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Decision-making models for choosing CAD software

Richard Devon, Gül Okudan, Hien Nguyen, Andras Gordon, Sven Bilén, Xinli Wu & Dhushy Sathianathan

Pennsylvania State University
University Park, United States of America

ABSTRACT: In this article, the authors provide a short history of entry-level Computer-Aided Design (CAD) and discuss three models that have helped Pennsylvania State University, University Park, USA, choose CAD software for undergraduate engineering students, namely: the scientific model, the trade expert model and the stakeholder model. Student survey data are used to illustrate their role as stakeholders.

INTRODUCTION

Since 1983, Computer-Aided Design (CAD) has been a part of the curriculum in the first year engineering course (EDSGN 100) at Pennsylvania State University, University Park, USA. The 24 years since then have seen many changes in both software and hardware platforms. The only commonalities over this period have been the fact that the College of Engineering at Penn State has always had a networked computer system, a reliance on undergraduates for running the computer networks and being teaching assistants for CAD in the first year course, plus a need to control costs in a potentially expensive environment. Throughout this time, the College has experimented with many software packages for teaching CAD to first year engineering students.

In this article, the authors document the accumulated CAD teaching experience of several faculty in addition to recommending how to select CAD software for the first year engineering curriculum. Furthermore, the results of a survey that document students' perceptions of the usage of two CAD packages are presented to support these recommendations.

The authors conclude with speculations about the future of CAD education and recommendations for future research. One caveat is that the authors are not trying to make a choice of CAD software in this article, but rather to lay out issues and decision-making approaches. The situation is also viewed as a *battle of the positives*. There are many different good CAD software choices with potentially similar effectiveness in an introductory CAD curriculum. Moreover, because professionals often use more than one software to do similar things and often have to change to new platforms with changes in organisational needs and/or changes in clients, instead of selecting the best software package providing an account of issues to be considered when selecting CAD software is more appropriate.

A Brief History of CAD

While the history of CAD dates back to the 1950s, most researchers consider the SketchPad thesis of Ivan Sutherland at MIT as the most dramatic moment in the history of computer graphics and hence CAD [1][2]. Sutherland was again at the centre of CAD history when he worked with Dale Evans and students, such as Bob Sproull, at the University of Utah in the late 1960s – along with stints at Harvard University and the University of California, Berkeley. Sutherland, his brother Bert, and Sproull later became an important nucleus at Sun Micro-systems in 1990 as that company started developing rapidly.

The early to mid-1980s saw the emergence of affordable, if limited-featured, desktop CAD and computer graphics with 2D systems running on the Apple II+s and IBM PCs. One of the earliest low-cost and popular 2D systems was *Generic CADD*, which was acquired by Autodesk and is still on the market at the low end. Autodesk itself was founded in 1984 and marketed *AutoCAD*, the best known name in desktop CAD, and still a major player in 2007. Another current major player is Dassault Systemes, which owns *CATIA*, high-end CAD software that was first developed in 1969 and is very widely used, especially in Europe. Dassault Systemes also acquired the mid-range package *SolidWorks* in 1997 (first developed in 1994), which is now an industry leader at its level. Another powerful company is EDS, which acquired *Unigraphics*, which had in turn acquired *SolidEdge* (created by Intergraph in 1996) and is also a competitive mid-range CAD package on the scene in 2004. In 2001, EDS also acquired SRDC, the owner of *IDEAS*, which is a very powerful competitor at the high end, particularly during the 1990s, and therefore a competitor with EDS' own *Unigraphics*. This acquisition process, which leaves companies with competing products rather than one getting terminated, is an odd characteristic of the CAD industry, and it has happened again recently with Autodesk buying *Revit* while upgrading its own *ADT 2004* [3]. Presumably the customer base of the acquired software is too large and too resistant to change.

