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Needs Assessment of Spatial Ability Improvement of Students in the Field of Design in Thai Higher Educational Institutions
การศึกษาความต้องการพัฒนาความสามารถด้านมิติสัมพันธ์ของผู้เรียนในสถาบันการอุดมศึกษาไทย สาขาวิชาออกแบบ

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บทคัดย่อ

การศึกษาครั้งนี้มีจุดประสงค์เพื่อศึกษาความต้องการพัฒนาความสามารถด้านมิติสัมพันธ์ของผู้เรียนในสาขาวิชาออกแบบ และศึกษาแนวทางการพัฒนาความความสามารถด้านมิติสัมพันธ์ของผู้เรียนในสาขาวิชาออกแบบ กลุ่มตัวอย่างที่ใช้ในการศึกษา ได้แก่ 1) ผู้สอนจากมหาวิทยาลัยของรัฐบาลและเอกชน โดยการเลือกตัวอย่างแบบเจาะจงจาก 5 ภูมิภาคของประเทศไทย 2) ผู้เรียนในระดับอุดมศึกษา สาขาวิชาที่เกี่ยวข้องกับการออกแบบ เครื่องมือที่ใช้ในการวิจัยได้แก่ 1) แบบสัมภาษณ์ผู้สอนแบบมีโครงสร้าง 2) แบบทดสอบวัดความสามารถด้านมิติสัมพันธ์ โดยการวิเคราะห์ข้อมูลที่ได้จากการสัมภาษณ์ วิเคราะห์ความถี่และร้อยละจากผลการทดสอบ ผลการศึกษาพบว่า 1) มีผู้เรียนกลุ่มอ่อนในสาขาวิชาการออกแบบและมีความต้องการจำเป็นในการพัฒนาทักษะการคิดเชิงมิติสัมพันธ์ 2) การมองภาพไอโซเมตริก (Isometric) ภาพออโธกราฟิก (Orthographic) และภาพตัด (Section) เป็นเนื้อหาที่มีความจำเป็นสำหรับการฝึกมองภาพ การรับรู้ขนาด สัดส่วน รูปร่าง รูปทรง การเปลี่ยนตำแหน่งมุมมองภาพ การเชื่อมโยงภาพ 2 มิติ กับภาพ 3 มิติ และการหมุนภาพในใจ โดยให้มีโจทย์ที่หลากหลาย ตั้งแต่ง่ายไปจนถึงระดับซับซ้อน 3) รูปแบบการเสริมต่อการเรียนรู้ทางทัศนภาพ (Visual scaffolding) เป็นส่วนสำคัญที่ช่วยในการมองภาพ ได้แก่ เส้นประ เส้นกริด เส้นโปรเจคชั่น ตัวอักษร สี และภาพวัตถุ 3 มิติเคลื่อนไหวแบบโต้ตอบ และ 4) มัลติมีเดียประเภทนำเสนอเนื้อหาและการฝึกฝน เพื่อให้ผู้เรียนได้เรียนรู้ด้วยตนเอง เหมาะสมแก่การนำไปใช้พัฒนาทักษะการคิดเชิงมิติสัมพันธ์

คำสำคัญ: *ความสามารถด้านมิติสัมพันธ์ การเสริมต่อการเรียนรู้ทางทัศนภาพ สาขาวิชาการออกแบบ*

Abstract

The purpose of this study was to assess needs for spatial ability improvement of undergraduate students majoring in design as well as provide guidelines for the improvement of their spatial ability. The samples were: 1) instructors from public and private universities sampled from five regions in Thailand by using purposive sampling method and 2) undergraduate students in the field of design. The instruments were: 1) the instructor interview schedule and 2) the spatial ability test. The data obtained from the interview were analyzed to find out frequency and percentage. The result revealed that 1) some samples were found to be students with low competency who needed spatial ability improvement; 2) practice of reading isometric, orthographic, and section views was found to be a key for spatial ability improvement, helping students to learn the scale, proportion, dimension, shape, form and viewpoint or perspective of illustrations, 2D and 3D visualization, and mental rotation through problems with different levels of difficulty; 3) visual scaffolding played a significant role as it could support students' comprehension of illustrations including dashed lines, grid lines, projection lines, letters, colors, and dynamic interactive 3D object; and 4) multimedia with tutorials and drills could support self-learning and improve students' spatial thinking.

