

# Future of 3D Visualizing Technologies in Engineering Education

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**Abstract** – A description of mixed stereoscopic environments is made. A use case of proprietary software is made for the education of engineering students. A methodology for including the technology in their curriculum is created and its application is planned. Personalized 3D objects are included along with university created educational materials. Tools for measuring students' reactions are discussed and implemented. An overview of the results from a similar preceding experiment is shown.

**Keywords** – 3D objects, learning methodology, student improvement, stereoscopic display.

## 1. Introduction

Continuous efforts have been made in integrating stereoscopic displays in the training and education of employees in the business and industry. Research shows that there are multiple conditions that have to be fulfilled in order to conduct a successful virtual reality teaching program, and the three main ones include a careful choice in learning environment, an appropriately implemented pedagogical methodology, and multisensory virtual stimuli through the use of 3D objects [1].

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Using these conditions as guidelines, we must first analyze the types of available software for teaching engineering students using our currently created 3D objects. We should follow that with creating or adapting a methodology for their lessons, after which we should consider altering it and including additional ways of interacting with the objects that are presented in the environment, thus completing the process.

Engineering students' curriculums are always changing according to the requirements of the current trends in the industry. It is difficult for educational institutions to always update the teaching materials and approaches, but this is still the most reliable way to push higher education forward. In order to see if the changes brought to the workshop plans are of significance, it is necessary to experiment and analyse the results using scientific approaches. Including cutting edge technologies and improving the coverage of fundamental knowledge lesson plans is what our research team aims at.

The University of Ruse has experimented with integrating different 3D viewing and manipulation software applications as workshops for our students. In this report the statistical data from the empirical research of one such tool is described. Based on these prior research results, it has been decided to create, adapt and apply methodologies for other software and hardware tools related to 3D technologies. The one discussed in this report is the stereoscopic display approach to visualizing objects. Equipment has been purchased and deployed to further our progress towards our goals.

## 2. Layout

New studies show the differences in navigating virtual and augmented reality workplaces [2], emphasizing the actions people fumble with when using such an environment. Results show that both types of display have their benefits and drawbacks. Stereoscopic displays focus on enhancing the positive qualities of 3D objects displayed in augmented reality.

Making use of the stereoscopic effect in the human eye, they display created three dimensional models for the user to manipulate.

Software written for such displays often provides the same toolset that many standard 3D manipulation software possesses. Taking into account the many different uses of 3D objects, most of them are a combination of simple parts, so that they can be “exploded”, or virtually disassembled, either for study, recreational or design purposes. Combining the physical manipulation and rotation of the object, as well as the stereoscopic effect, provides a strong alternative for a real life object, that can be either too expensive to make, or too difficult to disassemble. Such tools aid the design and educational process immensely, either ensuring a strong imprint made on a students’ mind, or giving a powerful visualization toolset to a designer. Such displays are often used for demonstration, and they are an impressive tool for showcasing software to clients or visitors.

In order for such a tool to be included in university education it must be evaluated. The evaluation and implementation process consists of several steps that are shown on Figure 1.



Figure 1 Evaluation and implementation process

### 2.1. Analysis of technology effects

Studies in the field of medicine have arrived to various conclusions on the topic of using stereoscopic displays in the operating procedures [3]. The usefulness of the technology for some medical domains is showing improvement over the years, as the quality of the images increases as well as the experience that the medical staff gains from working with it. Other studies conclude that the benefits of the technology are offset by the detriments – low quality imagery is not useful for the improving performance, as well as the physical problems that occur during the actual prolonged usage by humans [4]. Taking these conclusions into consideration, we have to move on to the next step.

### 2.2. Educational methodology for the curriculum

We have to factor in the medical risks of vertigo when using the toolset for a prolonged period of time, making exercises short and impactful, thus extracting the most out of the technology.

Budget constraints also forces us to choose an all-in-one display to fit our students’ classroom, as well as introducing exercises rotation for students (only one or several people use the tool at the same time, as the cost is prohibitive). Taking these into account, a team round-robin approach has been used. A version of the methodology is shown on Figure 2.

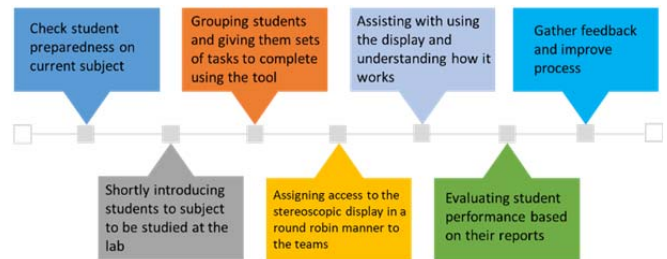


Figure 2 Educational methodology for the student curriculum

Educational tools have been created and used successfully as simulation environments [5]. Customizing and creating such tools for mechanical engineering students is thus feasible and worth analyzing. Comparisons have been made and measurements show the improvement in task effectiveness, learning outcomes and user experience while introducing such tools for specific fields [6].

