

# The Study on Engineering-Type Parametric 3D CAD Used in Training Art & Design Major Students

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## Abstract

Faced with international competition to lower production costs and shorten product development time, most 3C manufacturing and design industries have implemented parametric three-dimensional computer-aided design (3D CAD). At meanwhile, designers have been requested to use such engineering-type CAD for concept design modeling. Asian universities have recently responded to employment-related student demand by having an increasing number of their art and design faculties open training courses on this. These non-engineering majors will require more assistance in learning engineering-type CAD as it will be more difficult for them than for engineering majors. The ODSSE (Orientation, Decomposition, Simplify, Sketch, Ends, ODSSE) system-five modeling strategies for Web-based lectures were developed to help parametric 3D CAD learning among non-engineering majors to enhance learning efficiency. Thirty-four sophomore students with one semester of 2D (two-dimensional) CAD training were used as study subjects. They were randomly divided into two groups (experimental and control group). The performance of the students in the two groups was then systematically analyzed and compared.

**Keywords:** Parametric, 3D CAD, Non-engineering major, Performance, Web-based

## 1 Introduction

Multimedia technology refers to interactive, computer-based and mobile phone based applications that allow people to communicate ideas and information with digital elements [1]. Digital games that contain multimedia features can be designed to attract players' attention. Relevant studies have indicated that digital game-based learning (DGBL) possesses significant potential for increasing students' learning motivation and enhancing their learning effectiveness [2-5]. Woo developed a computer-aided

design (CAM) game, and lectured on CAM course for 8 weeks and provided the CAM game to guide learning. The experiment results confirmed that learners' learning motivation, cognitive load, and performance possess latent correlations in DGBL [6]. The researchers investigate the impact of Web-based learning technology on student engagement, and the results show a general positive relationship between the use of the Web-based learning technology and student engagement and learning outcomes [7]. For learning, the design of the digital world is becoming more and more important. And paying attention to users' interactive experience design can increase users' satisfaction [8-10].

Bauhaus's basic design education's "learning by doing" tradition incorporates the computational and parametric logic required for contemporary design techniques to be a feature of current industrial design courses [11]. Faced with international competition to lower production costs and shorten product development time, most 3C manufacturing and design industries have implemented parametric 3D CAD. Functions include design-change, integration of front-end design and back-end manufacturing resources, etc. At the same time, designers have been requested to carry out the direct application of such engineering-type software for concept design 3D modeling, so as to shorten the time required for product development. CAD model quality in parametric design scenarios largely determines the level of flexibility and adaptability of a 3D model as well as its reusability [12]. As opposed to intuitive 3D CAD applications such as Alias and Rhinoceros[13-14], which are favored by designers or users with non-engineering backgrounds, However, because most industrial design majors are trained in the field of aesthetics, with sketching and hand modeling as these students' background knowledge, they will require more assistance in learning engineering-type parametric 3D CAD (including mathematical foundations,

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computer skills, engineering knowledge and design methodologies) as it will be more difficult for them than for engineering majors. Most of the research that has been undertaken on 3D CAD training has focused on the disciplines of mechanical and electrical engineering [15-17]; there has been a pronounced lack of research on 3D CAD learning by students who do not have an engineering background. In 1962, Mr. Ivan E. in MIT first wrote about CAD in his doctoral thesis “Sketchpad – A Machines Graphical Communication System.” In 1980s, CAD was gradually developed to apply on mechanical and civil engineering. After Mr. Hartmut Esslinger in Germany proposed “Digital Bauhaus” in 1990, CAD was becoming a major subject in industrial design courses. Currently, CAD is a core technology for industries. Using CAD or not, is no longer a question in industrial capacity. The issue is to improve users’ skills on product development, procedures and maximizing the advantages of CAD by cost-effective training [15]. Because companies benefit from using CAD in terms of cost-effective, quality improvement and less production time [18], professional CAD users are in demand and have a competitive advantaged in the manpower market [19]. CAD has been the core course of many technologies based programs in Spain since the university course guidelines were revised in 1990s. Teachers have tried different methods or tools to teach CAD, but half of the teachers mentioned they need double the hours to finish the training [20]. Students get keyboard practice but very little CAD working knowledge. Not enough focus was put towards learning skills required for design procedure and working efficiency [21]. In fact, the use of CAD requires basic knowledge like geometry, computer science, and design methodologies. CAD has become a global engineering software, and updates from the developer keep industries current. More and more universities and industries are interested in training and education of 3D CAD, although the continuous challenges are coming [22-23]. To fulfill with the requirements of industries, parametric 3D CAD software has been gradually introduced to education [20]. 3D CAD software is demanded by companies with many drawings needs, because of the cost-effective benefit from parametric software, featured functions, and efficiency for product design. CAD software with parametric features is already the main stream of the technology in many

