The Use of Freeware in the Teaching of Engineering Design Graphics

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***Abstract* - In the modern education of Engineering Design Graphics, the use of CAD technology is essential in learning of theoretical concepts, such as Projective Geometry and Geometrical Modeling, for the development of spatial abilities and the mastering of the engineering graphics communication and design tool. Within this context, there is a demand for the CAD software in the Engineering courses. Recently, there are many freeware for graphics use, such 2D vector drawing and 3D modeler applications as well as CAD software. With constant improvement and updating, the potential of these freeware for the educational use is increasing quickly. Also, due to the cost, the availability of the CAD tools to the students is relatively limited. From the viewpoint of the students, the use of freeware instead of commercial CAD tools, whose access is limited due to the cost, may mean the possibility of doing the home works or practicing the projects at home. Thus, the objective of the present work is to analyze the feasibility of applying freeware for the teaching and learning of Engineering Design Graphics. The analyses were carried out by checking the functionalities of the freeware against the requirements of the course and by collecting information from mini-courses applied to the students.**

Index Terms – CAD, Engineering Education, Engineering Design Graphics, Freeware.

INTRODUCTION

In the modern education of Engineering Design Graphics, the use of CAD technology is essential in learning of theoretical concepts, such as Projective Geometry and Geometrical Modeling, for the development of spatial abilities and the mastering of the engineering graphics communication and design tool. Within this context, there is a demand for the CAD software in the Engineering courses. Most of the CAD software of professional use available nowadays has educational versions with reduced academic prices. Recently, there are many freeware for graphics use, such 2D vector drawing and 3D modeler applications as well as CAD software. With the constant improvement and version up, the potential of these freeware for the educational use is increasing quickly.

Beside the high quality of some of these freeware, there are several open source projects, which are in agreement with the educational and research purposes of the engineering schools, and allow the customization of the applications for the specific needs of each institution. On the other hand, the saving f the budged is a very attractive factor. Due to the scale of the usage and the need for periodical upgrade and daily maintenance, the budged to maintain a course of Engineering Design Graphics with commercial CAD software is not negligible. Even considering the academic discounts, the shortage of budged faced by many engineering schools of the developing countries requires a more cost-effective solution. Also, due to the cost, the availability of the CAD tools to the students is relatively limited. From the viewpoint of the students, the free access to the software is an important issue that means the possibility of doing the home works or practicing the projects at home and will banish definitively some undesirable illegal practices.

Since the most of the freeware are designed for specific task and have limited functionalities, it might be necessary to make use of several of them, integrated organically to form a free CAD system for the educational use. Thus, the objective of the present work is to study the feasibility of applying free CAD software to the teaching and learning of Engineering Design Graphics. At fist, a general survey, cataloguing is carried out. The freeware are analyzed considering their functionalities and portability. Then, based on the requirements of an Engineering Design Graphics course, several freeware are selected. Finally, the effectiveness of the free CAD system for the educational use is evaluated by lectures given to small groups of students and compared to results of a commercial CAD software.

In this paper, a brief overview on the teaching of Engineering Design Graphics in Brazil and in the Escola Politécnica of University of São Paulo (EPUSP), as wells as the results of the first part of the research regarding the freeware for two-dimensional constructions is presented.

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TEACHING OF ENGINEERING DESIGN GRAPHICS IN BRAZIL

In the beginning of the 20th century, due to the industrialization process, the teaching of Engineering Design Graphics gained spaces in the Brazilian engineering courses. The contents of the subject were strongly based on the theoretical topics such as Geometric Drawing and Descriptive Geometry that made parts of the contents of junior and senior high school's education in Brazil.

However, the change of the Brazilian education guidance in the 70's eliminated these theoretical topics by gathering them together with the artistic drawing under a subject of Artistic Education. Since then, the teaching of the theoretical topics has been restricted in few high schools and technical schools for the formation of intermediate level technicians. In this way, most of the freshman under graduating students of engineering courses started to face difficulties in the learning of Engineering Design Graphics due to the lack of the theoretical backgrounds. The reinforcement of the theoretical topics in the subjects of Engineering Design Graphics were challenged by curricular change in the Brazilian universities, that reduced gradually the time for the lectures. For this reason, several studies about more efficient methodology for the teaching of Engineering Design Graphics were reported [1].

In Brazil, the topics related to CAD were firstly included in the Engineering Design Graphics in the end of 80's. Despite of fast grow up of the professional usage of CAD technology and constant effort for the modernization of Engineering Design Graphics at the Brazilian universities, owing to the shortage of the budget, the spread of the teaching of CAD in the engineering courses occurs after the end of the 90's.

