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Analysis on the Influencing Factors of Spatial Learning Effect from the Perspective of Educational Communication

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Abstract. The interaction of the educators, learners and 3D design tools during the classroom-based education process impacts the learning outcome. In order to improve the learners' spatial visualization skills, this paper discussed how the spatial learning outcome is influenced by the three elements such as the educators, learners and 3D design tools in the engineering and design educational fields. According to the results of previous researches, this study summarized fifteen specific factors which influence the spatial learning effect, and established a theoretical framework of the spatial learning influencing factors and corresponding relationship; the purpose was to enlighten the educators on more concern with each influencing element and its interactive function to the educational communication system.

Keywords: Educational communication effect, spatial learning effect, influencing factors, learners, 3D aided design tools, educators.

1. Introduction

Spatial visualization skills have been recognized as a requirement for success in the fields such as engineering, architecture, and visual arts. Researchers have discussed the various definition of spatial visualization, Chaim et al (1988) presented the definition of spatial visualization as the ability to imagine the rotation of a represented object, to visualize the configuration, to transform a represented object into other shape, and to manipulate an object in the mind [1]. Due to this ability plays a key role in these fields. Learners need to receive a variety of trainings to improve their spatial visualization skills in traditional teaching methods, such as making sketches, creating detailed drawings, building three dimensional models and so on. The computing development has enabled the addition of computer aided design software packages such as Google Sketchup, 3DS Max, and other software for depicting three-dimensional objects, and allowed better viewing, validating and understanding the object's components and construction. These 3D aided design instruments are adopted to complement the conventional teaching methods, and also to become efficient instructional tools in engineering and design education.

For this reason, most of the studies addressed the 3D technology effects as enhancing the spatial visualization skills. However, few of them further analyzed specific reason, i.e. which factors influence the spatial abilities improvement and the spatial knowledge acquirement in the education process. Therefore, in order to better develop learners' spatial abilities and improve teaching effect with addition of 3D instruments. According to the three elements of influencing educational communication effect such as educators, learners and 3D aided design tools, this paper summarized fifteen specific factors which influence the spatial learning effect from the results of previous researches. Finally, the study established a theoretical framework of the spatial learning influencing factors and corresponding relationship. This framework aids the educators to comprehend which specific factors influence spatial learning effects in the technology-assisted instruction

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process, especially 3D visualization and interactive functions improve the learners' spatial abilities. These factors enlighten the educators with emphasis on the advantages of 3D representation and learners' application abilities of using 3D technologies, and also take various influencing elements into the comprehensive consideration when carrying out teaching design and activities. This framework further assists teaching and improves the learners' spatial learning effects.

2. Factors that Influence Educational Communication Effects

Learners' learning effectiveness were influenced by a variety of factors in education process, according to Garrison and Shale (1990), they defined all forms of education as essential interactions between content, students and teachers [2]. In the 3D CAD based spatial teaching and learning activities, 3D aided design tools are not only the carrier of learning content, but also the deliverer of spatial knowledge, so this study argued that teachers, learners, 3D aided design tools are the important elements of influencing educational communication effects. Figure 1 presented the three elements and their relationship in the educational communication system, the three influencing elements and their sub-elements are analyzed in details as the following.

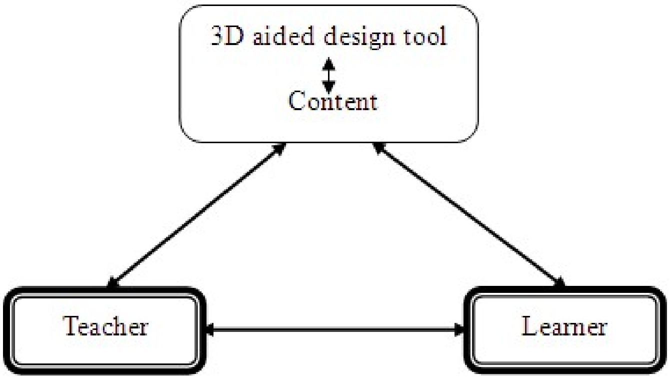

Fig. 1 Composition of Educational Communication System

3. Analysis of Factors that Influence Spatial Learning Effects

3.1. Educator Factors

In design education with addition of 3D instruments, educators need to analyze teaching resources, organize teaching content, design teaching activities, and also transmit teaching information to students in the guidance of teaching methods and with the aid of teaching media. During the teaching activities of training spatial thinking and skills, the influencing factors related to educators can mainly be analyzed in the following four aspects:

3.2. The Effective Integration of Spatial Knowledge and 3D Technology

Mayer and Anderson (1991) pointed out that when the multimedia instruction is designed properly that information encoded in multiple media representations is well integrated and permits cognitively referential processing to happen, it is likely to give result to positive learning effects [3]. Therefore, this requires educators fully recognize the metaphor and function of technologies, integrate spatial knowledge into the human-computer interaction interface accurately, and turn computer-integrated knowledge into some information which can be easily interpreted by learners, so as to improve the learners' understanding and employment of the spatial knowledge.

3.3. Appropriate Teaching Methods

Sexton (1992) found that it is possible to improve spatial visualization skills when the instruction is appropriate and the delivery time is long enough, it could be indicated that appropriate teaching method is one of the important elements of improving teaching effect. For instance, Scribner (2005) found that incorporate instructional methods which address modality learning styles can be beneficial to students' spatial visualization abilities. This study revealed that incorporating tools or methods such as sketching, three-dimensional solid model software, orthographic and isometric projections can enhance the ability to visualize spatially.

3.4. The Supporting and Guiding of Spatial Learning Process

Liu et al (2007) proclaimed that in the multi-representations of complicated materials, learners need to integrate information of different representations to carry out meaningful learning. However, the learners cannot effectively employ multi-representations [4], and they need extra help and support to understand the information. Chen et al (2005) investigated the effects of the virtual real-based learning environment on learners with different learning styles (e.g., cooperative learning, independent learning, guide learning), and the result shows regardless of the learners' learning styles, guiding exploration mode could be beneficial to learners. Mahler's investigation about freshmen major in engineering came up with a similar result. They attest that a teaching technique called mentored sketching has positive influence on improving the students' visualization and sketching abilities. These researches show that guide and support in both virtual real learning environment and traditional classes are very important.

3.5. Spatial Leaning Activities Diversities

Some researchers consider that offering diversified spatial learning activities for learners is vital to improve their spatial visualization ability. Sorby et al (1996) confirmed this viewpoint through a series of computer visualized activities and model operation trainings.

3.6. 3D Aided Design tools Factors

3D aided design technology is an engineering applied tool which integrates lots of spatial knowledge, it plays a vital role in helping learners to understand and construct spatial knowledge. In the engineering and design related education, it is generally acknowledged that the most obvious advantage of 3D aided design tools lies in its interactivity and representational fidelity. Interactivity means it provides the learners natural interaction with the objects to solve the spatial problems, while representational fidelity means that it can express the object's detailed information in the three-dimensional space.

Some researches summarized several important visual factors in the fidelity of 3D environment. First of all, human brains judge the spatial structures and stimulation characterization by making use of the in-depth clues which were processed via the skills like perspective, occlusion, texture, and lighting calculations to simulate a representation with photographic quality. Second, views should be real time updated smoothly so as to provide favorable conditions for the viewers to obtain important information. Third, the moving objects can be represented smoothly and the learners can set a parameter of velocity and adjust motion trail to observe the object's spatial movement. To this point, the research shows that the object's motion is helpful to attract the learners' attention, stimulate their interest and enhance their motivation.

Interactivity supports learners' interactive operation of spatial objects, and it helps to develop their spatial creativity. Through active practice and planned interaction, the learners can process relevant knowledge and skills of spatial cognition into their long-term memory, which helps them to realize their preset goals and the previously acquired information, skills or actions. Therefore, it is vital for the learners to obtaining the spatial knowledge. According to the results of previous researches, interactivity of 3D CAD technology mainly lies in the following five aspects. Firstly, it supports the learners to manipulate objects or components such as move, rotation, scale, etc. Secondly, it supports the learners to create and edit objects interactively and provides them with feedback information immediately. Thirdly, it allows the learners to observe objects from different angles and inner perspective, which helps them to get more realistic images and understand the complex environment better. Fourthly, it provides the learners with different options to display modes (wireframe, transparent, etc.), in order to further observe the objects contours and particular representation effect that are difficult to be achieve in traditional design environment. Finally, it supports the learners to change view layout (front, top, left, perspective, etc.), which helps them to understand the projection principle between the perspective and plan.