Keywords*: spatial ability, visual scaffolding, design field*

Introduction

Spatial thinking is a cognitive skill as well as special characteristic for the creation of architectural design. It is comprised of three elements: concepts of space, tool of representation, and processes of reasoning (National Research Council, 2006). Design learning should emphasize the development of learners' spatial perception through intensive learning activities, abstract thinking for 3D spatial design and scale or direction design, enabling presentation of the meaning of the symbol obtained from the intersection of two geometric forms. Therefore, it is a necessity for learners to understand 3D geometric forms, rotating images mentally and presenting their finished design (Hauptmana & Cohen, 2011; Hegarty & Cohen, 2012; Mitrache, 2013; Stieff & Uttal, 2015). Spatial ability is an intelligence that reflects an individual's ability to critically analyze and understand spaces. One with this critical thinking skill can think visually and learn well through images. According to Gardner (1993), one's spatial ability can be enhanced if he or she is appropriately promoted. Similarly, it is possible for learners with low, middle, or high learning competency to develop better spatial ability (David, 2011; Meneghetti, Beni, Gyselinck, & Pazzaglia, 2013).

Thai higher educational institutions' admission system incorporates a variety of admission methods. By such methods, students are admitted based on their probability of leaning success in the field. As a result, some admitted students are found to have low capability in some specific skills, and not meeting the standard criteria. The design of learning activities incorporated into scaffolding can support the enhancement of skills as required by the determined learning objectives and promote self-directed learning among students which helps them meet standard criteria of a program. Learning experiences through the designed learning activities can be meaningful to learners as they can spend fewer hours in classrrom learning (Lai & Hwang, 2015; Lee & Kolodner, 2011). Previous research reveals that the goal-based scenarios or goal-based learning can enhance learning acheivement due to subjects learning after case-based reasoning. Specially designed learning strategies and theoretical practice could enhance learners' spatial thinking (Feng, Spence, & Pratt, 2007; Hespanha, Goodchild, & Janelle, 2009; Ladley, 2010). Research evidence reveals that spatial ability is malleable and can be improved by intensive training. According to Sorby (2001), learners having achieved below average on standardized measures of spatial ability could improve their mental rotation, spatial visualization, and perspective taking skills once provided with training in 3D visualization, in the 3D blackboard module, in the web-based tutorials (Wang, Chang, & Li, 2007), virtual reality (VR) in virtual environments (Hauptmana & Cohen, 2011), solving spatial visualization problems involving orthographic projections drawing, reflections, rotations, and cross-sections of three-dimensional solids (Sorby, 2011), the 3D-item multiple choice test (Cohen & Hegarty, 2012), video game (Akinlofa, Holt, & Elyan, 2014; Feng et al., 2007; Uttal et al., 2013a), imagery strategy and visuospatial working memory (VSWM) in spatial text processing (Meneghetti et al., 2013), and application of interactive animation to virtual solids (Cohen & Hegarty, 2014).

Apart from in-class activities as well as a variety of training methods aimed at improving spatial skill, educational games are an alternative for spatial skill improvement. Basically, a game needs to be conducted based on three qualities: enjoyment, learning, and usability (Ak, 2012; Garris, Ahlers, & Driskell, 2002; Quaiser-Pohl, Geiser, & Lehmann, 2006). However, a game user needs to control extraneous variables to validify learning outcomes (David, 2011). Also, adaptive educational hypermedia or AEH is an efficient alternative (Akbulut & Cardak, 2012).

In this research, learning status as well as needs for the spatial skill improvement of students majoring in design or related in Thai higher educational institutions was investigated to discover appropriate educational technology as a tool used for the improvement of spatial skill that corresponds to current learning contexts. Learning models with an integration of visual scaffolding strategy supplementing learners with easy-to-use exercises that learners could easily access are related to learning acheivement and learning topics. In addition, the flow of learning activities needs to meet the levels of learners, which are generally different.

Research Objectives

1) To assess needs for spatial ability improvement of undergraduate students in the field of design

2) To investigate possible guidelines for spatial ability improvement of undergraduate students in the field of design

Research Methodology

This study used a descriptive research methodology. The data collection is conducted by using qualitative and quantitative methods with instructors and undergraduate students. The population were instructors from 57 institutions and 17,514 undergraduate students in the field of design, e.g. architecture, interior design, and product design. Two sample groups were selected by purposive samplings: 10 instructors in the field of design, e.g. architecture, interior design, and product design, and 393 undergraduate students in the field of architecture. The scope of the research was devided in two phases as following:

Phase 1

The sample group was selected by purposive sampling based on the qualifications. The sample group were 10 instructors who taught in public and private institutions from five regions of Thailand. They were university lecturers who taught basic drawing courses or related; or published research or textbooks in related fields; or had an academic title or a doctoral degree in any fields related to spatial studies or design. The numbers of the participants which were grouped by their regions and institutions are shown the Table 1.