Some pioneering CAD packages did not make it. One of the earliest CAD software packages for the Apple II+ was *New Kensington CAD*, named after a Penn State campus where it was developed circa 1984. The first good 3D wire-frame CAD for the PC was developed by Peter Smith and *CADKEY* in 1984-1986. Smith agreed to provide the University with 100 licenses of *CADKEY* free in 1985. This was one of the first efforts by a CAD vendor to use education as a marketing strategy. The first good desktop solid modeller was *Silver Screen*, developed around 1989, which was very popular on campuses throughout the 1990s, but not adopted widely in industry, although it is still extant. Nevertheless, these *desktop pioneers* figure prominently in the history of CAD education at Penn State in the first year engineering programme.

History of Entry-Level CAD Education at Penn State

At Penn State, CAD has been taught for over 20 years within the first year engineering course. The University's history of low-cost desktop computing and CAD software is reflected in several curricular changes (in addition to the computer platform and the software used throughout this period) were realised in order to keep up with software advances. A sketch of that history is given in Table 1 showing the platform, software and the relative presence in the curriculum of the first year course compared to traditional graphics instruction. While high-end CAD instruction has also been offered over the last decade, Table 1 only includes the developments in the College's CAD teaching for the first year course using entry- and mid-level software, which is the focus of this article.

In the 1980s, the emergence of desktop computer graphics and CAD caused much excitement, but the actual CAD products at the low-end were, at best, poor and of interest mostly as a glimpse into the future. The appearance of *Silver Screen* around 1989-1990, which provided affordable solid modelling on a desktop computer, was the watershed between CAD as a curiosity and CAD as a powerful tool. The University embraced it quickly and a widely-used text was produced [4]. Furthermore, research was conducted showing its utility for improving the spatial visualisation ability of students [5][6].

With the development of effective and affordable solid modelling software, there was a sharp increase in the use of CAD and, therefore, the demands on computer laboratory facilities. Accordingly, during the early 1990s, the College added a second computer laboratory and by 2000, there was a set of eight networked laboratories, workshops and classrooms [7][8].

The most striking thing about this history is that CAD education in engineering now employs, at a minimum, powerful mid-range CAD software. It has made entry-level software obsolete through a focus on user-centred design, as well as very effective learnability and usability supported by excellent online tutorials and help utilities. The best mid-range software is so powerful now that it competes with upper-level CAD and vice versa, as the high-end CAD developers have to compete with the best mid-range software's capacities in user-centred design for rapid learning and fast task performance. It is also of importance that vendors of many CAD packages have recognised the importance of providing large multi-user licenses for relatively little cost – in some cases no cost – directly to academia and students, bypassing resellers. After 5-10 hours, even first year students with no background in either CAD or mechanical drawing are building objects on screen that are often more complex than they could learn to draw manually on paper after three times as much studying in traditional graphics during the 1980s. Figure 1 displays an online, closed book CAD test that almost all students have completed successfully after as little as 10-15 hours of studying CAD.

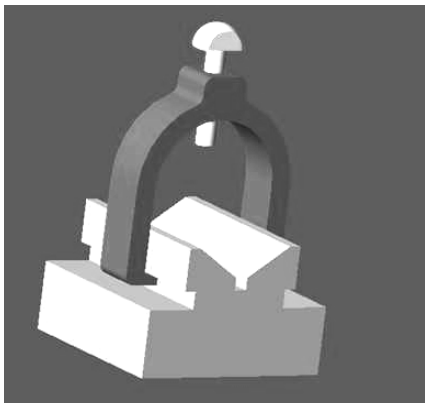

Figure 1: Real time test CAD problem.

Table 1: A history of CAD at Penn State in the first year engineering course.

