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EVALUATION OF THE WEB PLATFORM AS A LEARNING TOOL IN MECHANICAL ENGINEERING

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Abstract. *The Mechanical Engineering, as a traditional area among other engineering, still counts on a lagged teaching system, based on theoretical classes. In this scenario, computing has constantly allowed the development of tools that support teaching, one of the most relevant being the WEB platform. This platform, based on the HTML5 standard, has considerably raised the creation of educational content. Thus, this work had the objective of studying the didactic potential of WEB applications with three-dimensional environments in the improvement of the teaching of Mechanical Engineering. For this, a survey was carried out among the course's students about the current state of use of these tools in the classroom. In addition, we described the state of the art of using the WEB platform from systematic research in the literature and, finally, presented some examples of WEB applications that can be used to improve teaching. It was concluded that such applications, supported by the majority of students, have didactic potential, and can lead to an effective improvement of learning by simulating practical situations not previously experienced by the students, motivating them and facilitating the fixation of the studied contents.*

Keywords: *WEB, 3D Technology, Mechanical Engineering, Learning, Virtual Reality*

1. INTRODUCTION

The university of the future, theme of the Second Academic Congress of Unifesp, had as its most defended ideals the need for innovation in higher education and promotion of social inclusion and integration. The "Knowledge Society" requires new skills and expertise of its professionals, considering technical competences: application of knowledge and learning, continuous updating through research, openness to criticism, search for creative and innovative solutions, team management (Masetto, 2004). Such demands directly affect the university, which necessarily leads us to think of innovation in higher education.

The current young generation grows in frequent contact with virtual environments with profusion of images and videos of excellent quality, as well as easily accessible information, which inherently changes the dynamics of learning compared to previous generations (Hussein and Natterdal, 2015). Despite of this, it is a fact that current engineering education, in most of the country's universities, still ignores these new resources and relies on theoretical expository methodologies, which makes it obsolete and increasingly inefficient (Belhot, 1997).

In addition, it is observed that, currently, the greatest difficulty of engineering students, in general, concerns the ability to visualize and understand the problem analysed, as well as the interpretation of results, an essential skill for the engineering professional. The exact interpretation of a phenomenon is a result of training and perfecting these skills. In this sense, classes with a higher practical content can contribute to raise the quality of the training of these students.

Thus, in view of this deficiency observed in engineering courses and the growing demand for innovation, this paper aimed to present the WEB platform and its applications focused on virtual reality and three-dimensional environments as an innovative mechanism for teaching-learning in Mechanical Engineering courses, since it is a familiar tool to young students that allows the visualization and interaction with engineering systems and phenomena represented in three dimensions.

1.1 WEB Platform technologies

Before exploring the potential of these tools in the teaching of Mechanical Engineering, it is necessary to briefly contextualize the technologies used for their development, in order to highlight the simplicity with which such applications are developed and their capacity to reach the many areas of the knowledge.

Undoubtedly, the most important technology for the development of web pages is the HTML language (*HyperText Markup Language*, currently in its fifth version). It is a markup language based on tags used to build the base of any and every website that is hosted on the internet these days. It is responsible for the presentation of multimedia content, be it texts, photos, videos, aids or even 3D content, so that its emergence was what made possible the application of the WEB in the classroom. The HTML language is associated with CSS (*Cascading Style Sheets*), responsible for the visual style of the pages.

In spite of this, HTML is not enough for the creation of applications on the WEB, since, according to Waernér (2012), such applications use of scripting, structured like and works much like an ordinary desktop application. Therefore, other languages are required.

For the development of the logic of functioning of the tools or applications created, the language *Javascript* is utilized. It is a programming language with characteristics of the paradigms of imperative, functional and object-oriented programming, being also one of the most used due to its association with the web. It is very important for the computer graphics, since it allows the manipulation of the innumerable variables that involve the construction of objects and figures. Javascript is still a language of easy learning and with great power of expression (Crockford, 2008), which benefits the development of learning environments.

For the generation of two-dimensional (2D) figures, it is common to use two main technologies: HTML Canvas and SVG (*Scalable Vector Graphics*). While the first is an imperative language, that is, through command lines, the second works declaratively through the definition of scenery and objects.

