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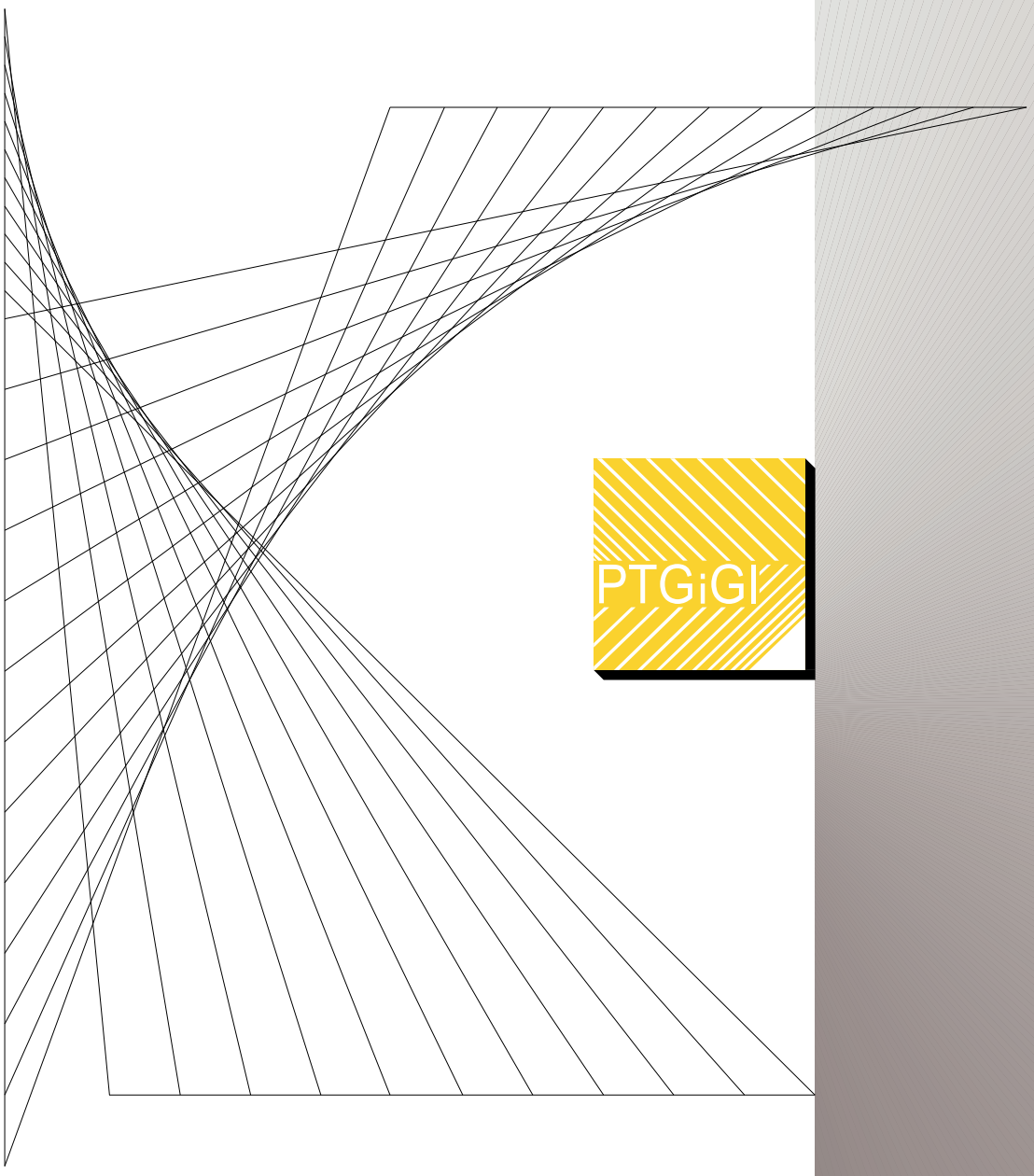