Table 1. Thai higher educational institutions which were investigated (November 2018- December 2019)

Regions	Public Institutions	Private Institutions
Northern Region	1. Rajamangala University of Technology Lanna (RMUTL)	
Central Region	2. Chulalongkorn University (CU) 3. Naresuan University (NU) 4. King Mongkut's Institute of Technology Ladkrabang (KMITL) 5. Silpakorn University (SU)	6. Rangsit University (RSU) 7. Kasem Bundit University (KBU)
Eastern Regions	8. Burapha University (BUU)	
Northeastern Regions	9. Mahasarakham University (MSU)	
Southern Region	10. Rajamangala University of Technology Srivijaya (RMUTSV)	

The research instrument included an instructor structured interview which had five sections of questions: 1) the current status and problems of instruction and curriculums, 2) students' current status and problems, 3) the current status and problems of instructional activities, 4) the current status and problems of learning media and resources, and 5) the current status and problems of learning assessment. Data were collected through individual interview set up via in-person interview or phone interview. The interview duration was approximately 1 hour per interview time.

Phase 2

Students were undergraduate sampled purposively, using Taro Yamane's formula. The population were 17,514 undergraduate students in the field of design or related in Thai higher educational institutions who never enrolled in a basic drawing course. The 5% allowable error of such population number was 392, and the total samples were 393 undergrauate students of architecture studying in private institution in the central region of Thailand in term 2/2018 and 1/2019.

The research tool was a spatial ability test for cross–section entitled 'Santa Barbara Solids Test' (Cohen & Hegarty, 2012, 2014) with 30 multiple choice questions.

Research findings

1 Instructor Interview Findings

From the depth interview with the sampled instructors who teach basic drawing in order to see the needs in the development of spatial ability among learners in the field of design in the higher education institutions, the findings were presented as follows:

1.1 Current Situations and Problems in the Curriculum and Teaching

All instructors teaching the basic drawing course agreed that spatial ability was essential in the study of all compulsory courses required by the curriculum since students learn the lessons through visualization, interpretation, and presentation.

Problems in the curriculum and teaching of spatial ability found by 90% of instructors were as follows:

1) There were different levels of students. Weak students were not likely to understand spatial relationships, volume and quantity, space, section, as well as relations between object's sides. Instructors, therefore, had to select proper learning activities suitable for different levels of students.

2) Time was limited. The contents in the basic drawing course were generally divided into various topics such as using equipment, isometric and orthographic drawing, section, unfold pattern, auxiliary view, and reflection. Each topic would be taught only once, except for orthographic drawing and perspective. In order to solve this problem, instructors had to assign the drawing tasks which could be done within class hours, and there would be no homework assigned to students.

In addition, 30% of the instructors also revealed that the proportion between instructors and students in each institution was not appropriate. The number of students in one group was 10 – 140 persons. The proportion of instructor to students should be 1:8 in order that each student would receive enough feedback from the instructor. This problem could be solved by recruiting more instructors.

1.2 Current Situation and Problems in Students

All instructors agreed that not all students possessed sufficient spatial ability for the study. The main reason lies in the admission process which could lead to a mix of students with different levels of spatial ability. The admission aptitude test tended to filter in all students who had ability to study, and the test emphasized theory rather than a practical skill like drawing. Therefore, students who went to cram school and received extra tutorial would do well in the exam, but if their drawing skill was evaluated, the score might not be good. Furthermore, in the assessment of visual ability, the multiple-choice test was employed, and this type of test could not really classify students. The problems found are as follows:

1) 50% of the students could understand the lesson well while 5-10% of the students were weak students who needed more visual skill practice. Most instructors solved this problem by arranging a make-up class for the weak students, yet there was still a limitation in terms of time since an instructor had to deal with a lot of weak students one by one.

2) It was found that students could neither convert 3D images into 2D nor understand complex section models leading to a failure in completing all assignments within time as well as having low assessment scores. In addition, each lesson was quite relevant. If students did not understand one topic, they would have difficulty in studying other topics.

There are various solutions to such problems as shown below:

1). Instructors should counsel their students both inside and outside the classroom.