Dates	Platform and Software	Notes	Curricula Presence
1983-1985	Apple II+ Networked *New Kensington CAD*-PSU	2D Local tutorial	10% CAD 30% Graphics
1985-Present	PCs Generic *CADD*	2D Local tutorial	15% CAD 30% Graphics
1987-1991	Colour PCs *CADKEY*	Wireframe 3D Local tutorial	25% CAD 25% Graphics
1992-1998	*Silver Screen*	Solid Modelling (SM) Local text	25% CAD 15% Graphics
1998-2002	*IronCAD*	Drag and Drop SM Local tutorial	25% CAD 12% Graphics
2002-Present	*Inventor*	Solid Modelling (SM) Online tutorial	25% CAD 10% Graphics sketching
2002-Present	*SolidWorks* 8-room network CEDE	Advanced SM Online tutorial	25% CAD 10% Graphics sketching
2002-Present	*Alibre Design*	Collaborative tools SM Online tutorial	25% CAD 10% Graphics sketching

Selecting CAD Software

Three different models for choosing CAD software are presented here. The most desirable is the scientific model based on a systematic assessment using objective measures. However, one lesson from history is that this approach is costly to implement when the technology changes rapidly. The second approach is to use the reviews of experts in journals and trade magazines. These are usually very subjective but are up-to-date, and reveal important information about the functionality, cost and availability of the latest software and its upgrades. The reviews also reveal information about adoptions, that is, about the assessments of others who commit resources to it. The third approach is the stakeholder model and this is the one most used by the College in the past although trade publications are certainly followed.

The Scientific Model

Despite the similarities in the capabilities of mid-level CAD packages, differences do exist in their functionality, performance, Graphical User Interfaces (GUI), learning curve, etc. Thus, one needs to carefully study alternative packages and choose the best to satisfy the needs of students and the curriculum. However, before the selection can be made, the selection roadmap and criteria should be clear. Accordingly, the literature on CAD software rating, criteria, and comparison has been studied. A summary of these findings is presented here.

Previous studies on comparing solid modelling software include: a CAD expert offering his/her review comments for various products without providing an established set of criteria; rating a software using a predetermined set of criteria; comparing several similar software packages using predetermined criteria. For example, one can find solid modeller review and ratings in *Professional Engineer* and *CADENCE* (now *CADALYST*) magazines. Several examples can be listed here. The January 1993 issue of *Professional Engineer* includes a review on four different low-cost CAD offerings by a CAD expert, where no particular review criteria are provided [9]. The October 2003 issue of *CADENCE* contains a review of *CATIA V5 R11*. After its review, ratings are provided for the criteria including installation and set-up, interface/ease of use, features/functionality, expandability/ customisation, interoperability/Web awareness, support/help, speed, operating systems, and innovation [10]. However, there are several problems with this type of rating scheme. For example, it is not possible to compare the ratings of two different software packages completed by different experts, because the way that the experts have interpreted the criteria might be different. Even when the same person has evaluated a number of different software packages, the potential bias the evaluator may have towards one application is very hard to eliminate – especially if the reviewer uses one of the reviewed packages in his/her work. In fact, this problem was brought up by Martin and Martin, and studied using published reviews and the expertise of reviewers [11].

It is possible, however, to eliminate the potential bias one can have towards one package by introducing expert users to the comparison. For example, Martin and Martin, as well as Kurland, invited various vendors to supply operators to partake in separate comparison studies [11][12]. In this manner, potential biases due to partiality towards one software over the other, or differences between software operators in terms of their skill levels, were eliminated. However, in this case, it is not clear if the solid modelling package can be utilised by any user as effectively as the expert user partaking in the studies after an adequate learning period. In other words, experimenting with an expert user cannot yield broader conclusions because the GUI of the modeller can be interpreted differently by different users. Therefore, the GUI is the primary determinant of the overall usability of the modelling package and the productivity of the user [13].

In the 1980s, the introduction of icons and small pictures, as well as the incorporation of a desktop mouse as an input mechanism, changed the Human-Computer Interaction (HCI) [14]. The implementation of the GUI takes advantage of the human capability to recognise and process graphical images quickly, and has become a universal HCI standard. Accordingly, most solid modellers use it today. However, the development of interfaces is a concern for software developers because it might be a barrier in solid modelling education and engineering practice [15]. It is believed that the layout of GUI elements influences the way that the user can interpret them [16]. While the user's correct mental model of the interface can help with his/her productivity, a false image of the interface might mislead them and limit their ability to work with the software effectively [17]. Therefore, it is clear that differences in the user's mental models of GUIs are expected and thus productivity differences may arise. This point makes it clear that any comparative study of solid modellers should involve multiple users being tested under similar circumstances.