industries [21].

The application of multimedia technology in Web-based learning [7, 24] and digital game-based learning [3-4, 6] has proven to improve student learning performance in recent years. Thus, this study analyzed the modeling knowledge of several parametric 3D CAD programs, figured out the common modeling strategy, and designed the common modeling procedures can be applied in different programs. This modeling strategy, which can help non-engineering majors (or novices) learn the software, is the base of CAD modeling. This study integrates these modeling strategies, interactive design and multimedia technology to develop the Web-based training system. At the end, this study discussed the experimental results from this training system.

## 2 Research Methods

### 2.1 Methodology

The faculty 3D CAD lecture implemented by this study was a weekly 3-hour lesson which lasted for 9 weeks from the beginning of the semester, with Creo Parametric (formerly known as Pro/ENGINEER) used as lecture software. Thirty-three sophomore students (department of art and design) with one semester of basic 2D CAD (AutoCAD) training were selected as study subjects. These 33 test subjects were then randomly divided into two groups: an experimental group and a control group.

Training of 3D CAD can be briefly categorized as Bottom-Up and Top-Down. Bottom-Up is widely introducing the functions and applications of every command, and then teaching how to use those commands in the modeling procedure. Top-Down is taking parts as examples and teaching the use of commands during the modeling procedure. Bottom-Up seems to be boring and less motivate for the students, while Top-Down usually motivate students better as students have more accomplishments during the process. Top-down teaching method was implemented in both groups, with Creo Parametric training material in the control group and ODSSE implemented in the experimental group during weeks 1-9 according to lecture progress (as shown in Table 1). All the lectures were provided during the regular teaching hours.

**Table 1.** A time-line for the experiment-long of parametric 3D CAD course show the interleaving of the general strategies of procedure of model design

weeks	1	2	3, 4	5, 6	7, 8	9
Lectures	Part orientation	Part Decomposition	properly Simplify features	2D-sketch geometry(1)	2D-sketch geometry(2)	Better Growth-Ends

Tests were provided in the 9th week, and test models are shown in Figure 1. Test1 is the model for beginner

[16], Test2 is designed for experienced users. Students have had two minutes to review and ask

questions before test started, and performance time of each student was recorded.

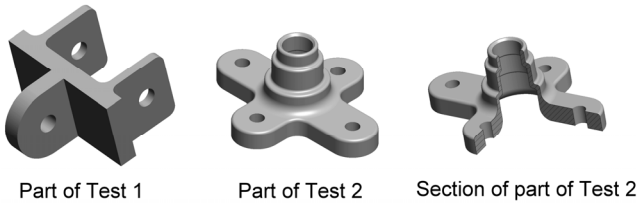


Figure 1. Test models

2.2 The ODSSE System (Five Modeling Strategies)

Programs as complicated as 3D CAD provide more than one method to complete some certain tasks. How to select an efficient model development method is a question that can't be answered by command-based training? Different commands from different programs will also limit the possibility to answer this question. There are so many similar software tools available on market, it is impossible to introduce every one of them in class. However, it is possible to find some common things about those software tools and tips to help students to learn software tools quickly [17]. Our study analyzed parametric 3D CAD programs like Creo Parametric, Solidworks and Inventor figured out the common modeling strategy, and designed the common modeling procedures as Figure 2. The general strategies of procedure of model design are called ODSSE method—Orientation, Decomposition, Simplify, Sketch, and Ends. In most universities, the teaching focus of CAD is procedural knowledge, so some students might not be aware of the concepts underlying the procedure used in 3D CAD [25]. ODSSE provides conceptual and procedural knowledge learning to enhance the understanding of domain knowledge.