The difficulties of the transition of the teaching from traditional instrumental drawing to that based on CAD technology can be shown by a survey made by Moraes [2]. At the beginning of the 21st century, amount the Brazilian engineering faculties that participated the survey, less than 20% have included the concepts and practice of CAD in the subjects related to Engineering Design Graphics.

In order to overcome the shortage of the budget, many innovative experiences about the introduction of CAD in the teaching have been reported. Lima [3] reported the experience of the Department of Graphic Expression of the Faculty of Engineering of the Federal University of Rio de Janeiro (UFRJ). Deganutti, et. al [4] showed method the adopted by the Department of Arts and Graphic Representation of the São Paulo State University (UNESP-Bauru).

Nowadays, with emphasis on the development of the ability of space visualization, the concepts and the practice of CAD already coexist with freehand drawing in the subjects related on Engineering Design Graphics of Brazilian Engineering courses. However, searching for alternatives of small impact on the budget is still a great challenge for majority of the engineering.

ENGINEERING DESIGN GRAPHICS AT EPUSP

Escola Poltécnica of the University of São Paulo (EPUSP) is the pioneer in the introduction of CAD in the teaching of the Engineering Design Graphics in Brazil. The topics related to CAD were included in the end of 80's. After the successful experience with some of the class, the concepts and practice of CAD were applied to all the freshman students in the beginning of 90's. Strongly focused on CAD, in that time, the new technology replaced the traditional drawing and its related theoretical backgrounds.

In 1996, as a result of reformulation of the subjects of the Engineering Design Graphics of EPUSP, priorities were given to the development of the spatial abilities and the mastering of the engineering graphics communication and design tool. Within this context, topics such as Geometrical Drawing, Projective Geometry and freehand sketch were reinserted, in order to achieve a better balance between traditional theoretical background and Geometric Modeling by using CAD technology [5].

Nowadays, two subjects compose the course of Engineering Design Graphics of EPUSP: Graphical Geometry and Graphical Representation, which are offered to 750 freshman students of all engineering courses in the first and the second semester, respectively. Each subject has 30 hours of lecture. All the lectures are carried out in two LECs (Laboratório de Ensino de CAD - Laboratory for Teaching of CAD). The LECs were reformed in 2005, as a result of partnerships between EPUSP and more than 20 private companies. Both the engineering workstations and software NX3.0 used in the course are supplied by PACE Program (Partners of Advanced Collaborative Engineering Enducation). The CAD software Microstation provided by Bentley Systems of Brazil is also adopted in the teaching.

A remarkable aspect of the subjects is the project-oriented teaching and learning. Beside the lectures about the theoretical lectures of Geometrical Drawing, Projective Geometry and Geometric Modeling, there are 'Programmed Activities', where the presence of the studentes is not obligatory. In the 'Programmed Activities', assisted by the teaching assistants, the students can practice the modeling by using CAD and develop their projects – the solution of an engineering problem by using topographic drawing in the first semester, and the design and construction of a small electric car for the competition in the end of the academic year.

The subject of Graphical Geometry, which is offered in the first semester, is focused on the theoretical aspects such as Geometric Drawing, Descriptive Geometry and Topographical Representation. The CAD software used is Microstation of Bentley Systems is used to practice two-dimensional drawings. Basically, the students learn the commands of creation, modification and manipulation of two-dimensional figures to accomplish the project of the first semester [6].

The subject of Graphical Representation, which is offered in the second semester deals with the concepts of Geometric Modeling and Technical Drawing, such as perspectives, orthographic views, section view and dimensioning. The practice of geometric modeling and

generation of technical drawings are carried out by using CAD NX3, three-dimensional objects and surfaces are created by applying instance of geometric primitives, sweepings, Boolean operations, parametric modeling and modeling by constraints. Concepts of top-down and bottom-up Assembly are also applied.

Figure 1 shows the LECs of the EPUSP. With the specially designed layout and furniture, and up-to-dated hardware and software provided by the partners, they are one of the most advanced laboratories for the teaching of the Engineering Design Graphics in Latin America and are a reference in Brazil.

FIGURE 1
LABORATORY FOR TEACHING OF CAD OF EPUSP.

However, this situation cannot be applied to other Brazilian universities. As the cost to maintain an up-to-dated Engineering Design Graphics is relatively high in most of the Engineering faculties of the country, whose budgets are generally limited, as what happens in the developing countries, the use of freeware may be a very cost-effective solution for the teaching purpose.

CAD FREEWARE

Freeware is software that is licensed for its redistribution, but not for its modification. Its source code is not available. Besides the freeware, there are others software with different licenses, less restrictive than the freeware, such as the free software, whose source code is open (Hexsel, 2002). For the sake of simplicity, we designate herein CAD freeware as Computer Aide Design programs with the above mentioned licenses.

