A Study of Course Design on the Spatial Abilities of Engineering Technology Students

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Abstract:

Spatial visualization ability has been known as an important factor in engineering technology education in recent decade. A course focusing on how to increase spatial visualization ability may be helpful to the students that failed in their engineering graphic or machine design courses. This research is going to investigate the perceptions and performances of the technology students on spatial ability and to examine the possibility and the approach to design a remedial course in improving the spatial visualization ability of technology students.

Introduction

To engineering or engineering technology students, especially in civil, construction, mechanical, manufacturing, and architecture fields, Technical Drawing is normally a required course to be taken in the first academic semester no matter in a two-year community college or a four-year university. It is a basic but important course. In my own teaching experience, about 15% of the students received a grade lower than C- each semester in this class, which blocked them from taking the next major courses according to the department's rule.

In recent years, research on spatial visualization ability has gained more and more attention. This is the ability to mentally manipulate 2-dimensional and 3-dimensional figures (Ozer, 1987). The ability to design is always an important aspect of engineering technology education (Alias, Black, and Gray, 2002, Yue, 2008). Because students in engineering (or engineering technology) majors are required to use spatial reasoning and visualization in designing, some researchers believe that engineering students with good spatial visualization ability also do well in their technical drawing or design courses and professional work in the future (Hsi, Lin, and Bell, 1997). Furthermore, the spatial visualization ability can get improved by certain method (Zhang and Salvendy (2001).

Therefore, a course or an instruction about how to increase spatial visualization ability may be helpful to the students that failed in their engineering graphic or design courses (Martin-Dorta, Saorin, and Contero, 2008; Yue & Chen, 2001). To build a design of spatial strategy instruction for engineering technology (ET) students and identify the efficiency of the course will be my research main goal.

Literature Review

Spatial visualization and spatial orientation are two major spatial factors which are always mentioned together as "Spatial ability" (McGee, 1979; Vandenberg, 1975). The first term is used interchangeably or has been combined into the broader terms of "visualization" and "spatial ability" (Braukmann, 1991)The term "spatial ability" also has many definitions which makes it difficult to be precise about its meaning. Nonetheless, spatial visualization ability is a subset of spatial ability - one of the factors of human intelligence structure (Alias, Black, and Gray, 2002).

Spatial reasoning and visualization have been used widely in engineering, such as designing of building of constructions, assembling the automobile parts, or laying out circuit designs (His, Linn, & Bell, 1997). They can be used to serve as a communication layer between data and user to support decision making as external artifacts. For example, an engineering drawing can convey the information—geometry, dimensions, materials, etc— to the manufacturing from the design engineer (Colin et al., 2011).

A recent survey from the Engineering Design Graphics Division of the American Society for Engineering Education (ASEE) concluded that the "ability to create 3-D solid computer models" and the "ability to sketch engineering objects in the freehand mode" were the two most important graphical communication outcomes for engineering students (Barr, 2004). Some authors have concluded that these skills also are related to spatial ones (Peters, Chisholm, and Laeng, 1995; Alias, Black, and Gray, 2002). Alias, Black, and Gray (2002) also suggested that there could be a relationship between an individual's spatial ability and their ability to use solid modeling software.

There are several popular methods to test the spatial skills. The first method is Mental Rotation Test (MRT), a holistic approach which can test the ability to rotate, in imagination, quickly and accurately two- or three-dimensional figures (Peters, Chisholm, and Laeng, 1995; Martin-Dorta, Saorin, and Contero, 2008; Yue & Chen, 2001).

The second one is Paper Folding Test (PFT), which is classified as an analytical spatial test but do not consistently find significant sex differences (Peters, Chisholm, and Laeng, 1995). Next, Martin-Dorta, Saorin, and Contero (2008) talked about Differential Aptitude Test-Spatial Relation subset (DAT: SR), which can test the ability to imagine rotations of objects or their parts in 3-D spatial by folding and unfolding.

Computer aided design software has also been used to approach the spatial visualization ability tests. A 3-D CAD model built by Teamcenter VisView Professional (Siemens PLM Software) was applied to compare with a conventional engineering drawing to investigate differences in the visual-cognitive process contributing to the performance outcome (Colln et al., 2011). AutoCAD drawings were used in most researchers' tests (Martin-Dorta, Saorin, and Contero, 2008; His, Linn, & Bell, 1997; Peters, Chisholm, and Laeng, 1995; Yue & Chen 2001). Moreover, Google SketchUp, which can be downloaded free from Google's official website, was chosen to be used at a spatial strategy course at La Laguna University, Spain (Dorta, Saorin, and Contero, 2008). Exercises based on practice with this modeling tool had a measurable and positive impact on students' spatial abilities, which were measured by both MRT and DAT: SR tests.