Accordingly, Okudan studied the student performance in an experiment where they were asked to complete two solid modelling test problems using two different modellers: *Inventor* and *SolidWorks* [18]. Two performance measures were used in this experimentation as follows:

- The correctness and completeness of the solid modelling drawing (assessed by a performance grade between 0-1);
- The time taken to complete the drawing in minutes.

For both test problems, students were asked to build the solid models, create standard multiviews and an isometric view, and complete the dimensioning. During the their work on test problems, students were not allowed to ask questions or talk to each other; they did use identical computers in the same computer laboratory.

Using *Minitab*™ Release 13.1, differences of sample averages for user performance and completion time for both test problems were tested for their significance. The P values for all four of the two-sample t-tests, differences in the sample means were not found to be statistically significant. This means that for the functions that were the subject of comparison, both software deliver similar results with a similar average time for students to complete the same problems. Moreover, variance tests were conducted for the completion time of test problems. When the hypothesis test for the equality of variances between the two samples for test problem 1 using an F-test was completed, the sample variances were found to be significantly different. The significant difference in sample variances indicated a more homogeneous user performance data for one of the software packages.

A follow up study by Okudan proposed the Solid Modeler Evaluation and Comparison Cycle (SMECC), which utilises the Analytic Hierarchy Process to model the software selection problem in a comprehensive fashion where user performance, environment and cost issues were considered as comparison criteria [19].

Ultimately, however, the scientific model is most useful for redesigning the next generation of CAD software. It can rarely produce enough definite results in a timely manner to help with acquisition decisions. That data reported here, however, are useful.

The Trade Expert Model

The less scientific approach of the expert testimony questioned above is nevertheless widely used and exemplified by the expert commentary available online. There are many good sources for this, like TechniCom, CADInfo, CAD User, CAD-Portal, CADwire and *CADD* Primer, which are actually promoting the name but have very good links [20-25]. These are invaluable, if risky, sources of information on a rapidly changing world. They provide critical insights on a subject that will be returned to later, ie functionality. In this regard, scientific studies cannot meet the need for that sort of information when making decisions about which CAD package to use as they are rarely comprehensive. As Martin noted in his review of competing Autodesk products, *Revit* and *ADT 2004*, *We now have a problem that we have to face in the CAD business time and time again—where do we invest our time and money?* [3].

The Stakeholder Model

In deciding what factors to consider in making a package selection decision, a stakeholder model has been developed since it embraces a broader view than just that of whomever makes the purchasing decision (see also ref. [26]). In such a model, even software performance is embedded as just another, albeit important, criterion. The criteria listed below have been roughly ranked and contain some commentary according to experience and some survey data. The authors explain this model fully since it has, at least in hindsight, been used by them extensively.

The administrative criteria are as follows:

- Cost to university: the College has been very successful in paying little to nothing for the CAD software used over almost 25 years, and only locally produced or online tutorials have been used. The unavoidable costs are, of course, associated with implementation, maintenance and training;
- Infrequency of upgrades/long-lived educational platform: one online source listed 17 CAD upgrades, and this was a weekly publication [27]. It has been a particular problem with one of the CAD systems used that upgrades easily on individual computers but was very inconvenient on the networked system used by the College for instruction;
- Ease of installation and maintenance in a networked environment;
- Stability of software (no lost files or crashed software);
- Well received by students.