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POSITIVE IMPACT OF 3D CAD MODELS EMPLOYMENT IN DESCRIPTIVE GEOMETRY EDUCATION

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Abstract. Classical Descriptive Geometry (DG) course used 2D drawings for 3D spatial elements representation. Computer graphic introduced simulation of a 3D geometric environment in contemporary DG teaching. Research aim is the impact of CAD models utilization in correlation to students' overall academic success. The research was performed on the freshmen students at Civil Engineering Faculty of Belgrade University. DG lecturing combines blackboard drawings, PowerPoint presentations and 3D AutoCAD models. Preparation of practices assumed handouts - AutoCAD solutions, both 2D drawings and 3D models available at the official Faculty's website. Paper based questionnaire was employed after the first examination term. The results show significant contribution to the students' achievement with 3D models assistance introduction in DG teaching/learning process.

Keywords: 3D model, AutoCAD model, Descriptive Geometry, learning process

1 Introduction

Contemporary engineering education as accepted standard uses adequate 3D digital environments in correlation to teaching course requirements. Classical Descriptive Geometry (DG) course (basic for engineers) as a drawing "language" is aimed for various engineering professional orientations [1,12]. The efficient engineering practice for solving geometry tasks used to be on sheet drawings prior to computer era. Computer graphic introduced simulation of a 3D geometric environment in DG teaching [9]. Various 3D environments were explored and discussed in the past decade as relevant in DG education, starting from 3D software (introduction of 3D models [2, 3] or 3D modeling [5,10]), and augmented reality [13], up to virtual reality context [1, 12]. The final goals of such research were visualization skills improvement [4, 8], as well as spatial ability [6,11] and engineering students learning motivation enhancements. The most common practice in DG teaching was implementation of 3D CAD models, regarding its availability and benefits [3]:

- "direct" visual contact of the observer with 3D virtual object;
- manipulation with 3D object;
- various 3D and 2D view options (perspective, axonometric, orthographic);
- simultaneous presentation of 3D and 2D views;
- various types of tasks presentations (considering limited class duration time);
- "step by step" presentation of the drawing – solution procedure (by layer control);
- quality and precision of drawings.

At the Faculty of Civil Engineering, University of Belgrade, computer aided 3D representations (AutoCAD geometric models) of spatial geometric elements and structures were introduced in DG teaching methodology previously strictly based on correlation of classical 2D drawings (orthographic, auxiliary, and axonometric projections) and spatial imagination/comprehension skills. The aim of this research is to evaluate the impact of CAD models utilization with respect to students' achievement, learning styles, and motivation level.

2 DG course: New teaching practice

The research was performed on the sample of freshmen students attending DG course during the first semester. DG lectures combined blackboard drawings, PowerPoint presentations, and 3D models in AutoCAD. For the purposes of student's active participation in the lecturing process, paper sheets (partly finished drawings) are being given as handouts, with assumed completion in accordance to professor's instructions. The practices are organized as classical geometric tasks to be manually performed in the form of sheet drawings using geometry accessories with the teacher's guidance/assistance. Conceived tasks and AutoCAD solutions are available at official Faculty's website as unique *.dwg files for example each practical class. 2D drawings/solutions and complementary 3D models were aimed to enable "step by step" manner learning guidance (Fig. 1a-b). Switching on one "step"/layer at the time, in succeeding order one can observe drawing procedure (Fig. 2).