Regarding to the generation of 3D objects and scenes, this can be done using different technologies, such as WebGL and X3D. However, the most promising when it comes to didactic application is the X3DOM architecture, a technology that links HTML to X3D using structured representation defined by the DOM (*Document Object Mode*), because it allows the creation of 3D environments without the need of plugins or extensions, as pointed out by Behr *et al.* (2010) simplifying and facilitating access.

The Figure 1 relates some technologies used in computer graphics and development of virtual environments.



Figure 1. Some computer graphics technologies (Jankowski *et al.*, 2013)

2. METHODOLOGY

For the development of this work, it was initially carried out a survey of the current scenario of the Mechanical Engineering course of the Federal University of Rio Grande do Norte (UFRN) regarding the greater difficulties faced by students and the use of the WEB in the disciplines, from this, we sought to present the advantages of using these 3D applications and their didactic potential, as well as some examples of environments that may favor learning in critical areas of the course.

2.1 Survey about the use of WEB Platform

In order to better evaluate the main difficulties of the course and, therefore, the potential of the 3D WEB platform as a teaching tool, a brief survey was carried out with the target audience, in this case, the graduates in Mechanical Engineering of the UFRN. This survey was carried out through an online questionnaire containing 11 questions, which are presented in the Table 1.

Table 1. Questions to students of Mechanical Engineering

Nº	QUESTION
1	What is your period in the course?
2	What is the area of the course that lacks practical classes and/or activity?
3	Do you know any 3D applications on the WEB?
4	Among the applications you know, is any application directed to Mechanical Engineering?
5	Do you know any professor who have used and/or uses any 3D application on the WEB during a class?
6	Do you believe that 3D WEB applications online that allow the visualization of practical phenomena can serve as an alternative to reduce the lack of practical classes?
7	How useful do you think these applications can be in learning?
8	The easy access to these 3D WEB applications, in terms of cost, is a decisive factor for its applicability?
9	The easy access to these 3D WEB applications, in terms of the necessary computational effort, is a decisive factor for its applicability?
10	How do you rate the ease of using 3D WEB applications?
11	It is known that most WEB applications make it possible to innovate because they are open source, would you be interested to develop and increase applications already available, or even create new ones?

The sample is composed of 91 students randomly selected from the undergraduate Mechanical Engineering course of the Federal University of Rio Grande do Norte (UFRN). Based on the methodology presented by Devore (2015), it was possible to affirm that the sample is large enough before the current 278 students of the course to guarantee a confidence of 95% considering a margin of error of 10%.

2.2 State of art

In order to justify the didactic potential of the applications on the WEB, a systematic research was done in the literature, using the Metasearch of CAPES (Brazil's Higher Education Coordination of Personnel Perfecting) and the Google Scholar website, about alternative teaching methodologies, focusing on those that use virtual reality and three-dimensional virtual environments. We sought answers to the following questioning: How 3D virtual environments on the WEB can benefit the teaching-learning process in Mechanical Engineering courses? Some papers, within the period of 1995 to 2016, were read, and, then, the information obtained in expository text form was synthesized.

In addition, similar research was carried out with the objective of determining the advantages of using the WEB platform in detriment of conventional software. These advantages were selected and listed objectively.

2.3 3D Environment examples

In order to exemplify some applications on the WEB that can be used to improve the classes of the Mechanical Engineering courses, two methodologies have been applied: the research of an existing 3D engineering applications on the Internet, and the implementation of some examples in WEB pages.

As for the research, the technology site was mainly used X3dom (2010), which brings together a series of examples, to obtain some engineering applications and concepts that could be better explored. In total, four interesting applications were chosen from the point of view of Mechanical Engineering.

Regarding to the virtual teaching environment, the same *framework* was used for its construction, with respect to the declaration and manipulation of three-dimensional objects. Auxiliary languages were used to build the site itself and its functioning logic such as HTML, CSS and Javascript. In total, two examples were implemented and made available on the WEB.

3. RESULTS AND DISCUSSION

According to the established methodology, results were obtained on the questionnaire carried out with the students and on the collection of references in the literature that support the advantages and didactic potential of the WEB platform applications. In addition, some examples of applications are presented to illustrate the use of virtual 3D environments in teaching.

