MULTIMEDIA LEARNING AND ENGINEERING STUDENTS SPATIAL ABILITY

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Abstract: A new multimedia environment engineering graphics is running through today, has been established step by step. An important factor that has been taken into consideration and that has influenced dynamic changes of engineering graphics is spatial ability. The introduction of 3D CAD systems has given additional importance to the necessity of highly developed sense of spatial reasoning.

Engineering graphics courses therefore have embraced both, the advantages of CAD system recent possibilities and the recommendations based on research results of spatial ability.

The first-year students at University of Rijeka Faculty of Engineering, Croatia were tested on spatial ability before and after one semester of engineering graphics course tuition. Two available classical tests, Mental Rotation Test (MRT) and Guay-Lippa Test (VVT), were utilised for the assessment at mechanical engineering, naval architecture and electrical engineering studies both, undergraduate university and professional.

The improvement of student spatial ability has been investigated and analysed after tuition performed in multimedia environment. The comparison of detected spatial ability for different studies has been made, and the relationship between initial student spatial ability and engineering graphics course total accomplishment, has been examined.

The students with higher initial spatial ability found electrical engineering study both, university and professional appropriate and attractive compared with the studies of mechanical engineering and naval architecture.

The gain in scores for the tests administered after in relation to the tests before accomplished engineering graphics course is obvious for all studies and confirmed the development of student spatial ability.

Key words: spatial ability; engineering graphics; testing

1. INTRODUCTION

The shift from traditional contents and modii engineering graphics is taught have initiated in the 1979’s driven by intensive and constant development of new tools offered by the CAD (Computer Aided Design) systems and the associated computer technologies [1-4]. Accordingly, new multimedia environment has been established step by step, among engineering graphics is running today.

An important factor that has been taken into consideration and that has influenced dynamic changes of engineering graphics is spatial ability. According to Miller [5], spatial cognition is the underlying mental process that allows an individual to develop spatial abilities. Sjölinder claims that “One mental ability crucial for navigation, both in the real world and in a virtual environment is spatial cognition” [6].

The introduction of 3D CAD systems has given additional importance to the necessity of highly developed sense of spatial reasoning [7, 8]. Therefore, engineering graphics courses have embraced both, the advantages of CAD system recent possibilities and the recommendations based on research results of spatial ability [9].

This paper deals with the evaluation of spatial ability of first-year students at University of Rijeka Faculty of Engineering, Croatia. The participants belonged to different studies that are performed: mechanical engineering and naval architecture, and electrical engineering studies both, undergraduate university and professional.

In spite of Faculty of Engineering tradition of more than 50 years, the evaluation of initial or acquired spatial ability/skills has been not measured until today. Therefore, the results obtained by means of classical tests for spatial ability are of utmost importance to:

- detect initial spatial ability/skills of engineering students and follow the possible improvement after one semester tuition of engineering graphics, and make the comparison for different studies under consideration,
- examine possible relationship between the measured spatial ability at the beginning of engineering graphics tuition and the achieved total course success.

2. ENGINEERING GRAPHICS COURSES AT FACULTY OF ENGINEERING

In general, engineering graphics courses at Faculty of Engineering are performed through first semester for all studies and levels. The exception is engineering graphics education for undergraduate university studies of mechanical engineering and naval architecture, which runs for first and second semester and includes two courses. First course contents correspond mainly to university electrical engineering study and all professional studies. The second course establishes the foundations for further design courses and processes the 3D modelling in detail. This course was introduced in academic year 2008-
2009., when the curricula were adjusted through the Bologna process [10]. The environment engineering graphics tuition has been performed through, included 2D CAD tools additionally to traditional ones from 1995. The contents regarding 3D modelling and the role of engineering graphics in design process were introduced from the beginning, but the circumstances did not allow the use 3D CAD tools at that time.

The use of CAD tools and the recognised importance of spatial reasoning for engineers, have pointed to the necessity of efficient incorporation of contents that can develop and enhance spatial ability/skills. The considered engineering graphics courses in the first semester represent the combination of traditional contents and tools, 2D CAD tools and the basics of 3D CAD modelling (the later excluded from the course for undergraduate university mechanical engineering and naval architecture studies due to the mentioned additional course). The software package AutoCAD [11] as 2D and 3D CAD tool has been utilised from the beginning. The instruction is running through multimedia environment and it is the combination of traditional/CAD instruction, e-learning by means of software package MudRI [12], and the utilisation of advantages offered by Internet [13].