From the research results, it looks that spatial visualization ability plays a necessary role to solve problems in engineering related areas that requires spatial strategies. And the results of

the spatial ability instruction showed the improvement of the students by the researchers' post-tests (His, Linn, & Bell, 1997; Dorta, Saorin, and Contero, 2008). Therefore, a better understanding of this ability should be potentially beneficial to the engineering education and profession (His, Linn, & Bell, 1997; Peters, Chisholm, and Laeng, 1995).

Methodology

The perspective is to find out the perception of existing technology students on spatial ability, to examine if an instructional course is required and needed to recent and future students of engineering technology, to study how students learn and improve their spatial abilities.

My research involves a course design which means the students of the course cannot participate my research in recent study. Therefore the focus of initial research was on the identification of spatial visualization ability of current students of engineering technology.

Participants

In this trial study, there were five male students from mechanical engineering technology major received interviews. The data collection method I applied here was convenience sampling (Berg, 2009). The reason I chose these five persons because they had a lot common attributes. 1) They were all White/Caucasians. 2) All of them came from Indiana State. 3) Most of the participants were about same age. Two students were 22 years old, two other students were 23 years old, and the last one was 28 years old. 4) They were in similar study level. Four students were juniors (or qualified to be a senior after this semester based on their credits total numbers) and one student (the 28 years old) was a senior who will graduate this May and continue his study in graduate school. 5) They had learned similar required courses which need to apply their spatial abilities. All the participants claimed that they could use more than one kind of 3-D

modeling computer software. Also they mentioned that they had already taken the course of Technical Graphics Communications and had taken at least one class which required mechanical design by using 3-D modeling computer software.

Methods

This research will be conducted through in-depth interview and participant observation. Participants' observation will be recorded from the routine class project discussions, class performance, and group design presentations. There was no observation in recent study yet.

In initial research, five MET students were interviewed separately in a one week period. The main topic of the interview questions was to identify the perception and performance of the students on spatial ability. The data collection method I used was the standardized interview (Berg, 2009; Maxwell, 2005). But both close-ended and open-ended questions were listed in my questionnaire. Seven are Yes or No questions, two are descriptive answer questions, and two of them are multiple-choice problems.

The interview questions inquired the knowledge of spatial ability and the example questions of testing spatial ability. I printed out the sample test problems on the paper previously. There was no time limit on thinking of the two problems. And I did not tell them the right answers' number(s). Except reading and solving sample test problems part, the interview was face-to-face talking.

Data Analysis

The data included in this study were drawn from a 1-week period in which I interviewed with mechanical engineering technology students. The five talks last around 8-12 minutes each.

One student used less than 30 seconds to give the answers for the sample test problems. Two students spent about one minute. And the other students spent between one to two minutes.

As a pervious engineering graphics course teacher, I am curious about how much students know about spatial ability and how they apply their course knowledge and learning to design their project. Also I want to see if they can solve the simple spatial ability test questions correctly as junior or senior engineering technology students. The students' ideas and thinking of spatial ability are very helpful and essential to design a course to help future students to improve their spatial abilities, so I tried to take this chance to collect more information from students. The questions I might need to add in the future interview will be the grade of their engineering graphics course and how to evaluate personal spatial ability.

For the initial interview questions, seven are Yes or No questions, two are descriptive answer questions, and two of them are multiple-choice problems. I recorded all the results and classified them. Firstly I drew an extra 5 by 11 grids table on the bottom of my printed original questionnaire. And I wrote letter A-E at the top to represent each participant by interview time order. Then I started to listen to my records one by one. For the Yes or No question and multiple-choice question, I just marked the answer in the correspondent grids. For the description questions, I stopped the recording each time to make sure I wrote down all the keywords. At the end I did simple calculation and made three tables to show my classifications on Excel Spreadsheet. All the tables will be presented in the results in the next section.

Results

Since my research involves a course design, there was no actual result from the participants in the class I designed in my initial study. However, five students got interviewed and the questions were about identifying their knowledge of spatial ability and their suggestions in adding an instructional course to improve spatial ability (see appendix for interview questions). I think it might be more helpful in sampling if I know their GPA.

There were three main themes found from my results. Other small themes found will also be discussed at the end of this section.