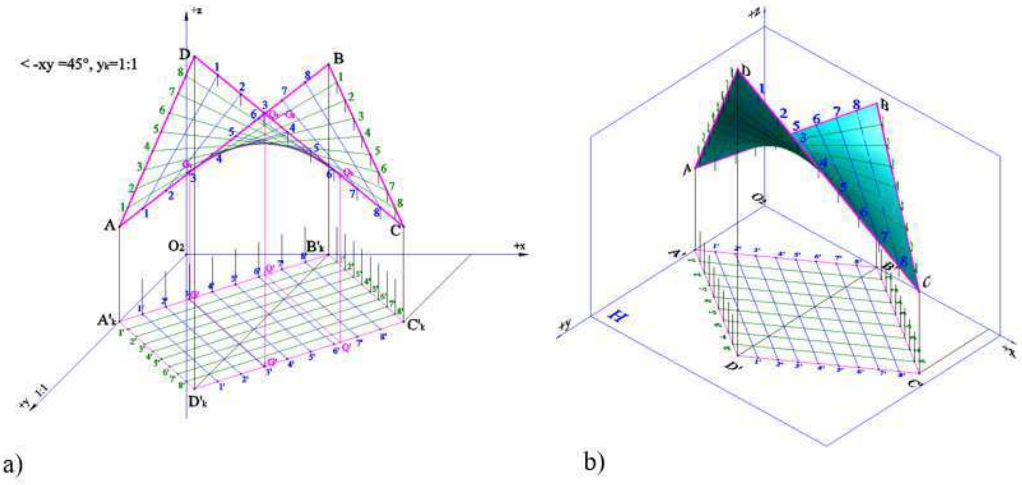

Figure1: Complementary drawing solutions in AutoCAD: a) 2D drawing; b) 3D model

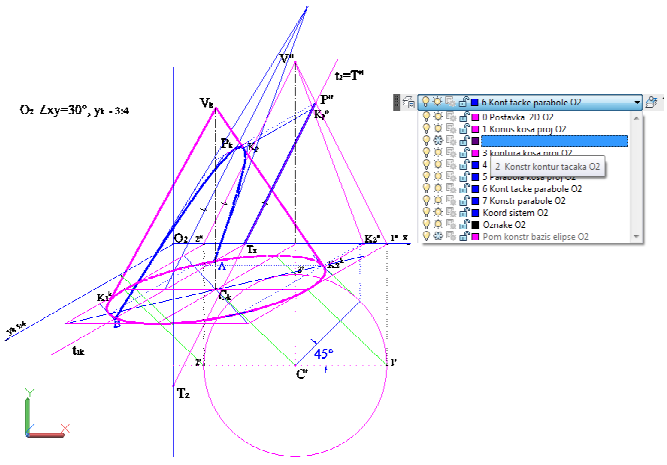

Figure 2: "Step by step" guidance (2D solution of geometric task) enabled by *layer* control

For an ease of use purpose, short instructions are provided for *layer control*, *view palette* and *orbit tool* (AutoCAD commands). Geometric correlation of 2D projections (parallel/orthographic or axonometric) and virtual 3D model of any geometric entity (element or structure) assumed to be achieved by *view palette* tool and *orbit* tool, in such way improving spatial perception. The collection of varying tasks (3D models) of each topic was given prior to mid-term and end-term tests (Fig. 3).

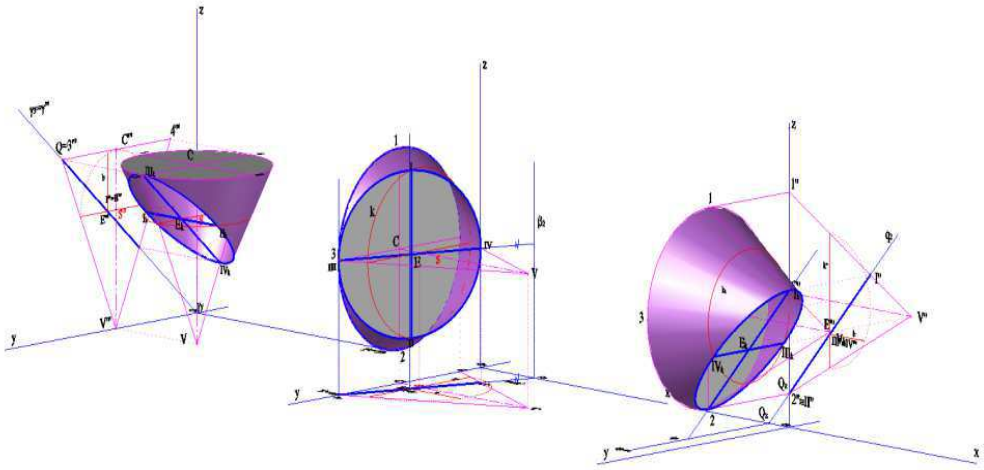

Figure 3: 3D representation of the topic - conics sections (AutoCAD 3D models)