The multimedia based instruction enables the students to approach the course contents, examples, individual exercises, standards, in a quicker and more effective way, which considerably supports the lecturer’s efforts and additionally captures student’s attention. The most important feature of this instruction is that it makes the communication lecturer-student easy and instantaneous. Traditional contents are based on descriptive geometry necessary to understand the shape description and to successfully move from 3D to 2D environment, and vice versa (Fig. 1), and the contents regarding efficient documenting according to the standards (Fig. 2).

These contents represent the means of indirect development of spatial ability. As well documented in literature, the most effective way for the enhancement of spatial ability/skills is sketching and drawing [14-16]. The design process starts with the sketching to convey the ideas, but in the same time this activity has been proved to enhance capacity for visual imaginary and creativity [17]. The sketching takes important place from the beginning to the end of the considered courses. Based on the literature recommendations [2, 18], the laboratory exercises contain the tasks that are aimed to the improvement of spatial ability/skills (Fig. 3). It was found that spatial visualization ability is directly linked with the usage tendency of sketching and drawing, and indirectly linked with engineering students’ view of professional role of sketching and drawing [16]. Therefore, the contents that enable the student more general insight into today’s role of engineering graphics in design process of concurrent engineering environment, have been added carefully.

For all considered studies the course has 1 hour (45 minutes) of lecture and 2 hours of laboratory exercises, per week, during one semester. The exception is the
course for mechanical engineering and naval architecture professional study that has 2 hours of lecture per week. As regarding the student’s attendance during lectures and laboratory exercises, it is determined at minimum value of 80%.

Practical work in the laboratory is accomplished in a group up to 20 students with the instructor circulating to assist the students. In addition, student has usually 2 homework assignments which are based on the materials presented through the e-learning package MudRI. For laboratory and homework assignments student predominantly use CAD tools, mainly 2D, traditional instruments are considerably less engaged, and the stress is constantly on the freehand sketching.

During the semester student has 2 partial exams when practical problems are to be solved. The exception is electrical engineering professional study without partial exams. Final exam consists of 10 theoretical questions that have to be answered for the limited time. The achieved scores (points) for every required activity during the semester, including the scores for attendance, forms the final course scores.

3. METHODS OF ASSESSMENT

For the measure of spatial ability, two classical paper-pencil tests were chosen owing firstly to their availability, then the frequency of their usage and consequently the possibility of the obtained results comparison. The tests represent the measure for both components of spatial ability: spatial visualization i.e. its component mental rotation (MRT - Mental Rotation Test) [19], and spatial orientation (VVT Guay-Lippa Test) [20].

A short questionnaire about sex and previous experience in engineering graphics was also fulfilled. The students were encouraged to take the participation in both tests, before and after completed engineering graphics course, to get few extra points, regardless of the obtained test scores.

In this paper the question of gender influence on spatial ability that has been broadly elaborated in the literature as undoubtedly existing [21-23] but still not fully explained, and the stress is constantly on the freehand sketching. Due to small population corresponding to naval architecture study both, university and professional, the related data were united with the data for mechanical engineering study.

3.1. MRT- Mental rotation test

This test includes 20 problems to solve in two parts. Each part has 3 minutes for the solution and the parts are separated by 4 minutes. For the 2D representation of 3D object seen from one angle, the participant has to identify two rotated versions of object between four offered representations (Fig. 4). The scores can be achieved from 0-20 and one point is given when both answers/ choices are correct.

3.2. VVT - Guay–Lippa test

3D object is given in isometric view positioned in the middle of the glass-box and below it the same object is represented from new viewing position. The participant has to identify the glass-box corner from which the object is viewed (Fig. 5). The test consists of 24 questions with maximum possible score 24 through 8 minutes. Final scores are influenced by incorrect answers, too.

3.3. Participants

The scores obtained by the students who participated in the tests before and after completed engineering graphics course, and who participated in both tests have been taken into account for analysis.