The five steps included in this modeling strategy are as follows:

(1) Part Orientation

A good strategy of part orientation would bring the convenience and efficiency of the future model development. Considering the mirror, axial symmetry, and common consist features, combining with the common basic planes (TOP, RIGHT, and FRONT) in parametric 3D CAD; better model development plans can be figured out. This is the applications of space geometry. Principals are illustrated in Figure 3.

(2) Part Decomposition

The first step of model development is usually difficult for the novices. Modeling of addition or subtraction can easily guide the novices to find out modeling steps. Traditional carving is using a piece of wood and cutting skills (modeling of subtraction) to finish a shape; clay molding is adding up material to finish the work (modeling of addition). These modeling of subtraction and addition methods are similar to the way art and design majors to make sculptures. Model development in 3D CAD programs

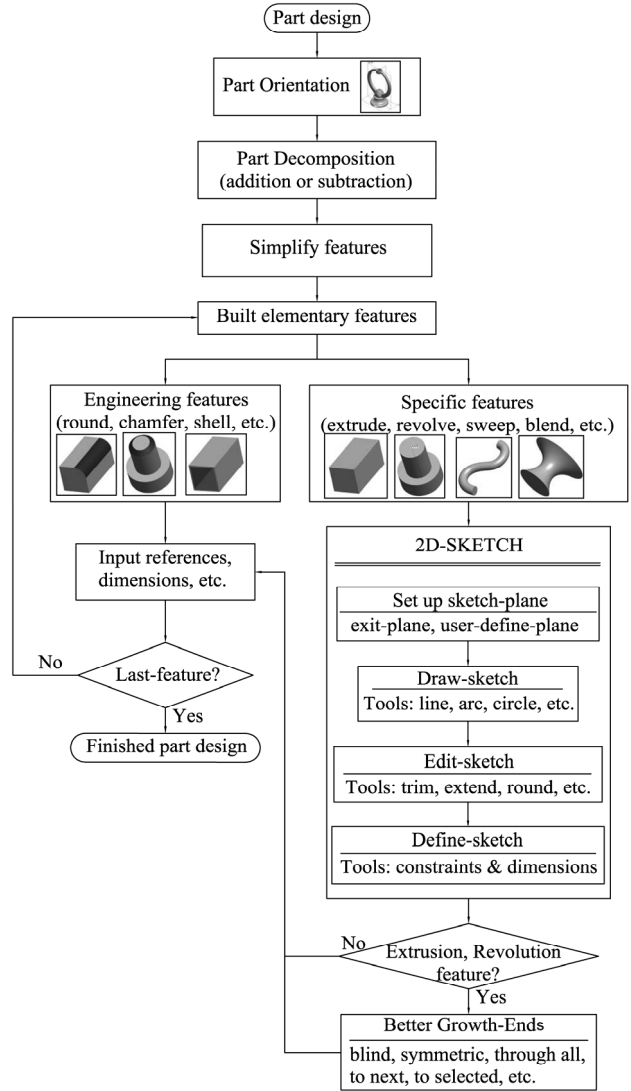


Figure 2. The ODSSE modeling procedures

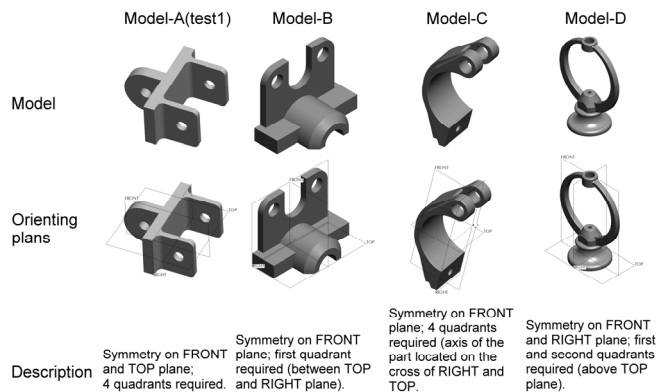


Figure 3. Part orientation

is using both these virtual methods (modeling of addition and subtraction). Figure 4 is using modeling of addition and subtraction, which is the most common method for product development. Properly using modeling of addition and subtraction based on the shape features can rapidly decompose a product to elementary features (specific features and engineering features).