### 2.3. Comparing different types of stereoscopic displays is a necessary step in this process

There are two main ways that stereoscopic displays are packaged and sold – all-in-one computers and laptops. Laptops are in general cheaper and less powerful [7], but give the opportunity to create a mobile laboratory. All-in-ones on the other hand have more powerful hardware and remove the necessity to maintain laptop batteries using charging stations, but give up mobility in exchange. Comparisons between head mounted displays and stereoscopic desktop displays in virtual reality have been made for specific fields and they are leaving the choice of technology to the specialists, advising testing and analyzing every particular use-case [8].

### 2.4. Choice of the most appropriate option, depending on the budget

For the purposes of the university, the all-in-one is the more feasible option, as a mobile display would require different support. While a mobile laboratory remains an attractive option, it is left for the future if the technology itself is deemed worth the investment after initial testing and implementing in the student curriculum. The software product that has been chosen is zStudio, a bi-annual subscription license that provides the necessary functionality to show proprietary university 3D models on the display.

Different experimental educational models are included in the software, some of which are worth including in different activities using the display.

### 2.5. Creating student exercises

Several existing workshops for engineering students have been adapted to include using the stereoscopic display, in order to analyze and measure the results and feedback.

### 2.6. Implementing and analyzing results

A workstation has been bought and set up (visible on Figure 3). An additional monitor that displays what happens on screen has been connected, in order to improve visibility and teamwork for the students. 3D models for each exercise have been imported into the zSpace studio and tested for visibility issues. The workstation has been included in the internal university network. Several proprietary 3D models have been bought for display purposes and eventual further analysis on the subject in different fields of education. A Likert scale survey has been created in order to measure student feedback after the workshops.



Figure 3 zSpace workstation, set up for educational, testing and display purposes

### 2.7. Practical research and statistics on the subject matter

The study on stereoscopic displays and their supposed effectiveness as a supporting teaching tool are supported by research on a similar topic made at the university. Assisting software applications for the education of mechanical engineers using 3D models and teaching methodologies were created by the department of computing and were supplied with 3D objects and models by an associate professor from the department of Machine tools and manufacturing.

After developing multiple initial software tools created for the different workshops for the subject Cutting tools, a web software system was created.

It was created using agile methodologies and a hybrid approach, taking the best elements from the waterfall and iterative agile methodologies in the process of crafting and further developing the system, based on feedback by professors and students. The system allows for new workshops to be created, each of which consists of a test, multimedia elements, multiple workshop steps – which have a 3D object and a measurement or a formula to evaluate the students’ understanding of the subject matter. A version of the user interface of the system can be seen on Figure 4.

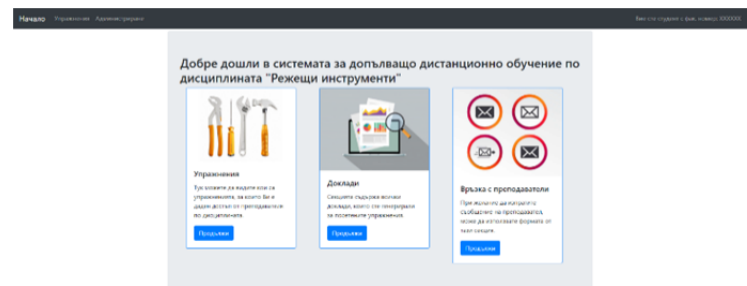


Figure 4. A version of the user interface of the web system, used to for the education of mechanical engineering students, using 3D objects

The software was used with groups of students during workshops in order to supplement their curriculum. Students were separated into groups who used the system and those who did not. Their grades were gathered throughout the years when the system was used and the data was analyzed using the following statistical methods, so as to understand whether the students who used it achieved better results compared to their colleagues.

### 2.8. Analyzing and processing the experiment results

In order to analyze the gathered data – the student results throughout the years, a choice of a scientific method was made. The data consists of qualitative variables, which are classified as nonparametric criteria, thus requiring us to use a method, capable of handling them. Using an approach used in the subject “Theory of the experiment” [9], a universal method applicable for most science subjects, the different characteristics of the qualitative values was weighted and evaluated. The subject that has to be evaluated is the “student”, meaning the student’s performance.