The student perspective is as follows:

- Cost to students: this is very important, but students have never been required to own their own copies of the software. Several of the CAD packages have used have offered inexpensive purchase options or free, limited-duration license (eg 150-day or *while registered as a student*). For example, *Alibre* has been provided free to the entire Penn State community;
- Personal ownership: this is also very important since it allows for students to work on their own computers and enhances their ability to use the CAD application for other productive purposes;
- Access to computer laboratories: this again very important if students do not own a copy of the software. At Penn State, it took some time to get *SolidWorks* available in most student laboratories other than the initial ones;
- Software efficacy: ease of learning and use, and functionally powerful;
- Stability of software and good file management;
- Reuse in other subsequent courses: there are currently requests to use *SolidWorks* from one department and *AutoCAD* from another; and this contributes to the need to offer two different courses. It does not look as though this will proliferate any time soon;
- Value in the professional world: some students use CAD during their summer internships as soon as at the end of their first year.

The instructor criteria with regard to software quality are as follows:

- Learnability (a quick learning curve is good);
- Intuitive with fast task performance;
- Comprehensive array of functions;
- Clarity: minimising student problems;
- Good online tutorials and help;
- Good resources, such as a parts library;
- Good integration with related tools, such as FEA;
- A defensible choice within the professional community.

The instructor criteria regarding curricula relevance are as follows:

- What do students need to know and why? Are students being trained as CAD experts or design engineers? Which idea is the driver?
- Should the focus be on one CAD software package only or is the idea that students will have to be versatile and use many CAD packages? Wiebe, for example, has studied transferable elements, such as high level modelling strategies [28]. One option is to show students how to do things in more than one CAD package. At least one such experience could make sense to show students how solid modelling skills learned on one package are transferred to another package. Students should avoid *package fixation*, which can occur due to a potential employer requesting familiarity with one package or another. Indeed, industry designers often use more than one CAD software package at a time. An example of this is the *Battle of the Bands: a 3d CAD Software Shootout* [29];
- In what courses will students subsequently require CAD: what are the needs of that course and will the same CAD package be available? If the next course is two years later, will students have forgotten how to use it? Will the software have changed?
- Are all the essential needs for CAD/computer graphics being met? This question is beginning to attract attention. Some graphics topics have been moved to the CAD

curriculum at Penn State and sketching is used for the others. But as more design is taught, the need for new tools is apparent during the conceptual design stage when most CAD packages are more than what is needed and manual sketches have to be scanned or photographed to get into the database for reports [30][31]. Manual sketches, therefore, are in a cumbersome mode for iteration and also lack colour. The College is experimenting with digital ink technologies like pens and tablet PCs. Similarly, the value of feature-based representation is being acknowledged where complex details are left blocked out and simplified with a text description, and the use of edited photographs and videos are appealing.

Industry Criteria

In a two-year curriculum where students may go to work in local companies, the industry use of CAD could influence the decision about what to teach. For example, *AutoCAD* is often chosen because of its use in many types of small-to-medium-sized companies. But in a four-year curriculum, there may be no such choice available in courses that teach students who enter a wide array of engineering fields. In this market, *Inventor* by AutoDesk may be a better choice. At the capstone level, there may be a tendency to use a particular CAD package in a particular discipline of engineering.

Overall, the governing assumptions are that industry is characterised by change with most companies use more than one CAD package at any given time, and that learning one CAD package makes learning the next one much faster. Thus, most of the time in a four-year curriculum, learning one or more good CAD packages may be more important and relevant than which ones. It is also important for students to learn what the functions and operations of CAD are and this is the core curriculum regardless of what software is used.

The Student Perspective: Report of a Survey

Data is presented below that was collected in an exploratory study that is serving mainly to start a new assessment process for the role for CAD in the engineering curriculum. The study and its analysis should trigger further inquiry yielding questions that will be targeted for examination and reporting in the future.