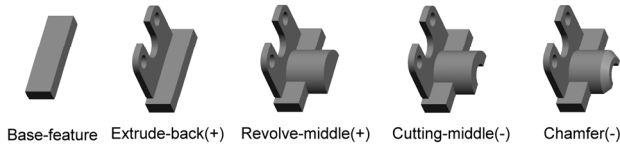


Figure 4. Modeling of Addition and Subtraction

(3) Proper Simplify Features

In a simple modeling, experienced users use less features to achieve better efficiency. However, modeling for complicated structures is similar but a little different. The minimum features (3 features) were used in the modeling illustrated in Figure 5; Figure 6 is another modeling procedure, which decompose feature #1 in Figure 5 to feature #3 - #6 in Figure 6. The advantages of this modeling are simplified geometry for easier thinking and controlling, properly decomposed shape for less interference between definitions, and easier for debugging.



Figure 5. Minimum feature modeling

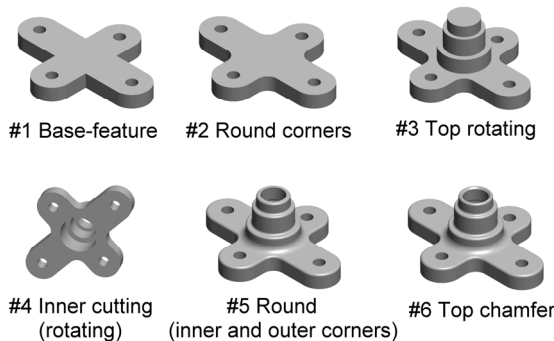


Figure 6. Properly simplify feature modeling procedures

(4) 2D-Sketch Geometry

2D-sketch geometry of parametric 3D CAD is using references (system defaults or user's definition) for positioning, and then finishing the 2D-sketch, which includes constraints and dimensions:

① Constraints

In fact, constraints and dimensions are interchangeable for each other in some cases (Figure 7), but constraints change would fit better for design change. Figure 7c is an example for changing only one dimension to change the size of regular triangle; Figure 7a needs 3 changes of dimension.

② Dimensions

Dimensions of 3D parametric software include dimensions of shape and dimensions of location. The different definitions, which are important to users, are illustrated in Figure 8.

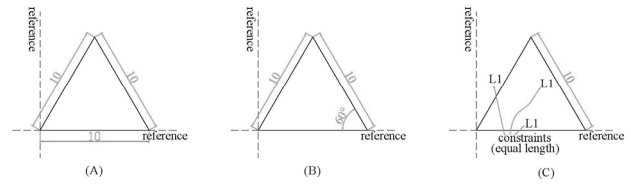


Figure 7. Constraints and dimensions are interchangeable for each other in some cases

