layout and movement of objects, as well as the interrelations between the objects and the relationship between the objects and the systems of reference. This information is present in the cognitive world of the individual, and its mental transformation enables manipulation, creation, and movement in the physical world as well as achievements in academic and intellectual activities. (Chatterjee, 2008) (Freksa, 1999). As a result of space cognition as well as learning and studying, people acquire their spatial skills. According to the conclusions drawn by Piaget, this skill is not genetically determined, but is rather the result of education and the process of cognition throughout one's life (Piaget & Inhelder, 1997). According to Squire, declarative memory, which is directly available in the process of intentional memorisation, implies, but is not limited to, memory of spatial location (Squire, 1987). According to the conclusions drawn by McCuistion, versatile research has provided more and more evidence for the belonging of spatial skills to the field of primary knowledge alongside with mathematical and verbal skills. (McCuistion, 1991).The concepts of spatial ability and spatial skills are often segregated in the studies conducted in educational psychology. Spatial ability is defined as innate ability to imagine, and, consequently, an individual is born with the ability (Silvermann, 2005).
Significant research to explore spatial abilities has been ongoing in educational psychology already since the twenties and thirties of the previous century. A range of various tests has been developed for the determination of spatial abilities. However, the work with the available tests and the applied statistical methods has not led to a consolidated scientific view of the structure of spatial intellect in general (Hegarty, 2005). Moreover, despite the considerable quantity of the tests, the key aspects of spatial functioning have been neglected in the evaluation of the results. Newcombe states that, using the currently available tools, it is not possible to define an overall structure of spatial intellect and offers a comprehensive typology of the structure of spatial intellect-spatial thinking, contrary to the inductive approach applied in the conventional psychometric research and factor analysis. According to Newcombe, spatial thinking is a complex way of cognising the world which combines an indivisible interaction of the idea of the concept of space, the type of spatial representation and the process of formation of spatial reasoning in order to recognise, assess, and understand the atmosphere, geosphere and anthrosphere (human impact) according to the scale and time of the research within the study:

1. Intrinsic-Static. Coding the spatial features of objects, including their size and the arrangement of their parts—i.e., their configuration.
2. Intrinsic-Dynamic Transforming the spatial codings of objects, including rotation, cross-sectioning, folding, plastic deformations. Extrinsic-Static. Coding the spatial location of objects relative to other objects or to a reference frame.
3. Extrinsic-Dynamic Transforming the inter-relations of objects as one or more of them moves, including the viewer (Newcombe N. S., 2003) (Newcombe N. S., 2010).

In other words, spatial thinking is an aggregate of cognitive skills characterised by ability to perceive and express the acquired information as well as to perform mental activities in order to structure, combine or otherwise transform the acquired data.

The concept and principles of the Universal Design, which assure availability of the environment, objects and information and opportunities for their use to everyone, have been used to develop several methodologies for the application of the principles of the Universal Design in education. The Universal Design focuses on a transformative process in education, targeted at reducing the potential barriers any students might have. The developed principles of Universal Design for Learning envisage providing the process of studies with the following:

1. versatility in the presentation of the material (symbols, numbers, images, real objects, text) which helps to notice the connections and improves understanding of the acquired knowledge;

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2. versatility of action and expression in the presentation of the acquired knowledge (verbally, in writing, a presentation of a spatial model in computer graphics, mock-up, technical drawing, draft) which develops efficient skills in setting and achieving aims;
3. versatility of the opportunities for involvement (individual or cooperative) which develops each student's individual abilities to control their emotions and maintain motivation regardless of the situation they face in the process of studies; creates an stimulating, motivating, and involving study environment. (Rose, 2002).

Spatial thinking is an essential (human) fundamental skill which any student can acquire and improve if well-considered support tools and technologies are included in the process of studies. A well-considered study programme and use of simpler or more complex technologies according to students' level; spatial thinking can be made a valuable mind habit for the entire future life. (Committee on the Support for the Thinking Spatially:The Incorporation of Geographic Information ScienceAcross the K-12 Curriculum, Committee on Geography,National Research Council, 2006)
Although spatial thinking is required in every area of knowledge, it is of particular importance in medicine, physics, pedagogy, and design (Lee & Bednarz, 2012).

3. STUDY OBJECTIVE

The objective of the current study is to find out pedagogical possibilities for promotion of spatial abilities of design students applying principles of Universal Design for Learning in learning process.

4. MATERIAL AND METHODS

23 interior design students, aged between 20 and 23 years, of the University of Latvia participated in the study. The following tests were used to determine the spatial abilities: Santa Barbara Sense-Of-Direction Scale, Spatial Orientation Test, the Visual-Spatial/Auditory-Sequential Identifier, the Mental Rotation Test (MRT), the Mental Cutting Test, the Differential Aptitude Test: Space Relations. The testing was done at the beginning of the studies and before the presentation of the final design project.
The test results revealed that the students could conditionally be divided into three groups:

1. high level of spatial abilities – more than 60% of correct answers,
2. medium level of spatial abilities – 60% to 30% of correct answers,
3. low level of spatial abilities – less than 30% of correct answers.