A short, online questionnaire was constructed and given to students in the first year engineering course (EDSGN 100). In fact, 80% of the 155 students who took the questionnaire were 1^{st}, 2^{nd} or 3^{rd} semesters, so it is not just first year students who take this first year course. Basic descriptive data was collected, such as semester standing, gender, intended major and if the students had CAD or mechanical drawing experience prior to attending Penn State. The remainder of the survey consisted of measures of student satisfaction using a Likert scale with the software for learning, using and access/owning. A subset of 119 responses were used coming from six sections that used two instructors. Each instructor taught two classes with *SolidWorks* and one class with *Alibre Design*. This experimental design provided the controls for the instructor. However, the study was viewed as a way to begin a new examination of what is being done with CAD and the data did not change how the authors felt about the two software packages used. They were both very good and both functionally different in ways that were considered important. It is not a big data set and only satisfaction data was looked at and not performance data. Indeed, it is hoped that this will lead to better questions and ideas for evaluation methodologies.

The Data

The data are reported in Figure 2. They were collected using a 5-point Likert scale where 5 is *strongly agree*. A few questions were stated in a negative manner to reduce response bias. Note that one question below was negative: agreement with the difficulty of file management.

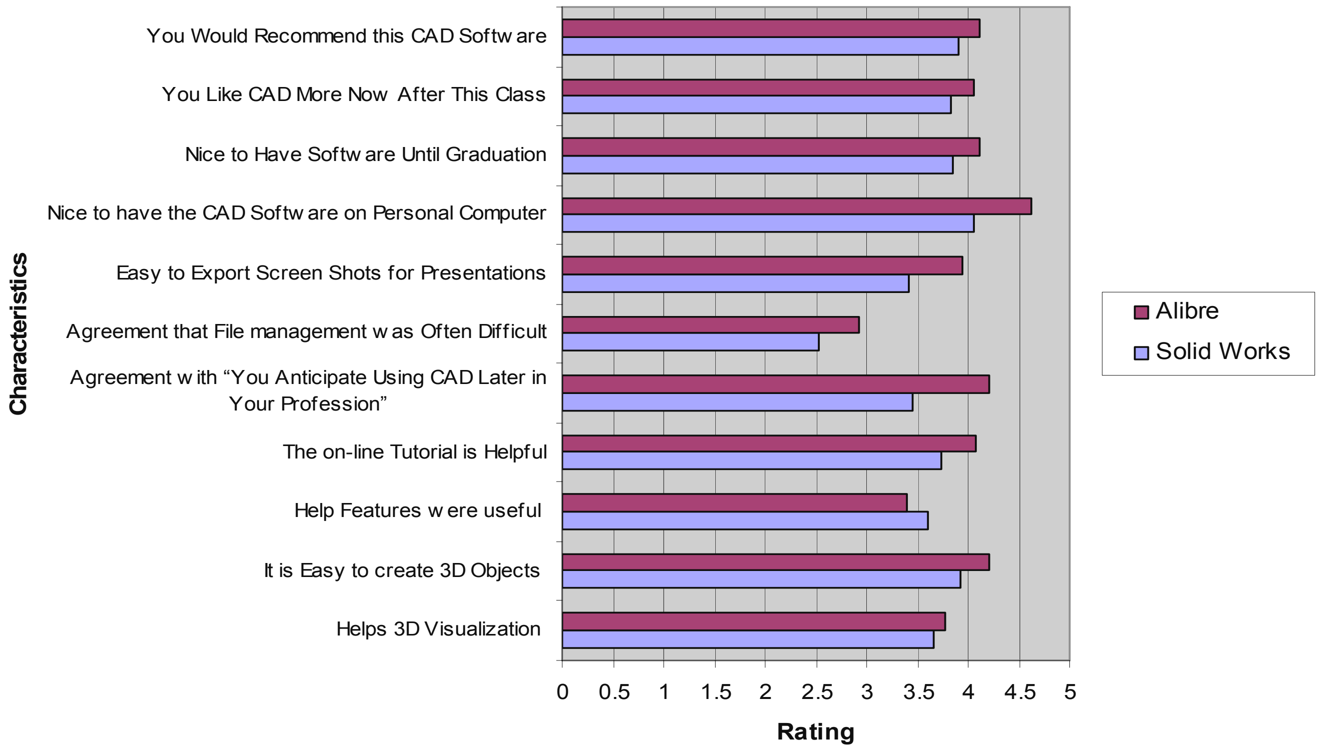

Figure 2: Student ratings of two CAD software (*Alibre* vs. *SolidWorks*).