Theme 1 – The conflict between having taken existing 3D modeling graphic courses and presenting low spatial ability in solving sample test problems.

All the students (interviewees) had already taken more than one machine design course and had experience in working with at least one kind of 3-D modeling computer aided engineering software. There were two sample test problems given at the end of each interview. Both were multiple-choice questions and no time limit to solve those problems. Based on my results, 20% of the participants chose the correct answer for sample question 1 and 80% of the students chose the right answer for sample problem 2 (See *Table 1*). There was possibility that I did not tell them the multiple-choice problems given could have more than one correct answer. Some students argued that they would get both right answers for problem 1 if they were told they can choose more than one answer after the interview.

I also agreed there was a chance that the correct results percentage may have increased in that case. However, there was no way to detect the truth at that time.

Table 1 Spatial Ability Sample Test Problems Results

	Correct percentage
Sample problem 1 (A, B both correct)	20% (60% got A only, 20% picked wrong answer)
Sample problem 2 (A is correct)	80%

Theme 2 – Similar examples and suggestions from participants

There were interview questions asking students to give examples in performing their spatial abilities and suggestions to practice and improve their spatial abilities. All the answers that I received were very similar (See *Table 2*). Students said they learned, performed, practiced, and improved their spatial abilities from the courses offered and required from the mechanical engineering technology department; such like technical drawing, machine design, and etc. Only one student, who had industrial experience, mentioned he also improved his spatial ability from his internship job. I may combine the two questions in future interviews. And the question of how spatial ability affects your life and study will be added in.

Table 2 Ideas of Spatial Ability Performance and Training

List experience of performing your spatial ability	In mechanical design class and graphic drawing class
Describe how you learned and practiced this skills	Graphical drawing class, mechanical design class, internship
The length of spatial ability training	A week(1), two weeks(1), a semester (3)

Theme 3 – Is spatial ability still too abstract to students?

Only one student could interpret the meaning of spatial ability in all the five interviewees (See *Table 3*). All the other students expressed that they have experience on performing their spatial abilities after my explanation of its definition. I am not sure and cannot tell how much they really understand in this case.

Table 3 Recognition and Identification of Spatial Ability

	Yes (percentage)	No (percentage)
Students heard of Spatial Ability before	1 (20%)	4 (80%)
Students have experience in performing their spatial skills	5(100%)	
Believe spatial visualization ability affect Math and Engineering design	4(80%)	1(20%)
Believe gender is a factor in spatial ability	2(40%)	3(60%)
Believe spatial activities affect males different than females	3(60%)	2(40%)
Believe age is a factor in spatial ability	5(100%)	
Agree training can improve spatial ability	5(100%)	

Others (See *Table 3 also*) – Everyone agreed that there was possibility to improve their spatial ability by training. Two people said a whole school semester will be good for training and three people said one to two weeks. I think my question needs to be changed to how many credit hours instead of how long. Some students told me they got confused to describe the length. Only one student does not agree spatial ability has relation with success in mathematics and engineering works.

Discussions

Based on the recent interview results, we can see spatial visualization ability has not become a common item to college senior students even though they had experiences in performing their spatial abilities. However, after the explanation of the definition, everybody showed that they knew what it is about and have personal ideas in improving this ability. And every participant agreed that certain training could improve the spatial ability. Only one student did not think the spatial ability could affect the performance of mathematics and engineering design work. There is a need to add a question in the future which can be "Do you think better spatial ability can benefit your life and study? If so, please sample it. If not, why?"

Also I did not ask their GPA or grades in the Technical Graphics Communications course. I think the grade can be used as one of the standards to pre-judge their spatial abilities. And it could be compared with their answers of the spatial ability sample test problems. It might be added in the future interview questions. However, the interviewees might not want to disclose their grades if they had bad scores. And I do not want to collect fake results to affect my analysis. I could let them choose to tell me or not.

What makes me really surprised is the low percentage of correct answer of sample problems since both questions are very basic examples. As junior / senior ET students who already took more than one design course and can use more than one 3-D computer software in design work, their spatial abilities might still need to be improved to help their professional career in the future. I even think there is a possibility to design an advanced course in improving senior students' spatial abilities.

In my initial study, I did not interview any female students or freshmen. They should get interviewed in the future to help to identify the factors during spatial ability performance. I also did not get a chance to interview any lecturers. I believe the results from professionals will be interesting and I expect to collect more ideas from them.