4. RESULTS AND DISCUSSION

4.1. The obtained test results before engineering graphics course

The results of testing performed at the beginning of semester i.e. before engineering graphics course are provided in Table 1, Fig. 6 and Fig. 7, for different studies and tests under consideration. This table includes mean test scores and the corresponding mean percentage correct, standard deviation, population, confidence level (95%) and significance.

Two findings are obvious: MRT generally represents more difficult task for the students in comparison with VVT, and the students of electrical engineering both, university and professional study, approached engineering graphics course with higher spatial ability than the students of other studies. This trend can be followed in Fig. 6 too, where mean percentage correct of both tests was shown.

In the absence of previous education impact on the development or improvement of spatial ability/skills, the facts that are known and can be helpful for some explanation of the obtained results, are as follows.

The students of both university studies are proved to be more successful during previous education than the students of both professional studies. For university studies the students of mechanical engineering & naval architecture achieved higher total scores than the students of electrical engineering. The students that approach to mechanical engineering & naval architecture professional
Table 1. The results for tests of spatial ability before engineering graphics course

<table>
<thead>
<tr>
<th>Study</th>
<th>University</th>
<th></th>
<th></th>
<th>Professional</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mechanical Engineering &amp; Naval Architecture</td>
<td>Electrical Engineering</td>
<td></td>
<td>Mechanical Engineering &amp; Naval Architecture</td>
<td>Electrical Engineering</td>
<td></td>
</tr>
<tr>
<td>MRT</td>
<td>VVT</td>
<td>MRT</td>
<td>VVT</td>
<td>MRT</td>
<td>VVT</td>
<td></td>
</tr>
<tr>
<td>Mean/ Percentage correct</td>
<td>9,79/ 48,94%</td>
<td>14,31/ 59,63%</td>
<td>10,32/ 51,60%</td>
<td>14,60/ 62,05%</td>
<td>9,53/ 47,65%</td>
<td>12,51/ 52,17%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3,94</td>
<td>7,56</td>
<td>3,91</td>
<td>6,77</td>
<td>3,01</td>
<td>6,78</td>
</tr>
<tr>
<td>Number of students</td>
<td>104</td>
<td>104</td>
<td>73</td>
<td>73</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Confidence level (95%)</td>
<td>0,76</td>
<td>1,45</td>
<td>0,90</td>
<td>1,59</td>
<td>1,52</td>
<td>3,43</td>
</tr>
<tr>
<td>MRT/VVT</td>
<td>p = 0,0000</td>
<td>p = 0,0000</td>
<td></td>
<td>p = 0,0746</td>
<td></td>
<td>p = 0,0021</td>
</tr>
</tbody>
</table>

Fig.6. Mean percentage correct for MRT before and after engineering graphics course

Fig.7. Mean percentage correct for VVT before and after engineering graphics course

study are recorded as previously less successful in relation to the students of electrical engineering professional study.

At the beginning of tuition the poor performance can be noted for mechanical engineering & naval architecture professional study, regardless of the test. The relationship between the tests is determined based on the analysis of differences in mean scores by use of standard statistical procedure of t-test and the obtained significance values p. Significance values that are equal to or less than 0,05 determine the differences that are statistically significant.

The differences between the tests are significant for all studies except for mechanical engineering & naval architecture professional study (Table 1). Furthermore, the correlation values between the mean scores of MRT and VVT spatial ability tests are calculated.

The correlation between the administrated tests scores pointed to a weak correlation for university studies, but moderate correlation for professional studies.

In order to relate initial spatial ability that is assessed before engineering graphics course and the achieved final course success, the corresponding calculated values are analysed for the correlation and statistical significance.

The established correlation between mean final course scores and test scores at the beginning of tuition, varies for university and professional studies from a week mostly positive correlation, to a week and moderate negative correlation, respectively.

The scores for VVT before engineering graphics course are a significant predictor of final course scores at university studies, and the scores for MRT are only significant predictor for electrical engineering university study.

4.2. Students’ spatial ability after engineering graphics course

At the end of semester that included the contents as described previously, the students again took MRT and VVT. Table 2 shows the results of testing and it contains mean and the corresponding mean percentage correct, standard deviation, population and confidence level. The results of mean percentage correct are presented in Fig. 6 and Fig. 7, too. The number of students that were administered the tests was lower in comparison with the number of students that took the tests before the course.