The data reveal that *Alibre*, by a new company, performs very well against the most popular mid-range CAD software; this confirms the view that the choice for CAD literacy is not very important from a student's perspective. There are many good choices at the entry level, and *Silver Screen*, *IronCAD* and *Inventor* have also been tried with good results. Other stakeholders, of course, have different considerations, such as the Department of Mechanical Engineering choosing *SolidWorks* for its upper division design courses.

The initial analysis of the data provided the following observations. The intended major does not show much effect except a tendency for chemical engineering students to show less interest than students in other majors. Gender also had few effects. Prior study of mechanical drawing regularly correlated with valuing CAD more. Most of the data confirmed views of the software and what is important to students. The only result not understood was why *Alibre* use correlated strongly with anticipating using CAD later professionally. This is a potentially significant metric of the impact of CAD that may be worth looking at more closely. Overall, given how powerful and well designed these CAD packages are, it is thought that better overall levels of satisfaction should have been achieved. What was found was a *good* response (except for file management) to the CAD software from the students, but why was it not *very good*? Perhaps history gives a perspective to the instructors that the students did not have: this is all they know.

How the Decisions Are Being Made

Although there are sensibilities about almost all the items on the stakeholder list, a few criteria have always been important: functionality, cost and performance.

Functionality

Online reviews of software are supplemented by commentary of industry adoptions. Such adoptions almost universally refer to the functional relevance of the software for, say, surface modelling, Product Lifecycle Management (PLM), or drawing management features, and for applications from naval architecture to powertrains [29].

Both of the CAD software packages discussed here are of very good quality. *SolidWorks* is considered one of the best, if not the best, mid-range-plus CAD software with excellent reviews and some features, such as a parts library and an animation capacity that *Alibre* did not yet have at the time of the assessment. *Alibre* has been under development and prone to more upgrades that occasionally trigger problems, but the upgrade frequency is slowing down and *SolidWorks* has not been entirely problem free. *Alibre* is equally well received by students and still offers a very competitive low cost option in industry. *Alibre*'s learning curve and task performance look particularly good, so this is one question that might be pursued: how to measure the learning curve and obtain good performance data? Perhaps this is an area for the development of a metric that would allow more use of the scientific model for decision making.

Alibre has excellent peer-to-peer collaborative tools that allow imports from almost any other CAD software and a shared resource environment on *Alibre*'s servers. Since cross-national teams are part of the University's global design initiatives, this is one reason why *Alibre* has been used in several classes.

Cost to the University and the Student

Although acquisition and support cost to the department/ university are important, the cost to acquire personal copies has always been of concern because students often wish to use it on their personal computers, which allows for work outside of the computer laboratories. It should be noted that, when a student owns the software, it is used more heavily in the course, as well as far more likely get used again after the course is over. Additionally, in the few engineering courses that require CAD but do not teach a specific package (eg capstone design courses), which CAD software is used may not be an issue as long as it is good and this seems to be well assured now. *Alibre Design* has been free until graduation – and now beyond – and *SolidWorks* has been providing free 150-day licenses. Placing copies of software in students' hands has become an area of intense competition among CAD software companies, and rightly so. It is believed that Penn State was one of the very first to do this with *CADKEY* in 1985.

Performance

Neither faculty nor students wish to waste time with poor-performing CAD software. It must be easy to learn and to use. However, measures of this are needed that can be used to assess the merits of software for these factors, even though one might be unsure that there is much of an issue here with so many good options on the market.