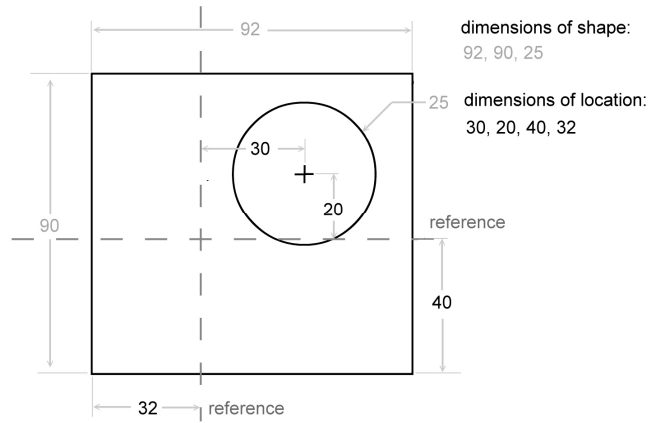


Figure 8. The types of dimension

(5) Better Growth-Ends

Better Growth-Ends is to select the proper growth ends for extrusion, rotating etc. with flexibility for the future design changes. There is a need in industry for learning in relation to reuse and ease of alteration of the CAD models, to reduce the launch times for new products [26]. Therefore, the convenience and efficiency can remain constant for uncertain design changes. The concept of better Growth-Ends is illustrated as Figure 9.

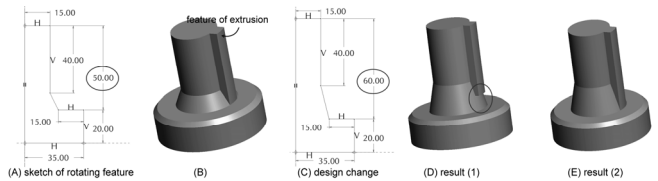


Figure 9. Results from design change of different Growth-Ends for the same product

The ODSSE system, developed to aid student learning in parametric 3D CAD, is designed as a Web-based teaching material which incorporates five strategic models (as shown in Figure 10).

3 Result and Discussion

This research applied performance time measurements to evaluating learning efficiency. Figure 11 and Figure 12 are the results from Test1 and Test2 from control group and experimental group. These figures also include AutoCAD grade.

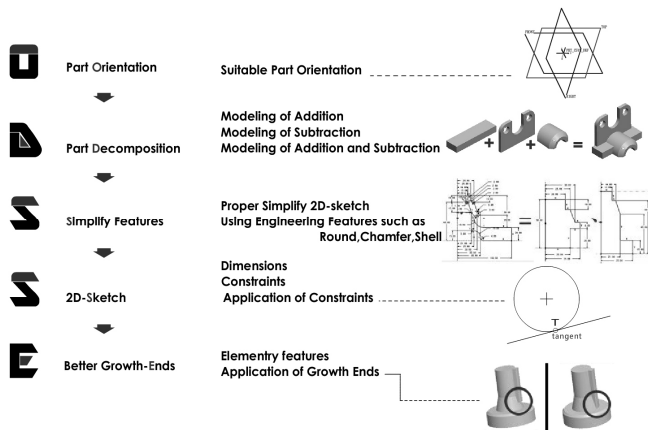


Figure 10. The ODSSE system screenshot

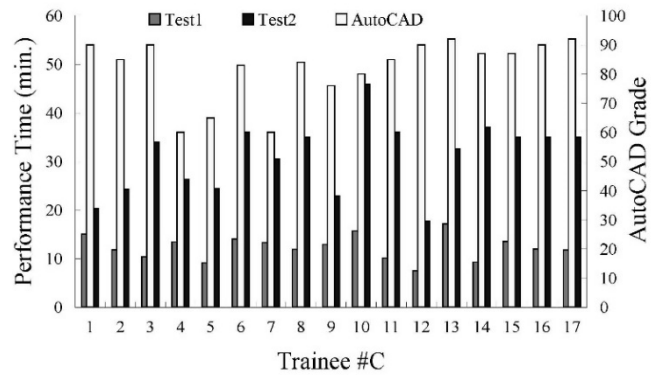


Figure 12. Results from experimental group

Parametric 3D CAD mainly based on 2D sketch developed 3D model. The experiment subjects in this study were the students with one semester of 2D CAD (AutoCAD) training. Therefore, covariance analysis was conducted with semester AutoCAD grade as covariance. Test1 and Test2 were conducted on the two groups after lecture completion. Performance time was used as test scores. The AutoCAD grade and two test scores were transformed into normalized T-scores. Besides, the two test scores were numbered in reverse coding. Table 2 gives information about raw scores (means, standard deviations), and normalized T-scores (means, standard deviations). The latter were used as covariance (N-T-AutoCAD) and dependent variables (N-T-Test1, N-T-Test2) in ANCOVA (analysis of covariance), as shown in Table 3.