2) Learning activities which might help improve students' skills should be implemented. These activities were, for example, using chalkboard to brainstorm, assigning more homework, using a sketchbook, and giving students a second chance to correct their work.

3) Instructors might employ effective teaching techniques such as giving students a step-by-step drawing demonstration, showing good drawing examples, as well as using authentic models or real objects.

1.3 Current Situations and Problems in Learning Activities

The teaching methods and techniques as well as the problems shared by the instructors teaching basic drawing lie in the following topics: 1) 3D image visualization from 2D image (plan, elevation, section), 2) perception of size and proportion, and 3) mental rotation.

1) Teaching the visualization of 3D images (plan, elevation, section) from 2D images

The teaching methods employed by all instructors were 1) lecture, 2) showing examples of simple 3D images as well as the projection lines for the students to draw the top view, front view, and side view, and 3) drawing demonstration, and 4) project assignment.

Teaching techniques to increase students' understanding

1) Using geometric models with different colors on each side, and 2) using tasks with different levels of difficulty.

Obstacles

1) Students' readiness in terms of equipment

2) Students' collaboration

3) Students' ignorance and lack of practice and time constraint

2) Teaching sizes and proportions

The teaching methods employed by all instructors were 1) Giving lectures, 2) Showing examples of objects with different sizes and proportions, 3) Using a scale ruler to measure the minimizing and maximizing scale of an object, 4) Using grid lines along with the image and asking students to count the grids, and 5) Assigning projects.

Teaching techniques to increase students' understanding

1) Using real objects in the measure work, and 2) Using tasks with different levels of difficulty

Obstacles

1) Students' readiness in terms of equipment

2) Students' collaboration

3) Time consuming in terms of model creation

3) Teaching mental rotation

The teaching methods employed by all instructors were 1) Giving Lectures, 2) Showing examples, and 3) Assigning projects which require students to practice mental rotation using projection from the examples

Teaching techniques to increase students' understanding

1) Using 3D images, 2) Assigning students to create their own model, and 3) Using tasks with different levels of difficulty.

Obstacles

1) Students' readiness in terms of equipment

2) Students' collaboration

3) Students' worry about their drawing formats

1.4 Current Situations and Problems in Learning Media

Learning materials and media, e.g. worksheets, models, blackboard, VDO clips, visualizer, posters, multimedia, PowerPoint presentations, and real objects, were employed by all instructors in lessons of measuring. In addition, only one instructor from all had used multimedia learning materials in their classroom as supplementary learning sources as demonstrated in Figure 1.

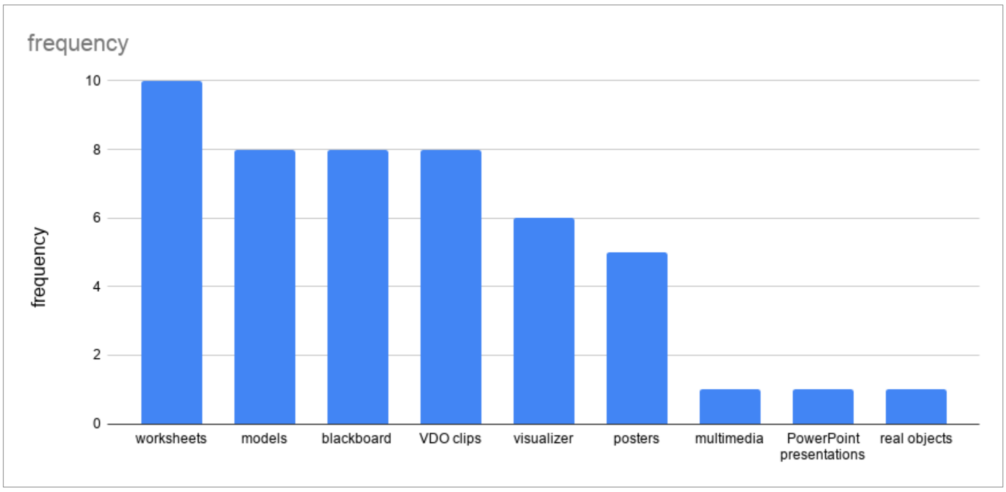

Figure 1. Types of learning media implemented in the classroom sorted by frequency of use

1.5 Current Situations and Problems in the Evaluation and Assessment

The evaluation method employed by all instructors (100%) was the criterion-referenced evaluation by considering the total score from both practical and theoretical sections. In addition, it was found that the evaluation of practical section of 90% of the institutions would be instructor-based, while only 10% of the institutions employed peer-based evaluation with the aim to promote peer scaffolding.