The use of CAD freeware presents several advantages, mainly in terms of cost. As in most of the developing countries, many Brazilian universities, mainly the public ones, faces the shortage of budged to maintain up-to-dated CAD systems used in their subjects related to Engineering Design Graphics. Even though that most of the commercial software has academic versions with discount, the students have limited access because the cost is still relatively high for them.

In this way, considering the possibility of using CAD freeware in the teaching of Engineering Design Graphics, we did a survey of the software. The Table 1 shows the results of the survey.

As shown by Table 1, there are few CAD programs with freeware license and even fewer with the open source; many of them are “demos”, whose resources is generally limited when compared to the paid versions, or are “trial”, whose license lasts a short period of time, normally 30 days. The size of majority of the programs is small, around 30 MB, what make the download very easy.

ANALYSIS

The analysis of the CAD software is carried out considering the content of the subjects related to Engineering Design Graphics. In Table 1, DeltaCAD is not freeware and it is trial version is used as reference for the comparison. The software QCAD is an open source GPL.

In this study, we based our analysis on the contents of the two subjects of Graphical Geometry and Graphical Representation, which are good references on up-to-dated course of Engineering Design Graphics in Brazil, and work, respectively, with two-dimensional and three-dimensional CAD. We divide the research in two parts. The first one, whose results are presented in this paper, is analysis concerning two-dimensional CAD freeware, aiming the development of a CAD system that can be used by the students to practice the basic two-dimensional CAD concepts. The second part is the analysis of the CAD and geometrical modelers for three-dimensional representations. The works about the second part is being undertaken and will be reported later.

After the survey and cataloguing of the freeware available, the first step of the analysis is the establishment of the criteria for the evaluation of the functionalities of each CAD freeware. For this purpose, the essential CAD software’s functionalities, which are required to practicing the concepts and developing of the projects, are identified and listed as following:

- Data input, including basic interface, coordinate systems, object snaps;
- Commands for creation: line, polyline, circles, arcs, ellipses;
- Commands for selection: select, unselect;
- Commands for visualization: zoom, pan, fit view;
- Commands for modification: trim, extend, chamfer, fillet;
- Commands for manipulation: copy, move, mirror, scale;
- Curves, hatch, and text;
- Supported file format;
- Macros...

A checklist is then created to serve as guidance for the evaluation of each freeware. In total, 21 freeware were catalogued and evaluated.

The results of the evaluation shows that the majority of the freeware CAD obtained satisfactory score in the items such as data input and commands for creation and manipulation. The data input of some software could be only made in relation to the last point. Undesirable error occurs in few programs when the manipulation command if applied, showing some instability. Regarding the curves, few work with b-spline and none presented the option to construct

TABLE I
THE RESULTS OF THE SURVEY ON CAD FREEWARE.

2D			
Name	Supplier	Type of License	Site
A9CAD	A9 Tech	Freeware	http://www.a9tech.com
CadStd	John Apperson	Freeware	http://www.apperson.org/cadstd/
Delta CAD	Cypress Software	Trial	http://www.deltacad.com
DESI-III	H. Mariën	Freeware	http://users.pandora.be/desi-iii/index.html
FelixCAD 5 LT	GiveMePower GmbH	Freeware	http://www.givemepower.de
Free 2Desing	Think3	Freeware	http://www.free2design.org
JustCad	Jon Hoke	Freeware	http://www.justcad.com
QCad	RibbonSoft GmbH	Open source	http://www.qcad.org
Solid Edge Free 2D	UGS	Freeware	www.solidedge.com/free2d/
3D			
Name	Supplier	Type of License	Site
3D Canvas	Amabalis	Freeware	www.amabalis.com
Blender		Open source	http://www.blender.org
CADX11	GRAYTECH	Freeware	http://www.graytechsoftware.com/products/cadx11/index.asp
DesingCAD	IMSI	Trial	www.imsisoft.com/faminfo.asp?fam=2
DesingWorkshop	Artifice	Freeware	http://www.artifice.com/
Free CAD	Aik-Siong Koh	Freeware	www.askoh.com
Google SketchUp		Freeware	http://sketchup.google.com/download.html
Minos CAD 2.2	John Apperson	Freeware	www.le-boite.com/downl.htm
My3DEngine	i-compute	Freeware	www.i-compute.net/projects_My3DEngine.php
Turbo CAD	IMSI	Trial	www.turbocad.com
VectorEngineer		Freeware	http://www.vectorengineer.com/
WorkCAD	CIENGE	Trial	http://www.workcad.com.br/index.php?session=download_trial

parabola. In all of the freeware, the hatching functions are very limited: Few have hatching command, and in those having the hatching command, only few hatching patterns are available or can only applied to regions whose shape is very simple.