Curricula Relevance

In the first year course, the engineering design process is used as the driver. There has been a move steadily into design over the last 15 years [32]. The first year course is now considered to be a design course and CAD is taught as a tool for the design process [33][34]. This actually does not change things much except that it can be arranged to have CAD (and graphics) needs in design projects that help contextualise their learning in the course, such as in drawing concepts and fabricating small rapid prototype models (see Table 2).

Table 2: CAD use in the phases of the engineering design process.

Concept Generation Stage	Solution & Analysis Stage	Testing & Prototyping Stage	Implementation Stage
CAD features used: 2D sketching 3D modelling of solid parts Assemblies of parts Online collaboration (available with *Alibre Design*, also in *SolidWorks* but not in student version)	*CAD features used:* Assemblies of parts Animation of assemblies FEA analysis of solid parts (*SolidWorks* only) Online collaboration (*Alibre Design* only)	*CAD features used:* Assemblies of parts Animation of assemblies FEA analysis of solid parts (*SolidWorks* only) 3D printing (rapid prototyping) Online collaboration (*Alibre Design* only)	*CAD features used:* Complete working drawings Building BOMs 3D printing (rapid prototyping) Online collaboration (*Alibre Design* only)

Next Generation CAD Features

While not disavowing the assessment criteria discussed above, there are some other important factors that could help facilitate the next generation decisions for both the choice and use of CAD software in CAD education. The suggestion is to examine end-use criteria more closely and stay focused on the changing professional context. There are three dimensions that interest us at present, namely:

- CAD for co-located teams, or for distributed, virtual teams. Messenger software is used and Adobe *Connect* for global design teams, but there is not a common ground for CAD;
- CAD for innovative conceptual design that supports the entirely different needs of conceptual design communication [30][31];
- CAD for engineering design or CAD (surface modellers) for industrial product design.

If engineers can expect their work environments to be increasingly characterised by global, mobile and virtual work, then CAD software that readily allows such collaborations and which may be readily integrated with other tools of the workplace would be the better choice. In this regard, peer-to-peer (P2P) software like *Alibre* are worth a closer look, but they will not always get that unless they are viewed as having comparable functionality for other features. Web-based software, such as Google SketchUp, wikis and spreadsheets, also seem destined to grow in quality and significance. Finally, new digital ink software is emerging, particularly for tablet PCs, as the importance of conceptual design in mobile environments grows.

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11th Baltic Region Seminar on Engineering Education: Seminar Proceedings

edited by Zenon J. Pudlowski

The yearly *11th Baltic Region Seminar on Engineering Education* was organised by the UNESCO International Centre for Engineering Education (UICEE) and held Tallinn, Estonia, between 18 and 20 June 2007. The Seminar attracted participants from 10 countries worldwide. Almost 40 papers have been published in this Volume of Proceedings, which grossly document and present academic contributions to the Seminar. All of these published papers present a diverse scope of important issues that currently affect on engineering and technology education locally, regionally and internationally.

The principal objective of this Seminar was to bring together educators from the Baltic Region to continue dialogue about common problems in engineering and technology education under the umbrella of the UICEE. To consider and debate the impact of globalisation on engineering and technology education within the context of the recent economic changes in the Baltic Region, as well as in relation to the strong revival of the sea economy. Moreover, the other important objectives were to discuss the need for innovation and entrepreneurship in engineering and technology education, and to establish new links and foster existing contacts, collaboration and friendships already established in the region through the leadership of the UICEE.

The papers incorporated in these Proceedings reflect on the international debate regarding the processes and structure of current engineering education. They are grouped under the following broad topics:

- Opening address
- Education and training for engineering entrepreneurship
- Innovation and alternatives in engineering education
- New developments and technologies in engineering education
- Quality issues and improvements in engineering education
- New trends and approaches to engineering education
- Simulation, multimedia and the Internet in engineering education

It should be noted that all of the papers published in this volume have undergone an international formal peer review process, as is the case with all UICEE publications. As such, it is envisaged that these Proceedings will contribute to the international debate in engineering education and become a valuable source of information and reference on research and development in engineering education.