Using the universal model, shown on Figure 5, we can describe the different factors that change the subject in a meaningful way.

The factors that can be changed – “X”, the factors that are random and cannot be manipulated – “W”, and the changes of the subject are noted as “Y” – the response parameters (as they respond to the factors which change the subject).

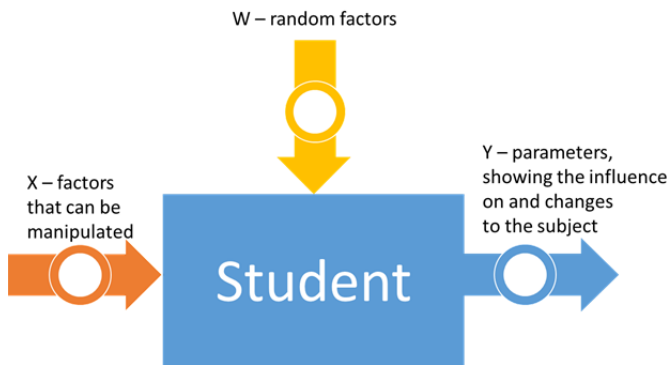


Figure 5 The model of the subject “student” - the factors that influence it and the parameters that show its change according to changes in the input factors

The factors that can be manipulated – “X”, in our case are the student groups (which show the groups of students who have used the tool and those that have not). The “Y” parameters that show influence are the students’ grades.

The input factors (X) are classified as qualitative, as they cannot be put on a linear scale – two groups are used, a control group and an experimental group, the experimental group uses the software system and the control group does not. Another input factor that will be used later is the semester in which the subject is taught – giving us a scale so that we can make a comparison between the groups through time.

The number of students are a significant enough part of the total population of the university - it can be concluded that the conditions for an independent sample have been fulfilled. The subject has been classified with one input factor that can be manipulated, thus one-factor dispersion analysis has to be used.

After calculating the dependencies using the mathematical apparatus from the specialized software product “Statistica 13” is used [9]. The student group is included as a qualitative factor and the student grade is the result. The Phisher coefficient is designated with p.

The data is filtered through the mathematical apparatus in such a way that the random factors lose most of their significance, and their influence can be seen in the possibility for error on Figure 6.

Univariate Tests of Significance for Grade (Grade data)					
Sigma-restricted parameterization					
Effective hypothesis decomposition					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	2435,948	1	2435,948	3560,625	0,000000
Group	6,341	1	6,341	9,269	0,002842
Error	85,517	125	0,684		

Figure 6 Result from Statistica 13 for the significance of the factor “student group” (values are “control” and “experimental”) on the student grades

In order to reach a scientifically accurate conclusion, two hypotheses are formed:

$H_0$  – the factor does not influence the subject (meaning the software tool does not influence the results of the students in the experimental group as there is no significant difference between the control and experimental groups’ results)

$H_1$  – the factor does influence the subject through the output parameter Y

Phishers’ method relies on disproving the hypothesis that the factor does not influence the output. After F is calculated (seen on Figure 6), it is compared to the table of references for the Phishers’ criteria. As in our calculations  $F = 9,269$ , it is bigger that the table value of  $- F(\alpha, k1, k2) = F(0,5;1;125) = 3,84$ , and the probability is  $p = 0,002842 \ll 0,05$  (significantly lower than 0,05), meaning the factor has big influence over the output parameter Y. The software helpfully colors the entire row for group in red, showing that  $H_0$  is incorrect.

From this we can conclude that for 95% accuracy of the algorithm (meaning random factors have a level of error  $\alpha = 0,05$ , or 5%), the hypothesis  $H_1$  is proven as correct.

After reaching that conclusion, we can continue analyzing the data using dispersion analysis. An additional analysis of the mean interval values that show the difference between the experimental and control group can be seen on Figure 7.

We can again conclude that the factor “student group” is influential enough in the experiment.

A similar analysis is made on the data that represents the grade distribution in semesters, where the influential factor is semester, the results can be seen on Figure 8.