The commercial CAD software being used by EPUSP, Microstation, which has an excellent features for the creation and manipulation of curves and a very efficient system for data input. Only one CAD listed in Table 1 present a data input system and commands for the manipulation of curves that is almost as good as the commercial software.

Due to the limitation on availability of time and space to carry out the mini-lectures, only three of the CAD programs were selected for a further analysis by applying a mini-lecture offered to freshman undergraduate students of EPUSP. The selection took into account the matching between functionalities of the software and the requirements of the subject of Engineering Design Graphics. The select software were: DeltaCad, FelixCad and QCad. The interfaces of the CAD programs are shown in Figure 2, 3 and 4.

The mini-lectures had duration of one 100 minutes. For each of the three above-mentioned CAD programs, a mini-lecture was applied. The application of the mini-lecture occurred one month after the beginning of the engineering course, because in that moment the freshman students were just being introduced to some basic concept and interface of the commercial CAD system actually being used by the course. Thus, they have no way to establish comparison or have some preferences influenced by the mastering of specific software.

The procedure adopted by the mini-lectures was to make first a brief introduction about the software, to show the interface and where to find the main commands. A sample exercise is solved and, after that, an exercise was proposed to the students. The proposed exercise is specially created to make the students test, step-by-step, all of the main

functionalities required by the subject, as listed in the following:

- Commands of creation;
- Commands of selection;
- Commands of manipulation;
- Commands of modification;
- Other commands: zoom, curves, hatches and etc.

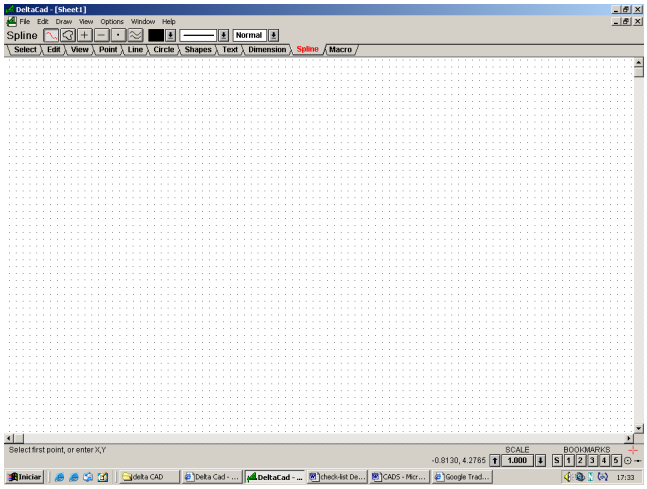


FIGURE 2
INTERFACE OF DELTACAD.

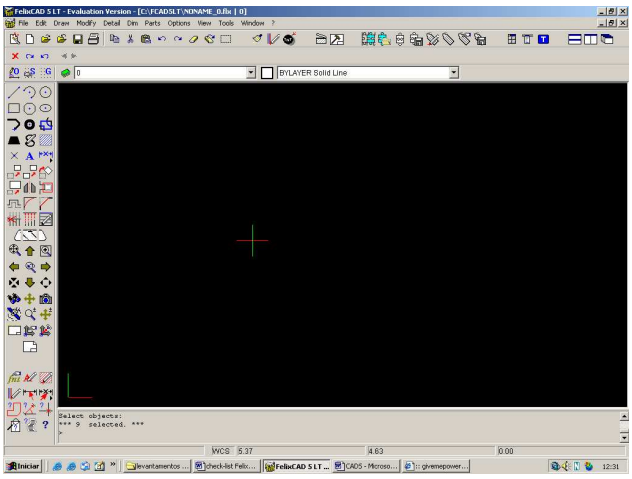


FIGURE 3
INTERFACE OF FELIXCAD.

In each step, the students were asked to give scores about the software regarding five attributes associates to usability, based on that used by Cheng and Yamamoto [7]:

- **Facility of learning:** the program must be of easy learning and allow the beginner to master the tool quickly.
- **Efficiency:** the program must be efficient so that the user, after learned how to use the program, presents the biggest possible productivity.
- **Low rate of errors:** the program must have verifications of the operations done the users with the objective to intercept errors. When error occurs, it must allow easy corrections.