3.1 Survey answers

Following, the data obtained after the survey conducted with the student body of the course of Mechanical Engineering of UFRN are found. A total of 91 students answered the survey, which gives confidence to her.

It was observed that the lowest period of the students was the fifth due to the fact that the course used here as a sample

consists of 2 cycles (basic and professional/specific). Having the disciplines really directed to the Mechanical Engineering only from the aforementioned period.

As shown by Figure 2, the most prominent areas were: Solids Mechanics, Thermodynamics, Manufacturing Processes and Industrial Maintenance with 61 (65.6%), 55 (59.1%), 45 (48.4%) and 45 (48.4%) votes, respectively.

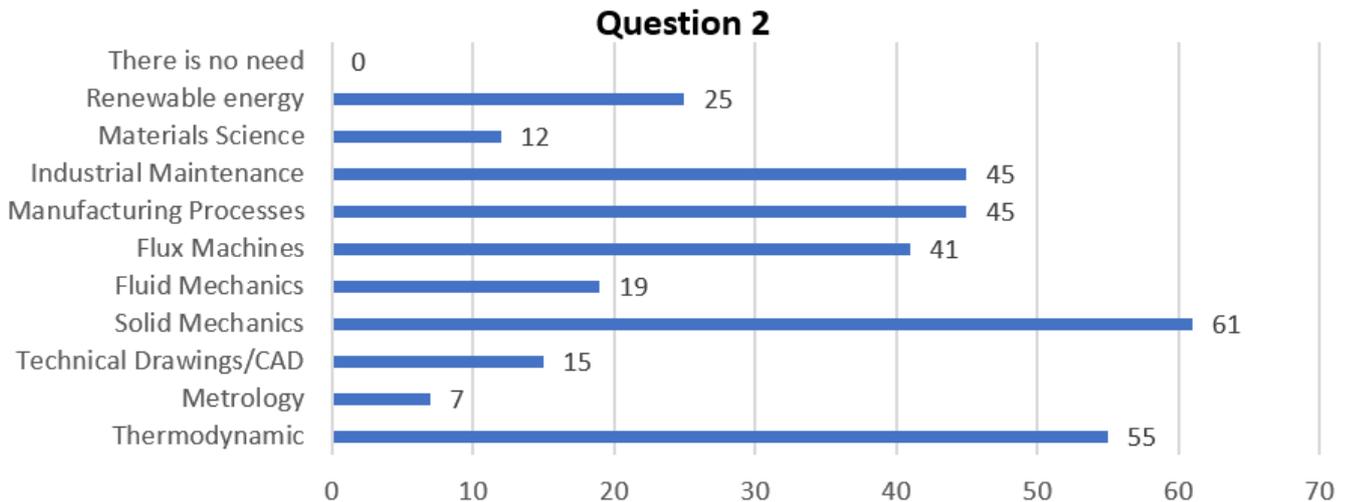


Figure 2. What is the area of the course that lacks practical classes and/or activity?

We observed that no student opted for the option "There is no need", that is, it was generally agreed that there is at least one area with some deficit in the practical classes. Meanwhile, the lowest voted was Metrology, with only 7.6%, which was expected given the high hourly workload of laboratory activities in the area.

Table 2 presents the answers to questions whose only possible answers are "yes" or "no".

Table 2. Answers to the questions with only "yes" or "no" answers

Nº	Yes	No
3	55%	45%
4*	41%	45%
5	29%	71%
6	91%	9%
8	90%	10%
9	83%	17%
11	68%	32%

*14% answered "No, not applied to Mechanical Engineering"

For the questions 3 and 4, it is observed that more than half of the students (55%) claimed to know the tool, but only 41% know applications to Mechanical Engineering. Besides, according to answers to the question 5, a percentage of 71% of student's state that their teachers do not use or have never used such tools, which represents the lag of teaching in this course.

As shown by answers to the question 6 and by Figure 3, a total of 91% of the students believe that this tool will serve to reduce the deficit of practical classes, allowing the visualization of practical applications, where 90% answered 7 or more, on a scale of 1 to 10, for the utility of this tool as a learning enabler.