In order to evaluate students' academic achievement and to assess the efficiency of the teaching-learning processes the survey concerning new educational environment acceptance and utilization was performed. The intention was to measure the impact of computer-aided learning mode (2D/3D; active/passive) in DG course. DG course practice faces the long term obstacle – students' "focus on memorizing constructions and centering attention on the views of the object rather than on the object itself" [7]. Therefore the data provided by the students, as valuable source of information, will play the important role in future improvements and modifications of teaching/learning methodology.

3 Methodology

For the purposes of this study, 130 freshman students attending DG course at the Faculty of Civil Engineering of the University in Belgrade were recruited as participants. Data were collected from the three generations of civil engineering students (2014-2016) who were monitored and inquired succeeding the final exam.

Paper based questionnaire (formulated by the lecturers for the purpose of this study) was employed after the first examination term. Data entries from Microsoft Excel spreadsheet were imported into IBM SPSS Statistics base. Frequency histograms and the Kolmogorov-Smirnov Test were used to determine whether the mean scores obtained during testing had a normal distribution. Since the distribution of all interval variables significantly deviated from the normal distribution, the nonparametric Kruskal-Wallis's test was employed. Binary logistic regression was used for predicting the outcome variables (evaluation success).

4 Results and discussion

The results show significant differences in final exam grades (χ^2=12.260; p=0.007), as well as in exam pass rates (χ^2=12.228; p=0.006) between students who were passive observers or used only printed versions of the drawing solutions and those who used 3D models assistance in geometry course learning. The overall pass rate and exam scores were higher for students

who used 3D models assistance in the spatial perception and comprehension (Figs. 4-5). Obviously AutoCAD solution usages lead to significantly higher exam pass rate (Fig. 4). On the other hand there are rather small differences between passive and active usage mode (2.3%). However greater differences appear in final exam grades when considering passive and active usage mode (8.46 vs. 9.05, respectively), as shown in Fig. 5. Such results emphasize the benefits of active 3D environment utilization.

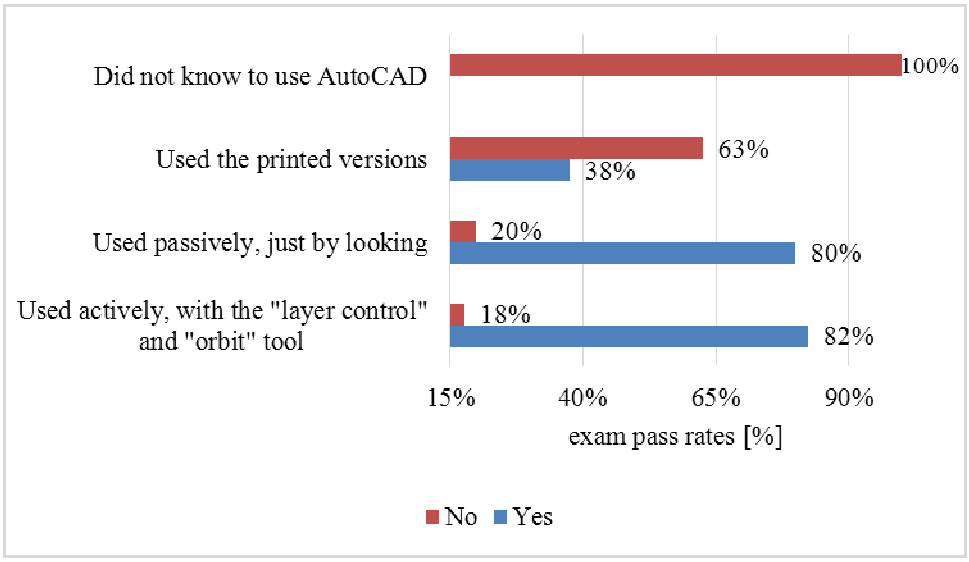

Figure 4: Differences in exam pass rates for students who did/did not use 3D models