Investigation of architectonic space was performed as part of the studies by using symbols, text, images and diagrams as well as ArchiCad virtual models for the presentation of the information. Investigation of the shape of some design objects or structures (stairs, room dividers, doors) and analysis of the spatial structure (Intrinsic-Static) took place**.** The 2D and 3D, sectional presentation (Intrinsic-Dynamic), the mutual arrangement of the objects, and the scale (Extrinsic-Static) were evaluated. During the sessions, the students drew free-hand sketches, constructed a room plan by analysing images of the presented room from various view-points (Extrinsic-Dynamic). The learning process is characterised by continual dialogue. Students learned from sharing information with one another and critiques of the instructors. Design students learned by experiencing, reflecting, thinking and doing in the process of finding solutions to assigned design problems. By explaining their opinion, the students acquired spatial reasoning skills.

The students conducted a complex independent study in interior structures, their history, function, shape, design and possible technical solutions in a room. At the end there was a design project assignment based on an actual problem in the premises of the university. The study was conducted individually or in groups choosing the topic and type of cooperation freely. Problem-based learning environments improve motivation and cognition. (Bellanda, 2013).

Upon completion of the studies, the students carried out a project involving transformation of a multifunctional room in the university. For evaluation of final design project the following 5 spatial cognition criteria were used: disembedding (perceiving objects, paths, or spatial configurations amidst distracting background information); spatial visualization (piecing together objects into more complex configurations or visualizing and mentally transforming objects, often from 2D to 3D or vice versa); mental rotation (rotating 2D or 3D objects); spatial perception (understanding abstract spatial principles, such as horizontal invariance or verticality); perspective taking (visualizing an environment in its entirety from a different position) (Uttal, 2012). The course of the development of the design idea was presented, discussed and evaluated during the discussions several times. The design project was presented at the end of the course, and the presentation included justification of the concept of the spatial solution in general and in detail, as well as from the point of view of the potential user.

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By giving their presentations, the students with a higher level of spatial ability acquired ability to present the course of the project sequentially, whereas the students with a lower level of spatial ability were able to see the overall picture of the design solution.

5. RESULTS AND DISCUSSION

The analysis of the obtained results of the testing shows an increase in the level of the spatial abilities, as compared to the results of the testing at the beginning of the studies. (Table 1). This indicates that the activities performed during the process have facilitated the improvement of the spatial abilities in students with various levels of spatial abilities.

Table 1. The results of the testing at the beginning of the studies.

Testing	High spatial ability	Medium spatial ability	Low spatial ability
Baseline testing	34.8% n=8	47.8% n=11	17.3% n=4
End-point testing	56.5% n=13	34.8% n= 8	8.7% n=2

Based on the acquired data, it was found out that there was a difference between the median scores of the individual spatial ability tests, the entire group of the students being tested, and the groups of students with different levels of spatial abilities. (Fig.1).

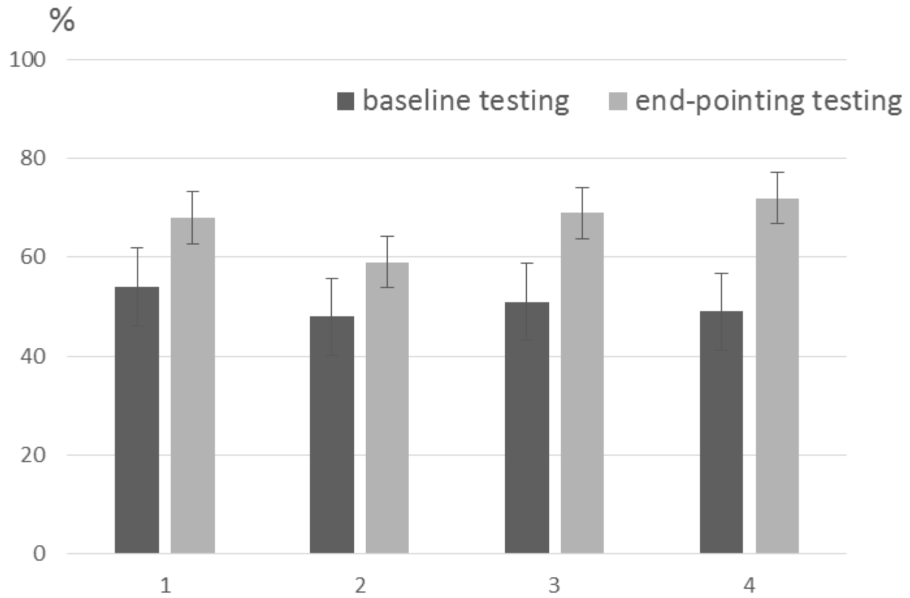

Fig. 1. The median scores of the individual spatial ability tests.
(1 - Spatial Orientation Test; 2 - The Mental Rotation Test, 3 - The Mental Cutting Test, 4 - The Differential Aptitude Test: Space Relations)

The development of the advanced technologies brings about a merger of the virtual and physical space in the rapidly changing contemporary world. By understanding space in its widest meaning, it is possible to use its properties (distance, continuity, integrity, and isolation) to structure the concepts and problems, find answers, and express their interrelations.