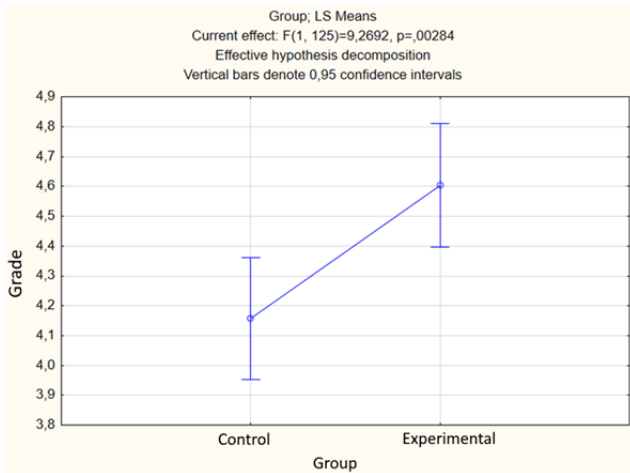


Figure 7 Graphical representation of the mean interval values of the experimental data, with 95% accuracy factor. The influencing factor is “student group”

Univariate Tests of Significance for Grade (Grades by semesters)					
Sigma-restricted parameterization					
Effective hypothesis decomposition					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	2041,661	1	2041,661	3914,690	0,000000
Semester	31,360	10	3,136	6,013	0,000000
Error	60,498	116	0,522		

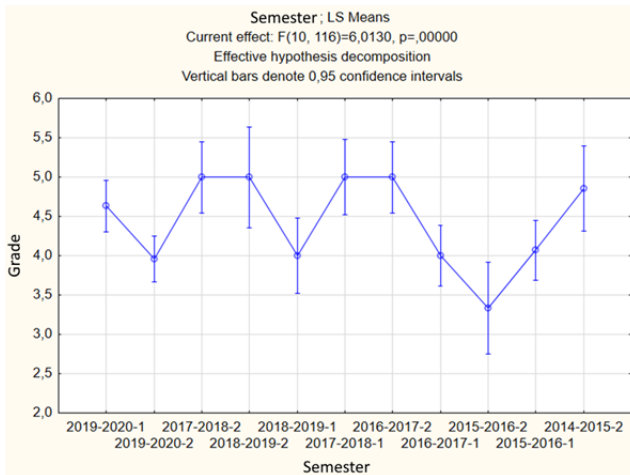


Figure 8 Graphical representation of the mean interval values of the experimental data, with 95% accuracy factor. The influencing factor is “semester”, or the time distribution

This analysis shows the enormous influence that the random factors have on the student results (the Phisher criteria is  $F = 6,013 \gg$  table value for  $F(0,5;10;116) = 1,83$ ), which leads us to the conclusion that we have to analyze both factors at the same time, using a multifactor dispersion analysis. In our case, a two-factor dispersion analysis will be appropriate, to accommodate our two factors at the same time – student group and semester.

After using the specialized software Statistica 13 again for the purposes of analyzing the calculated parameters, the results can be seen on Figure 9.

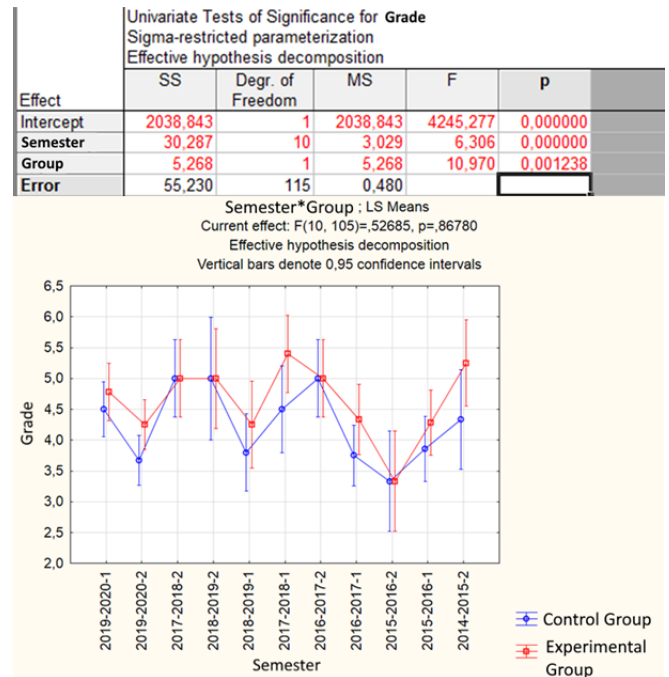


Figure 9 Graphical representation of the mean interval values of the experimental data, with 95% accuracy factor. The influencing factors are “semester” and “student group”

Keeping in mind the level of mistake p, we can conclude that both factors have an influence on student results. The mean interval values show that the experimental group achieves the same or better results than the control group, proving that the influence on the results is positive.

It can be concluded that by making the one-factor and two-factor dispersion analysis it has been proven that the experimental group achieves higher results than the control group, independent on the random factors and the distribution in time.