2 Results from the Students' Spatial Ability Test

After implementing the spatial ability assessment test called "Santa Barbara Solids Test: cross-section test" with 393 samples who had not yet enrolled in the basic drawing course, it was found that there were 80 weak students (20.36%) whose score did not exceed 50% and there were 313 strong students (79.64%) whose scores were above 50% as demonstrated in Figure 2. The results indicated that the number of students who needed improvement in the spatial ability was related to the data received from the interviews with instructors.

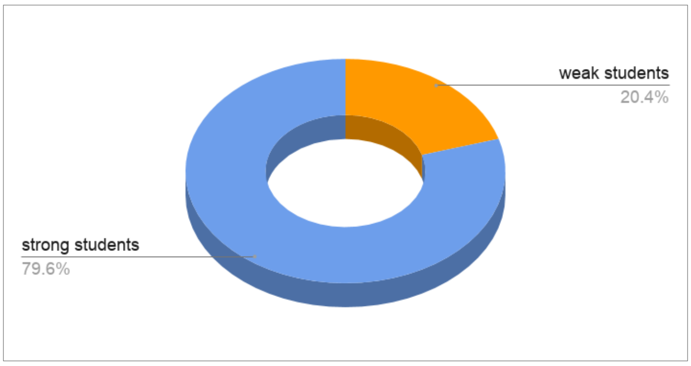

Figure 2. Proportion of strong and weak students categorized by the test

Conclusion and Discussion

From the study of the needs in the development of spatial ability among university students in the field of design through interviews with instructors and student evaluation using Santa Barbara Solids Test: cross–section test, it was possible to conclude that:

1) The contents related to the spatial ability involved various topics, namely 3D image visualization from 2D image (plan, elevation, section), perception of size and proportion, and 3) mental rotation. The instructors employed various learning media in the classroom, yet there was a lack of multimedia which could assist students with different learning abilities. Furthermore, from the investigation of course materials, it was found that visual scaffolding was a suitable learning media which promoted students' spatial ability.

2) There existed weak students. Some of these students struggled yet graduated, while some resigned from the university leading to educational wastage.

From a review of literature, it was found that weak students should be informed about the aims and the main contents of the course in order to make the course meaningful and purposeful. In addition, the tasks given to the students should promote critical thinking and problem solving. Instructors should also provide students with feedback and the opportunity to correct their work in order that they could be proud of their achievement and continue to improve themselves. This is supported by Thorndike's connectionism stating that students' improvement was based upon the law of readiness, the law of exercise, and the law of effect (Karadut, 2012).

The researcher, therefore, proposed some guidelines for the development of courseware which would promote students' spatial ability.

1) The contents of the course should focus on isometric projection, orthographic projection, as well as section so that students would gain more understanding about the perception of size, proportion, shape, changes in projection, relation between 3D and 2D images, and mental rotation. In

addition, the contents should be arranged in order of difficulty. The students should start with simple geometric models and then move on to other higher levels of difficulty. Considering teaching methods, the instructors should scaffold the students by giving clear directions and examples. In addition, each drawing skill should be taught separately, each with various methods. Finally, the students must be assessed to measure their improvement.

2) The Visual scaffolding is an essential part in the explanation of 3D visualization which helped students to see the relation between each position in 2D image and 3D image. The visual scaffolding included the use of projection lines, colors, grid line, letters, dashed lines, and 3D images. In this case, the researcher suggested the use of authentic 3D objects in replacement of 3D images since students could have a physical contact with the objects as shown in Figure 3, 4, and 5.