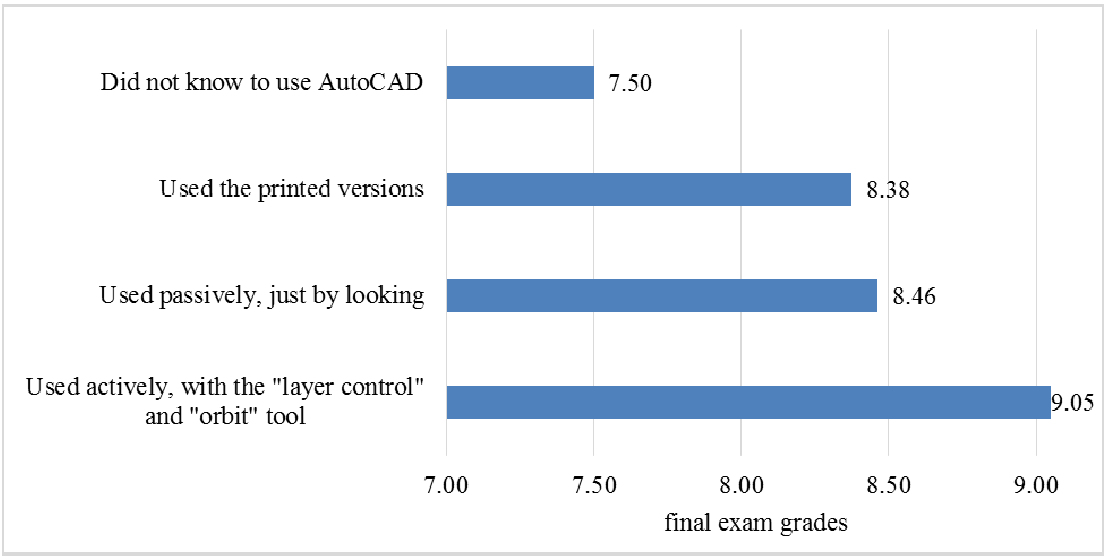

Figure 5: Differences in final exam grades for students who did/did not use 3D models

Furthermore, Kruskal-Wallis's test shows statistically significant differences in final exam grades between students who actively used 3D AutoCAD models - task solutions (χ^2=12.453; p=0.002) and those who encountered only classical approach (2D drawing vs. spatial comprehension) in solving geometrical problems. The results suggest that students who utilized 3D environment received higher exam scores in comparison to those who have partially, or did not used this option at all (Fig. 6).