Question 7

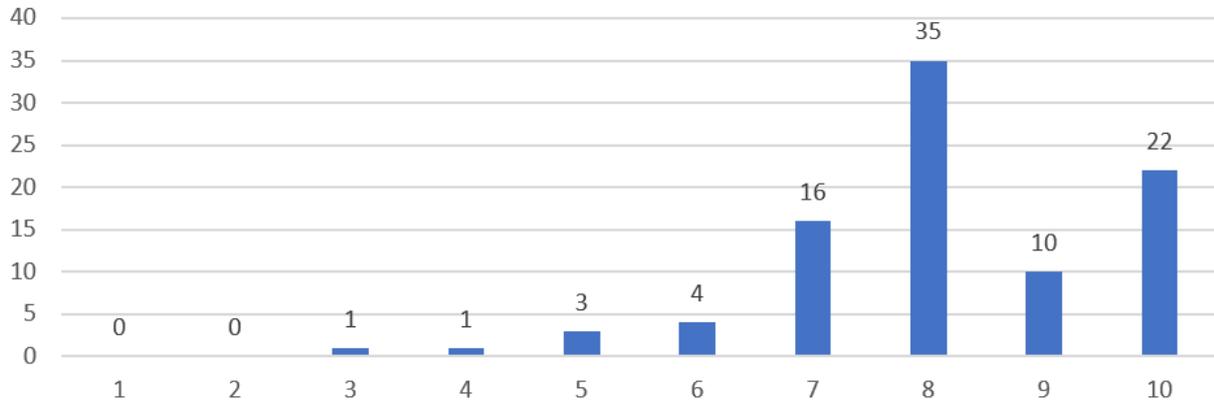


Figure 3. How useful do you think these applications can be in learning?

As can be seen for the questions 8 and 9, a total of 90% of student's state that cost is an important factor and 83% holds that the computational effort factor is important.

Finally, we can observe in Figure 4 that 55.5 % responded 7 or more, on a scale of 1 to 10, for ease of use of the tool. In addition, according to answers to the question 11, a total of 68.5% responded that it would be in the interest of developing and increasing existing applications or even creating new applications.

Question 10

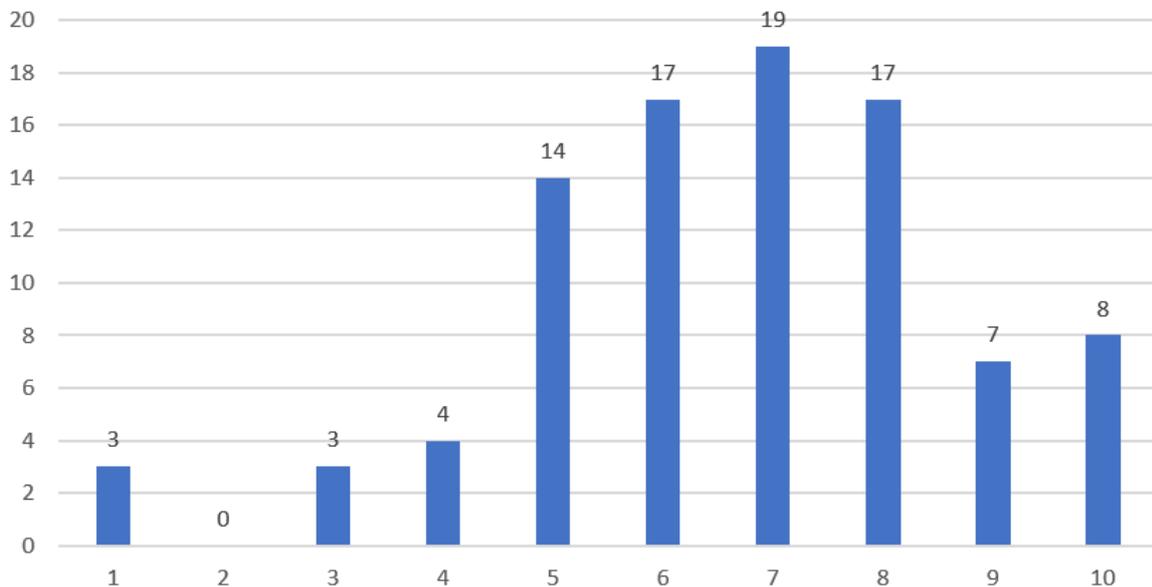


Figure 4. How do you rate the ease of using 3D WEB applications?