3.7. Learners' Factors

The learners begin interacting with the learning content and get different learning effects by their interaction with the media. Some researches show that the learners' computer application ability and learning strategy influence the spatial learning effect, such as previous experience, proficiency level of application interface, problem solving strategies. The details are listed as follows.

3.8. The Previous Experience

The previous experience of computer is an important factor to fulfill learning tasks effectively. Elkerton and Williges (1984) proved that the experience level can account for approximately 25% of the variance in performance at a variety of computer tasks [5]. Moreover, Mayer (1997) analyzed the causes of its importance, as people gain experience with computers, they tend to change the way that they mentally represent computer functions and tasks [5]. This means that the common computer application experience is able to enhance performance with novel computer tasks.

3.9. The Proficient Level of Operating Interfaces

Personal ability of operating and understanding the system interface is vital to the spatial information extraction. Waller (2000) claimed that the efforts made in understanding and applying system interface may, to a certain extent, interfere learners' cognition about spatial knowledge or attention to relevant learning resources [5]. It indicates that only if the learners can control the representation of graphs freely, could they, to some degree, overcome a series of cognitive challenges brought by computer-control graph so as to have active learning behaviors.

3.10. Problem Solving Strategies

Information processing is an active process that involves the use of strategies (Forrest, 2001). And the research shows that different people would use different strategies while solving spatial tasks. Gages (1994) studied the relationships among spatial ability, strategy usages and learning styles of students. The result shows that participants with higher level spatial ability favored holistic strategies, and they combined and shifted strategies more frequently than those students with lower level spatial ability. As problems became more difficult, a majority of the students would use a combination of strategies.

In a word, the interaction of the learners, educators and 3D aided design tools influence to improve the learners' spatial abilities and to achieve the spatial knowledge in the classroom-based education process. According to the three elements and their specific sub-elements, a brief description of the influential factors and sources of relevant viewpoints can be found in Table 1.

Table 1 Corresponding Relationship between Influencing Factors and Their Sources

Influencing elements	**Influencing sub-elements**	**Corresponding to spatial learning influencing factors**	**Sources of views**
Educator	Teaching content and instrument analysis	The effective integration of spatial knowledge and media skills	Mayer & Anderson (1991)
	Teaching method choice	Appropriate teaching methods of spatial learning	Scribner (2005), Sexton (1992)
	Explanation, demonstration of teaching information	Supporting and guiding of spatial learning process	Mohler (2008), Chen (2005), Liu etc. (2007)
	Teaching activity design	Offering the diversities of spatial learning activities	Sorby & Baartmans (1996)
3D aided design tool	Photorealistic visualization	Simulating quality representing effects with perspective, occlusion and so on	Dalgarno, Hedberg & Harper (2002)
		Updating views	Dalgarno, Hedberg & Harper

			(2002)
		Representing objects' movement smoothly	Dalgarno, Hedberg & Harper (2002), Paul N.(2002)
		Supporting the manipulating objects	Dalgarno & Harper (2003)
		Supporting the creating and modification of objects interactively	Morrison (1999), Sykes (2003)
	Interactive manipulations	Supporting the representation and interactive control of 2D planar and 3D perspective	Duesbury & O'Neal (1996), Tory (2003)
		Supporting the observation of objects from different angles	Weiss & Adam (1998)
		Supporting the observation of spatial structure with different display models	Zavotka (1987)
	Computer application ability	The Previous experience	Elkerton & Williges (1984), Mayer (1997)
Learner		The proficient level of operation interface	Waller (2000)
	Learning strategy	Problem solution strategy	Forrest (2001), Gages (1994)

4. Summary

A theoretical framework of the spatial learning influencing factors was generated in the engineering and design educational fields. This framework included the three core elements which contain fifteen specific influencing factors. It could be concluded and recommended that the spatial learning effects were influenced by every actors participating in the education process. The effective spatial learning requires the educators to be more concerned with the integration of spatial knowledge and 3D technology, guiding of learning process, understanding of learners' personal differences and so on. We would also expect that this framework would be optimized or expanded in terms of their actors participating in the interactive learning environment in order to better improve their spatial visualization skills. Furthermore, we would assess the level of effectiveness of these influencing elements through a teaching experiment in the display spatial design course.

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