A survey was made to accommodate student feedback to the agile development process of the system. A Likert scale was used, distributing the answers from a1 to a5, where a5 is the most positive answer to the functionality of the system and a1 is the most negative answer. The results were processed using the dispersion analysis (shown on Figure 10), and their mean intervals were analyzed, comparing the results from the beginning of teaching the subject with the help of the system, until 2018 and the aggregated results until 2020 (mean average values can be seen on Figure 11). After the analysis, it can be concluded that scientifically, the system was received better and better in time.

Univariate Tests of Significance for Count (survey responses)					
Sigma-restricted parameterization					
Effective hypothesis decomposition					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	2022,480	1	2022,480	95,26519	0,000000
Response	2070,920	4	517,730	24,38672	0,000000
Question	0,320	9	0,036	0,00167	1,000000
Error	764,280	36	21,230		

Univariate Tests of Significance for Count(survey responses 2020)					
Sigma-restricted parameterization					
Effective hypothesis decomposition					
Effect	SS	Degr. of Freedom	MS	F	p
Intercept	7887,68	1	7887,680	165,8934	0,000000
Question	0,32	9	0,036	0,0007	1,000000
Response	11636,32	4	2909,080	61,1837	0,000000
Error	1711,68	36	47,547		

Figure 10 Compared results from analyzing the survey data from students from years 2015-2018 and 2015-2020

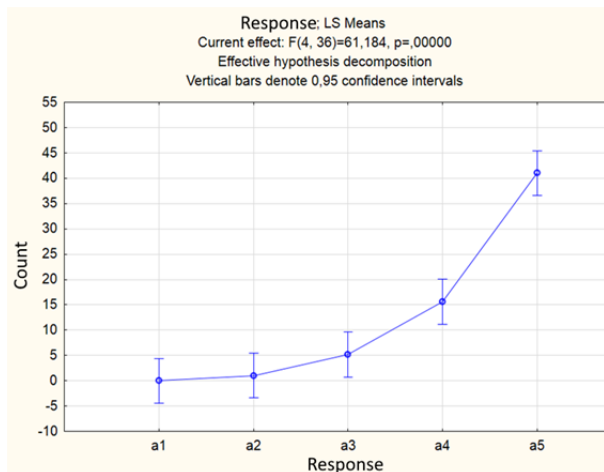
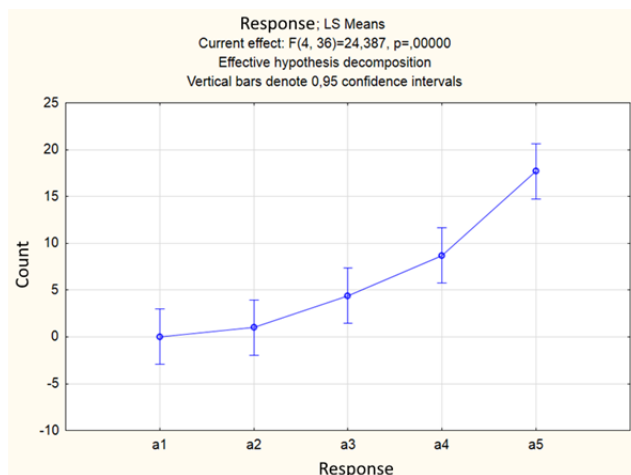


Figure 11 Graphical representation of the mean interval values of the survey data, calculated using a dispersion analysis

The dispersion analysis proves that the answers have a statistical significance for the experiment. The answers are overwhelmingly positive, which increases over time. The mean interval values show that improvement.

Based on the integration of the system to the curriculum of the mechanical engineering students, several other options for including hardware and software related to manipulating 3D objects were considered. Interesting solutions exist for augmented reality [10], virtual reality systems and their hardware [11], [12], and mixed reality.

### 3. Conclusion

Stereoscopic displays are an interesting approach to improving visualization techniques when working with 3D models. When educating engineering students, it is obligatory to impart knowledge of working with three-dimensional space, and the chosen method is deemed appropriate. Manipulating objects in a virtual laboratory is a necessary addition to the skillset of any engineer, and exploiting the stereoscopic effect, and adding another axis to an object helps instill a confident mind-set in the students. The tools that have been previously created and experimented with during the student workshops are shown to have undoubtedly statistically improved their understanding on the subject. Further studies are required in order to analyze the achieved results using stereoscopic displays, and improve on the process of including such technologies to the university engineering curriculum.

The current industry, business and education systems are including and improving 3D manipulation tools, which expand the range of knowledge in students, learners and workers alike. It is a steady direction in which most big companies and universities are headed. These technologies are not only the future, but the present as well.

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