3.2 WEB Platform advantages

Before justifying the didactic potential of the WEB Platform, it is important to highlight the advantages of using these applications online.

According to Waernér (2012), a WEB application has the advantage that it can be executed on a wider variety of devices when compared to conventional software.

In addition, according to Potkonjak *et al.* (2016), which studied the use of virtual laboratories in teaching, 3D applications on the WEB have the benefits of low cost, flexibility, allowing multiple accesses at the same time and possibility to show details not seen in real environments.

Also, it is possible to emphasize the learning curve of these applications, which usually is soft and gradual.

3.3 Didactic potential

One of the main theories that support the use of the WEB Platform as a teaching tool is Constructivism. According to Chen (2010), the constructivist philosophy holds that knowledge is constructed through an individual's interaction with the environment. As opposed to behaviorism that holds to knowledge reproduction, constructivism as a learning theory emphasizes the combination of inputs from the senses, existing knowledge, and new information to develop new meaning and understanding through active, authentic, cooperative and reflective learning activities (Chen, 2010). Also, according to Tornincasa *et al.* (2008), the constructivist fundamental theory motivates educational uses of Virtual Environments because it provides an experience close to the direct interaction with the world, and allow the process of knowledge construction that takes place when learners are intellectually engaged in "personally meaningful tasks".

In this sense, it is observed that, as pointed out by Aiello *et al.* (2012), virtual reality provides total body involvement, which allows one to see the world through sensorimotor learning whose experiential component is one of the stages of a process that leads to the world's symbolic representation. The learning tools applications help the learner to transform intuition into understanding and to consolidate certain experiences into pervasive rules (Kommers, 2003).

Other advantages, presented by Palomäki (2009), are the conducting activities in a risk-free environment, enchanting collaboration and communication, increasing engagement, enabling an alternative space for instruction and tasks, and the visualization of difficult content.

In addition, Hussein and Natterdal (2015) states that visual effects and 3D objects can explain certain topics where text can't. A mixture of both can help the students achieve better results especially in science and engineering education.

Bell and Fogler (1995) notes that the most engineering students learn best from learning processes which are sensory, visual, inductive, and active, while most lectures tend to be intuitive, verbal, deductive, and passive in nature.

In this way, it can be considered that interactive and immersive 3D visualization virtual reality technology is an emerging technology that is promising for the engineering education and training. It represents a tool that can create a pipeline for cooperation with industry to prepare the next generation of graduate engineering with the skills required for business (Abulrub *et al.*, 2011). Abulrub *et al.* (2011) also asserts that virtual reality environments enhance significantly the learning experience as they provide the learner with realism and interactivity.

3.4 3D Environment examples

One of the applications found was CAD Viewer (X3dom, 2017b), shown in Figure 5. It allows you to view 3D models inside the browser without any other software or plugins. This is useful because it facilitates access to these templates by allowing them to be opened on any computer with the internet.

Another application is CAD Component Editor (X3dom, 2017a), shown in Figure 6. It is a CAD application that allows the construction of models from primitive objects, besides allowing extrusions and revolutions of profiles. It is, therefore, an alternative, albeit limited, to the commonly used *softwares* in this area, which brings accessibility and unpaid use as advantages.

The Interactive Paraview Export (X3dom, 2017c), Figure 7, allows the scientific visualization of complex phenomena, such as fluid flow, as well as interaction with the model, allowing to obtain properties of each point. Considering the computational effort required to run CFD softwares and visualize such phenomena, this application becomes feasible.

Finally, CAEplex (Seamplex, 2017), shown in Figure 8, can be cited as one of the most complete and interesting online applications. It is a tool that allows structural analysis using the Finite Element Method without making use of any plugin or auxiliary software. Moreover, it allows the storage of the projects in the cloud, the sharing of the same with other people and, also, the access by smartphones. Its low price associated with easy access and smooth learning curve guarantee its didactic potential, especially in institutions that do not have educational license of other programs.