Conclusion

Spatial visualization ability is not a new term; however, more and more people think it can be improved by certain training (Lin, and Bell, 1997; Alias, Black, and Gray, 2002). There are also researches focusing on the gender in academic performance (Peters, Chisholm, and Laeng, 1994; Boyle, Neumann, Furedy, and Westbury, 2010). The research in identify the effects of instructions of spatial abilities in improving performance in mathematics and engineering studies received more attention (Braukmann, 1991; Alias, Black, and Grey, 2002; Peters, Chisholm, and Laeng, 1995; Martin-Dorta, Saorin, and Contero, 2008). Based on previous researches, my research tries to find the approach to design a remedial course in improving the spatial visualization ability to engineering technology students and helping the students that failed in their engineering graphic or design courses. The benefit of this course to the students might be a reduction in the chance of failing an engineering technology course. Therefore they will be encouraged to persist in their current major study.

My current study results from a one-week interview with five students showed there is a need to have an instructional course in spatial ability to the students of engineering technology. Our senior students were not good at the sample test of spatial abilities even though they took the existing graphical drawing courses and practiced in design projects. Limitation in my interviews are lacking of female students, freshmen, lecturers. At least 10% of the interviewees should be

female students. Also the interview questions need to be more clarified. Some sensitive questions such as GPA inquiring might be helpful to the research but the interview techniques are also required.

I hope the development of spatial abilities can be achieved effectively through specific training from further research results. And I'd like to collect and observe the useful skills in improving spatial ability from relative curriculums in ET departments. On the other side, I need to examine and identify if the remedial course can provide a significant gain in spatial abilities to all the participant students. And more interviews and surveys with more students and teachers might present more efficient educational skills and strategies to improve the spatial ability to the students in ET departments.

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APPENDIX

- Sample spatial visualization ability test problems and key from *Purdue spatial visualization test* (Guay, 1976) (90 pages)
- **Interview questions (students):**

1. Have you heard about spatial visualization? If so, could you describe it? If not, I will explain it.
2. Do you have any experience of performing your spatial visualization skills? If so, please give examples.
3. And could you describe how you learned and practiced these skills?
4. Do you believe spatial visualization contributes to success in mathematics and engineering?
5. Do you think gender is a factor in spatial visualization ability?
6. Do you think spatial activities affect males and female differently?
7. Do you think age is a factor in spatial visualization ability?
8. Do you think special training can improve your spatial visualization skills? If so, what kind of training?
9. How long do you think will be appropriate for a fast remedial course in spatial visualization ability?
10. Have you had Mental Rotation Test (MRT) before (See Figure 1)? One example question showing without answer
11. Have you had Differential Aptitude Test—Spatial Relations Subset (DAT:SR) before (See Figure 2)? One example question showing without answer

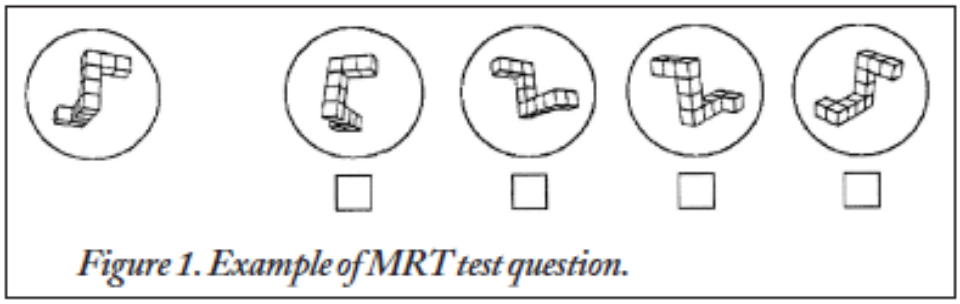

Figure 1. Example of MRT test question.

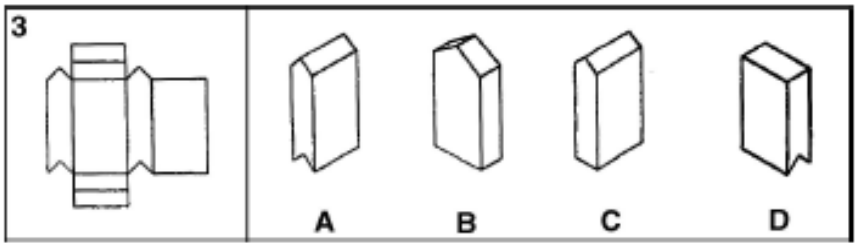

Figure 2. Example of DAT:SR test question.