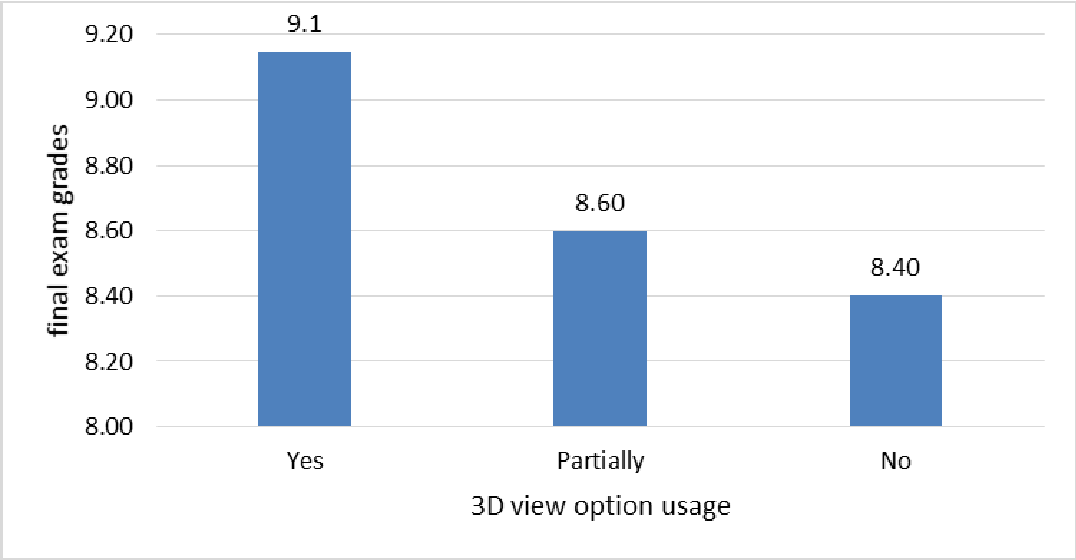

Figure 6: Students' final exam grades with respect to 3D view option usage

4.1 Binary Logistic Regression

For predicting students' achievement (the outcomes), a logistic regression was performed to ascertain the likelihood that students passed or failed to pass the exam. The model included the following predictor variables: usage of 3D models assistance in preparation of the practices and students' motivation for working with 3D. The logistic regression model was statistically significant, (χ^2=11.67; df=2; p<0.003; pseudo R_N^2 =0.119) and correctly classifies in 78.1% of cases.

Students who used 3D models assistance in solving geometrical problems were 2.43 times more likely to pass the exam. Besides, students who were motivated to work with 3D models have 1.93 times bigger chances to pass the exam.

Motivation for usage of 3D models assistance in solving geometrical problems was associated with an increased probability of passing the exam.

5 Conclusion

Based on the results of the study, it can be concluded that introduction of modern software packages (e.g. AutoCAD) and other IT media in Descriptive Geometry course improves the quality of studies, the students become more motivated and interested. Students who were active users of 3D CAD models assistance showed better success and achieved higher exam scores, in comparison to those who were passive observers, or used only printed versions of the drawing solutions. With respect to overall improvement of educational outcomes one could emphasize students' active engagement in versatile tools that new technologies offer.

Further research might consider enlargement of the survey sample to different age and/or gender groups, as well as other engineering fields to ascertain their spatial ability post course improvement. Some other 3D environment implementation (e.g. augmented reality or virtual reality) should be compared with 3D software as well.

Aknowledgements

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POZYTYWNY WPŁYW WYKORZYSTANIA MODELI CAD 3D W NAUCZANIU GEOMETRII WYKEŚLNEJ

W kursie klasycznej geometrii wykreślnej rysunki 2D wykorzystywano do reprezentacji elementów przestrzennych 3D. Grafika komputerowa wprowadziła symulację środowiska geometrycznego 3D we współczesnym nauczaniu geometrii wykreślnej. Celem niniejszych badań jest wpływ wykorzystania modeli CAD na ogólne wyniki studentów z tego przedmiotu. Badanie przeprowadzono na próbie studentów pierwszego roku na Wydziale Inżynierii Lądowej Uniwersytetu w Belgradzie. Wykłady z geometrii wykreślnej łączą w sobie klasyczne rysunki tablicowe, prezentacje PowerPoint i modele AutoCAD 3D. Przygotowanie przyjętych praktyk - rozwiązania AutoCAD, zarówno rysunki 2D, jak i modele 3D są dostępne na oficjalnej stronie Wydziału. Kwestionariusz w formie papierowej zastosowano na egzaminie po pierwszym semestrze. Wyniki pokazują znaczący wkład w osiągnięcia uczniów dzięki wprowadzeniu modeli 3D do pomocy w procesie nauczania/uczenia się geometrii wykreślnej.