The gain of scores for the tests after in relation to the tests before the course is obvious, regardless of the tests and studies. This can be noticed from Fig. 6 and Fig. 7 too, that present mean percentage correct of MRT and VVT before and after course, respectively.

The gain of scores for tests after the course indicates the overall development of student’s spatial ability resulting after one semester tuition. As in [21] was pointed to, the obtained results have to be interpreted with caution considering various factors that can be hardly identified and that “can influence and be influenced by mental rotation performance”.

Therefore, the gain in scores is not purely the result of one semester tuition, but it is certainly affected by.
### Table 2. The results for tests of spatial ability after engineering graphics course

<table>
<thead>
<tr>
<th>Study</th>
<th>University</th>
<th>Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mechanical Engineering &amp; Naval Architecture</td>
<td>Electrical Engineering</td>
</tr>
<tr>
<td></td>
<td>MRT</td>
<td>VVT</td>
</tr>
<tr>
<td>Mean/Percentage correct</td>
<td>13,36/66,78%</td>
<td>16,98/70,76%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3,91</td>
<td>6,77</td>
</tr>
<tr>
<td>Number of students</td>
<td>90</td>
<td>63</td>
</tr>
<tr>
<td>Confidence level (95%)</td>
<td>0,81</td>
<td>1,25</td>
</tr>
</tbody>
</table>

### Table 3. Mean scores for tests before and after course and gain scores in percentage correct

<table>
<thead>
<tr>
<th>Study</th>
<th>MRT</th>
<th>VVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Gain</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>Number of students</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>Before course</td>
<td>After course</td>
<td>Before course</td>
</tr>
<tr>
<td>University</td>
<td>Mechanical Engineering &amp; Naval Architecture</td>
<td>49,13</td>
</tr>
<tr>
<td></td>
<td>19,74</td>
<td>18,69</td>
</tr>
<tr>
<td></td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>48,48</td>
<td>65,27</td>
</tr>
<tr>
<td></td>
<td>19,75</td>
<td>17,02</td>
</tr>
<tr>
<td></td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Professional</td>
<td>Mechanical Engineering &amp; Naval Architecture</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>7,48</td>
<td>12,09</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>55</td>
<td>73,18</td>
</tr>
<tr>
<td></td>
<td>18,63</td>
<td>17,49</td>
</tr>
</tbody>
</table>

Table 3 shows the mean scores, standard deviation, number of students and the gain of scores for tests after the course in percentage correct. The population in Table 3 corresponds to the number of students that took both tests, at the beginning and at the end of the semester. It is to be noted that some students achieved lower test scores after the engineering graphics course, which can be explained by the diminishing of interest doing the same test for the second time. This is mostly expressed for electrical engineering professional study with small population accompanied by lower scores for VVT test after the course and consequently lower gain scores (Table 3). The highest test gain occurred at mechanical engineering & naval architecture professional study for MRT, but the test gain for VVT is among the highest, too. The reason can be that engineering graphics course for this study includes 2 hours/week of lectures, unlike 1 hour/week for other studies. The significance of differences in mean gain scores between different studies is determined, too.

The difference in performance between the studies is not significant, as expected considering the common contents and the modus tuition is performed. The exception is mechanical engineering & naval architecture professional study with mean gains for MRT significantly higher than electrical engineering university study. The comparison with the gain in scores for MRT reported in literature [23] for 2 hours/week through one semester and multimedia tuition environment is made. It shows that the gain in scores for the students of mechanical engineering & naval architecture professional study (2 hours/week) at Faculty of Engineering is considerably greater, while for other studies (1 hour/week) varies being higher and lower.

### 5. CONCLUSIONS

The performed assessment of engineering students’ spatial ability at University of Rijeka Faculty of Engineering, have been intended to give an overall insight
into initial level of spatial ability the students are approaching to different studies.

The students with higher spatial ability found electrical engineering study both, university and professional engineering study both, university and professional appropriate and attractive compared with other studies. The results of assessment obtained by the adopted measures of spatial ability before engineering graphics course have been found to be a significant predictor of final course success at university studies.

REFERENCES