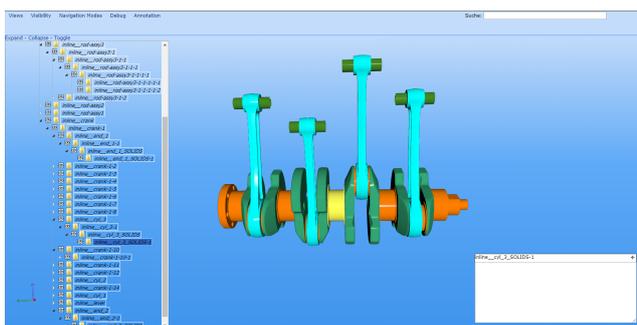


Figure 5. CAD Viewer

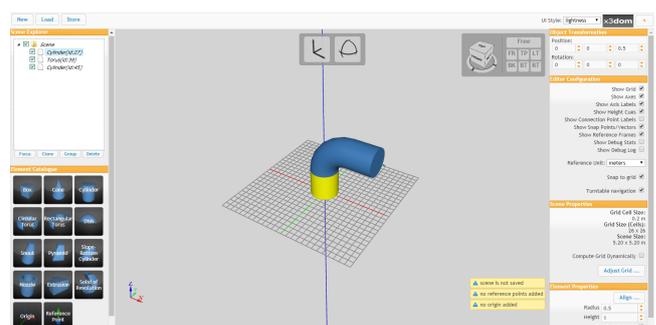


Figure 6. CAD Component Editor

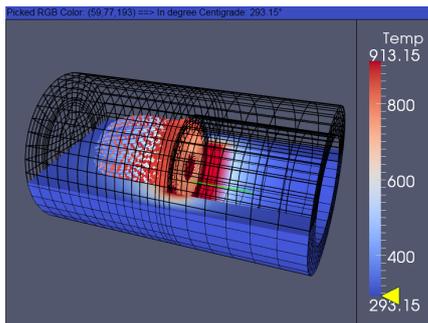


Figure 7. Interactive Paraview Export

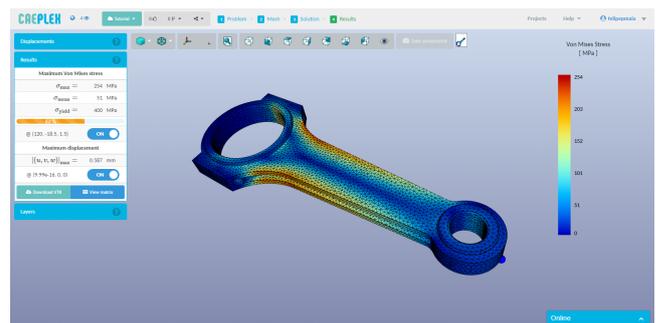


Figure 8. CAEplex

Regarding to examples implemented by the authors, one can observe in the Figures 9 and 10 models of a cutting tool and an academic rocket developed by the local rocket team, Potiguar Rocket Design. While the first model can be used to explain the different angles, edges and planes that exist in a cutting tool, the second allows you to explore the different components that make up a small rocket and may be used by the aforementioned team for disclosure purposes, for example.

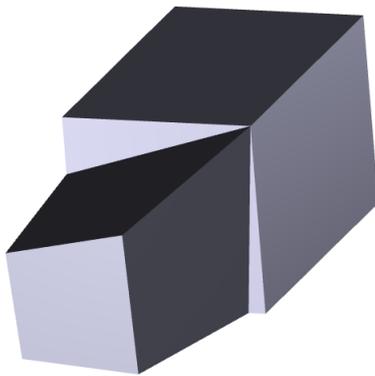


Figure 9. Cutting tool

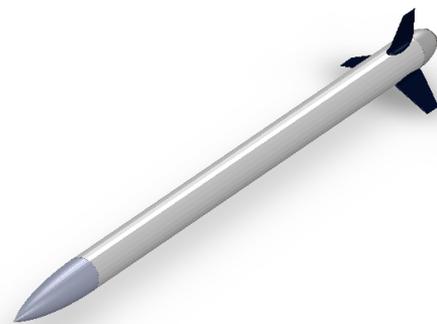


Figure 10. Academic rocket

4. CONCLUSION

Based on the results obtained, and following the methodology established in this paper, it can be concluded that:

1. The Mechanical Engineering areas that are most lacking in practice are, according to the students of the course of Mechanical Engineering of UFRN, the Mechanics of Solids, Thermodynamics and Manufacturing Processes.
2. Most students consulted support the use of 3D applications on the WEB as a way to reduce the lack of practice in the course.
3. According to the authors cited above, the WEB platform has didactic potential and, therefore, can be applied in the classroom as a teaching tool.
4. Several examples of online applications for Mechanical Engineering are already available on the WEB, and new applications can be easily developed.