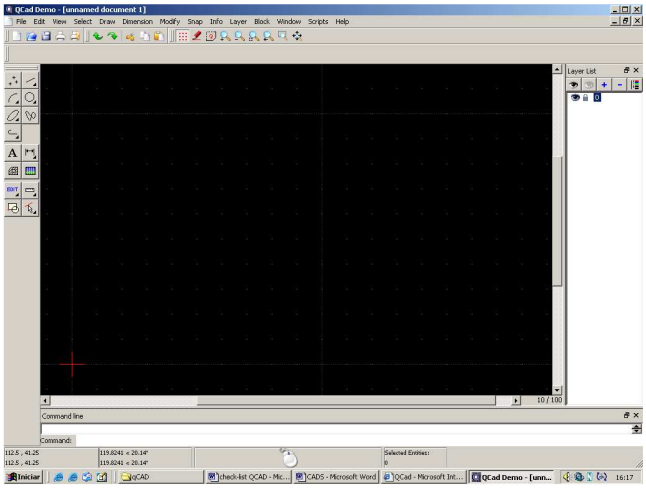
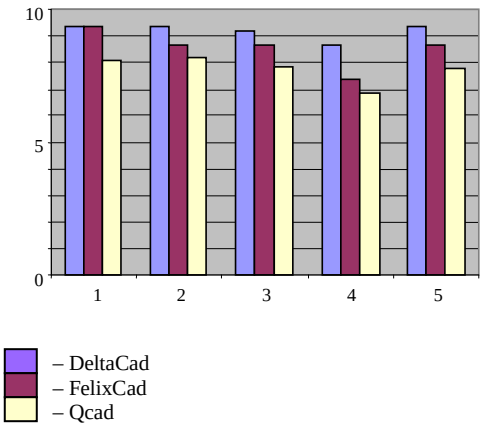


FIGURE 4
INTERFACE OF QCAD.

- **Help documentation:** the program must have a good documentation to help the user.
- **Satisfaction of the user:** the system must be pleasant to use.

Beside the scores attributed for each item, in the end of the mini-lectures, the students were asked to make comments about the interface, the help documentation, satisfaction, and the positive and negative aspects of the software. The results are shown in Figure 5 and 6.



1 – Commands of creation;
2 – Commands of selection;
3 – Commands of manipulation;
4 – Commands of modification;
5 – Other commands.

FIGURE 5
THE SCORE OF COMMANDS.

- **DeltaCad:** the students commented that the help documentation could be in Portuguese; the interface is satisfactory and functional through the tabs. The program seems to be simpler to understand than the commercial one used in the course.

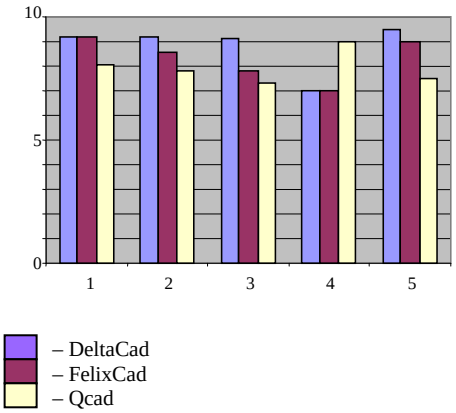


FIGURE 6
THE SCORE OF THE ATTRIBUTES.

- **FelixCad:** the students commented that the help documentation could be in Portuguese. Its interface is satisfactory as well as the software in general, and it is easy to learn. The data input seems to have some problems.
- **QCad:** according to the students, the help documentation is complete, detailed and of easy understanding. The program is easy to work and the commands are objective, the interface is very simple. Some problems occurred when applying the commands for modification.

CONCLUDING REMARKS

With regard to limitation of the budged faced by most of Brazilian universities to maintain up-to-dated CAD system for the teaching of Engineering Design Graphics, the use of CD freeware is presented herein as an alternative to reduce these costs.

In order to study the feasibility of using CAD freeware in the teaching, a survey about CAD freeware was carried out and it was found nine software for 2D projects and sixteen designed for 3D modeling. The 2D ones were evaluated considering the contents and the requirements of the subjects of Engineering Design Graphics of Escola Politécnica (EPUSP). As a result, three of them were selected and further analyzed by applying mini-lectures to the freshman under graduating students. The mini-lectures were consisted of a brief presentation of the program as well as of its interface, with an example, and then it was asked the students to solve a proposed exercise using the software. The results were satisfying, and the students, in general, enjoyed the interfaces but made some specific complaints about the programs.

In a first analysis, it was concluded that the utilization of CAD freeware is both valid and feasible to reach some didactics objectives.

The next step of the research is to evaluate the 3D programs available. After this, the possibility of integrating several CAD freeware to fully satisfy the requirements of an Engineering Design Graphics course will also be carried out.

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