Architects and interior designers require spatial thinking: to perceive and analyse the existing space and its components, to create a new spatial object in their imagination, to place the designed new spatial object both mentally and actually in the existing room environment based on thorough understanding of the scale and the fundamental principles of composition.

A technical drawing is a means of graphical communication used by designers, architects, and engineers to share technical information about the object, such as buildings, systems, products, and structures. To present the idea of the project efficiently, clearly and comprehensibly in the graphical 'language of symbols', interior designers require a developed skill of spatial reasoning, as it is frequently described in scientific sources. Nevertheless, study programmes still include this skill indirectly as an “ability” which is necessary to comprehend and solve tasks of Descriptive Geometry when drawing and reading technical drawings. (Contero.M., 2007).

Ferguson (Ferguson, 1992) indicates that graphical engineering drawings are a tool used to materialise the visualisation of the idea of one individual and inform others about it. Thus, it is a form of communication between people with its own standardised regularities and rules in the depiction of a space. Ferguson believes that the best and possibly the only efficient way of learning to “read” technical drawings is to acquire how technical drawings are made. The development and use of the graphics software 3D CAD has reduced the role of spatial reasoning because virtual 3D models are used in designing. As indicated by Cohn, modelling of a spatial object in a computer program involves entry of quantitative data which, without assessing their interconnections through qualitative spatial reasoning, can be used to obtain a spatial virtual model that cannot be implemented or the implementation of which would not be adequate for the needs of the potential user. Spatial reasoning is a tool we can use to assess the surrounding real world, and, what is more, not direct (quantitative) data, but qualitative abstractions of the reality are used in most cases, and spatial reasoning is also necessary in the fields in which the concept of space is a metaphor, for example, in understanding the structure of a document. Cohn notes the quantitative (distance, dimensions) and qualitative nature (mutual arrangement and relationships) of spatial reasoning (Cohn & Hazarika, 2001).

Field indicates that all CAD users will also require a developed ability of spatial reasoning in the future at least for as long as technical drawings are used as a way of graphical presentation of the thought and the idea in the implementation of spatial solutions (Field, 2004).

There are no students who are alike. When starting their studies, each of them has a different level of spatial cognition and skills, which then become the system of reference and the starting point for acquisition of new information, understanding, and type of action when solving their study assignments. A standardised programme and process of studies do not provide equal opportunities for a continued process of cognition and involvement in it. Based on extensive research conducted in early 1980-s, Dr. Linda Silverman concluded that there were 2 conceptually different approaches to learning which she called “auditory-sequential” and “visual-spatial.” Students with more developed spatial thinking -“visual-spatial” learners perceive general concepts better than separate facts. They are able to synthesise and create conceptual schemes by linking concepts into interconnections. Nevertheless, such students often find it difficult to remember formulae or mathematical facts in case they are presented in isolation, without demonstrating the interconnections. “Visual-spatial” students perceive better by seeing than listening. To note the acquired information, they may draw pictures even when listening to an oral presentation. As specified by Silverman, diverse teaching methods, which correspond to diversity of learning, facilitate the development of spatial abilities and imagination, which is a fundamental element of mental activity (Silvermann, 2005).

Traditionally standardised study programmes are mainly based on verbal and sequential presentation of information. There are uniform requirements established for doing tasks. The obstacles caused by such standardised approach in the creation of the study process do not support active involvement or motivation in students.

To support students' motivation to acquire knowledge purposefully, the teacher's ability to make one interested and carry them away is as significant as the choice of appropriate technical tools. The conventional approach to the development of spatial perception is passive, and students learn from demonstrations given by the teacher which mainly address standard models of objects. The theory of Situated Learning envisages that knowledge should be reflected in a context which allows it to be used in practice. The information viewed in a practical context in the process of studies contrasts with the standardised sessions in which students learn general concepts without a context. Understanding of the context with their real future professional career motivates students to perform tasks, make calculations, solve problems, make informed decisions based on understanding, and the process of studies requires social interaction and cooperation (Lave, 1991).

For the acquisition of complex (spatial) skills, the process of learning in students’ groups is more efficient than individual sessions. In a group of students, it is possible to discuss tasks and ways of solving them. Accurate and justified use and presentation of essential ideas and symbols facilitate creative and analytical thinking in students. Use of debate allows students and teachers to clarify ambiguities and assure adjustment of any misunderstood concepts (Alias, 2002).

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