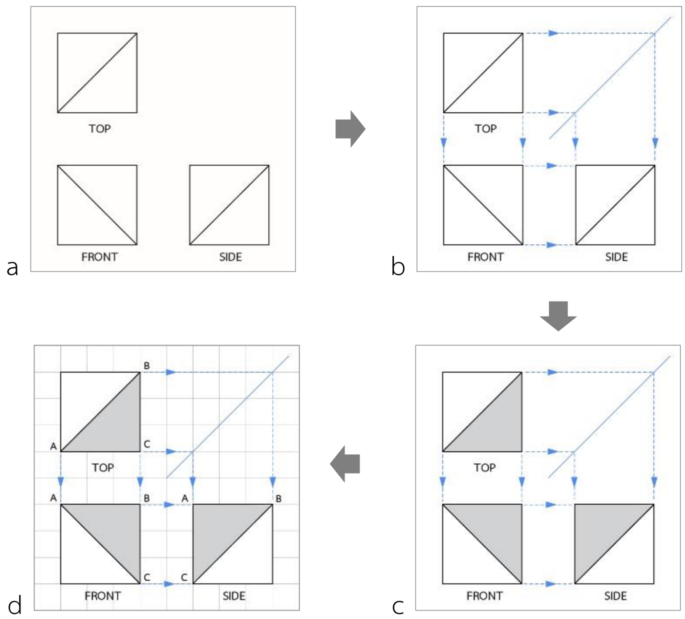

Figure 3. An example of visual scaffolding for the visualization of 2D images

Figure 3 exemplifies the visual scaffolding for 2D images. Picture ‘a’ demonstrates the top view, the front view, and the side view of an object; Picture ‘b’ was similar to ‘a’ but with projection lines added; Picture C contained images of the object with color on one side; In picture ‘d’, grid lines and letters were used to indicate the positions. This visual scaffolding helped students to understand the scale and size in the positioning of images in design.

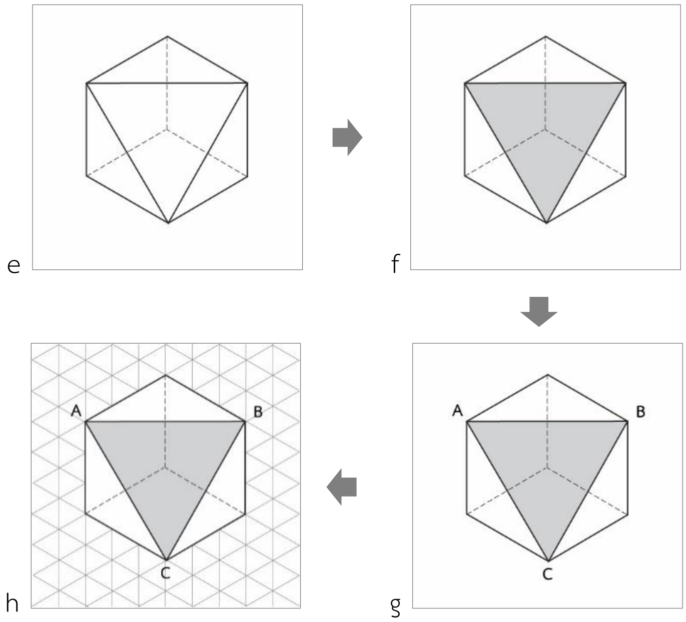

Figure 4. An example of visual scaffolding for the visualization of 3D images

Figure 4 represented isometric images in which picture ‘e’ presents the use of dashed lines to indicate hidden edges or sides of an object. Picture ‘f’ shows the use of color on an inclined plane appearing on the top view, the front view, and the side view. In picture ‘g’, letters were used to indicate each angle. In picture ‘h’, the isometric grid lines were added and used to measure the scale and proportion of an object.

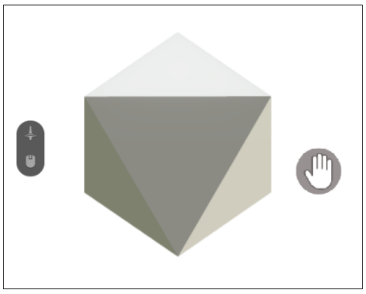

Figure 5. Visual scaffolding for the visualization of 3D image using an authentic 3D object

According to Figure 5, an authentic 3D object was used in replacement of a geometric paper model. This authentic 3D object presented the same image of the object as shown in Figure 4 but with more quality in the sense that students could touch and rotate the object to see it from different angles.

3) There should be an implementation of multimedia with tutorials and drills so that students could learn by themselves on any available device such as computers, tablets, and iPads without being constrained by time. In addition, there should be tests which provide immediate feedback to students as well.

Further Research

In the field of design, the improvement of learners' spatial ability was supported through an application of AutoCAD, drawing software, which could help learners to recognize 2D images in isometric, orthographic, and section views and 3D images. However, the foundation courses available for first-year students emphasized the practice of visual recognition. In spite of the fact that drawing courses were available in all institutions, and out-of-class activities were supplemented for learners with low competency, none of the institutions applied basic drawing lessons to the development of their design lessons with visual-scaffolding exercises that could improve the learning skills of those learners in presence of learning technology that allows all learners to access useful information. Therefore, it is possible for further studies to emphasize multimedia learning models that could promote learners' visual recognition to improve their spatial ability.

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