As a suggestion for future work, can be develop a web portal that brings together several 3D applications aimed at different areas of different engineering. A collaborative system can be developed, allowing users to share the tools they develop.

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6. REFERENCES

- Abulrub, A.G., Attridge, A.N. and Williams, M.A., 2011. "Virtual reality in engineering education - the future of creative learning". In *IEEE Global Engineering Education Conference (EDUCON)*. Amman, Jordan.
- Aiello, P., D'elia, F., Tore, S.D. and Sibilio, M., 2012. "A constructivist approach to virtual reality for experiential learning". *E-Learning and Digital Media*, Vol. 9.
- Behr, J., Jung, Y., Keil, J., Drevensek, T., Zoellner, M., Eschler, P. and Fellner, D., 2010. "A scalable architecture for the html5/ x3d integration model x3dom". In *Proceedings of the 15th International Conference on Web 3D Technology*. Los Angeles, California.
- Belhot, R.V., 1997. *Reflexões e propostas sobre o "ensinar engenharia" para o século XXI*. Master's thesis, Escola de Engenharia de São Carlos.
- Bell, J.T. and Fogler, H.S., 1995. "The investigation and application of virtual reality as an educational tool". In *Proceedings of the American Society for Engineering Education 1995 Annual Conference*. Anaheim, CA.
- Chen, C.J., 2010. "Theoretical bases for using virtual reality in education". *Themes in Science and Technology Education*.
- Crockford, D., 2008. *JavaScript: The Good Parts*. O'Reilly, 1st edition.
- Devore, J.L., 2015. *Probability and Statistics for Engineering and the Sciences*. Brooks Cole, 9th edition.
- Hussein, M. and Natterdal, C., 2015. *The Benefits of Virtual Reality in Education - A Comparison Study*. Master's thesis, halmers University of Technology, University of Gothenburg.
- Jankowski, J., Ressler, S., Sons, K., Jung, Y., Behr, J. and et al., 2013. "Declarative integration of interactive 3d graphics into the world-wide web: Principles, current approaches, and research agenda". In *18th International Conference on 3D Web Technology (Web3D'13), Jun 2013*. San Sebastian, Spain.
- Kommers, P., 2003. "Experiential learning through constructivist learning tools". *International Journal of Computers and Applications*, Vol. 25.
- Masetto, M., 2004. "Innovation in higher education". *Interface – Comunic., Saúde, Educ.*, Vol. 8.
- Palomäki, E., 2009. *Applying 3D Virtual Worlds to Higher Education*. Master's thesis, Helsinki University of Technology.
- Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrovic, V.M. and Jovanovic, K., 2016. "Virtual laboratories for education in science, technology, and engineering: A review". *Computers and Education*, Vol. 95.
- Seamplex, 2017. "Caeplex". URL <https://www.caeplex.com>.
- Tornincasa, S., Vezzetti, E., Calignano, F. and Moos, S., 2008. "Integration of web3d technologies for e-learning platform oriented to product lifecycle management". In *20 Congreso Internacional de Ingeniería Gráfica*. Valencia, Spain.
- Waernér, M., 2012. *3D Graphics Technologies for Web Applications - An Evaluation from the Perspective of a Real World Application*. Master's thesis, Linköping universitet.
- X3dom, 2010. "X3dom". URL <https://www.x3dom.org>.
- X3dom, 2017a. "Cad component editor". URL <https://examples.x3dom.org/editor>.
- X3dom, 2017b. "Cad viewer". URL <https://examples.x3dom.org/cadViewer/sceneGraphConrod>.
- X3dom, 2017c. "Interactive paraview export". URL <https://examples.x3dom.org/example>.

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