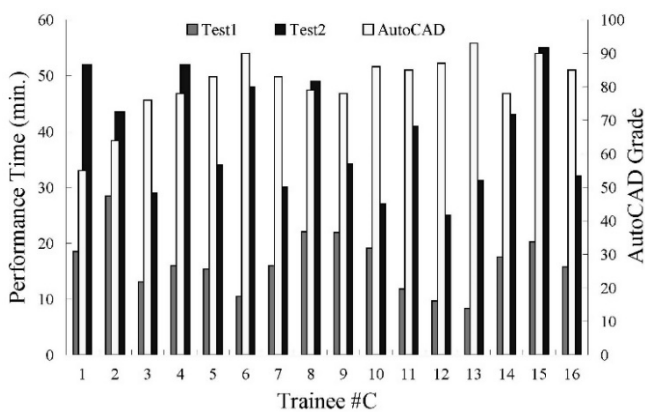


Figure 11. Results from control group

Table 2. Raw scores and Normalized T-scores of the AutoCAD-grade, Test1 and Test2

Groups	Variables	Raw scores		Normalized T-scores	
		Mean	Std. Deviation	Mean	Std. Deviation
Experimental (N=17)	AutoCAD-grade	82.12	10.68	51.24	9.80
	Test1	12.31 (min.)	2.51	54.29	7.37
	Test2	31.07 (min.)	7.29	53.62	8.99
Control (N=16)	AutoCAD-grade	80.63	9.75	48.62	10.02
	Test1	16.52 (min.)	5.26	45.45	10.53
	Test2	39.13 (min.)	9.97	46.17	9.70

Table 3. Comparison of two test scores after adjustment for normalized T-score of AutoCAD-grade in two groups (N=33)

Source of variation	SS	df	MS	F	P
N-T-Test1					
Covariate (N-T-AutoCAD)	376.163	1	376.163	5.236	.029
Group	507.268	1	507.268	7.061	.013
Error	2155.262	30	71.842		
N-T-Test2					
Covariate (N-T-AutoCAD)	11.590	1	11.590	.129	.722
Group	429.172	1	429.172	4.779	.037
Error	2694.060	30	89.802		

To analyze data, ANCOVA was conducted after checking its assumption, which are normality, homogeneity of variances, independence of dependent variable scores and homogeneity-of-slopes assumption.

All assumptions were met. Analysis indicated a significant difference between control and experimental groups with respect to Test1 when N-T-AutoCAD were assigned as a covariance,  $F = 7.061$ ,

$p=0.013$ . Mean performance time of Test1 for the control group was 16.52 (min.), and for the experimental group was 12.31 (min.). The results from Test2 were also found a significant difference between control and experimental groups,  $F = 4.779$ ,  $p = 0.037$ . Mean performance time of Test2 for the control group was 39.13 (min.), and for the experimental group was 31.07 (min.). This indicated a better learning effect in the experimental group with ODSSE teaching material implemented. Table 3 gives the information of comparison of two test scores after adjustment for N-T-AutoCAD in two groups ( $N = 33$ ). Using Pearson's correlation to examine the relationship between Test1 and Test2, we found that there was a significant positive correlation ( $r = 0.479$ ,  $p < 0.01$ ), shown as Table 4.

**Table 4.** Pearson Correlation of Test1 and Test2

N-T-Test1	N-T-Test2		
	N	r	p
	33	.479(**)	.005

## 4 Conclusion

In addition to cultivation of traditional aesthetics and sketching courses, CAD has become a mandatory skill for industrial design majors. Engineering-type parametric 3D CAD has become the mainstream in the industry for many years. Teaching professionals ought to investigate how to assist students' effective learning in this area.

This study proposed the ODSSE modeling strategy for non-engineering majors to use parametric 3D CAD software. The following is a summary of the study:

(1) Summarize common modeling strategies based on different parametric 3D CAD (Creo Parametric, Inventor, Solidworks) and propose five modeling strategies process-ODSSE for related different software.

(2) The ODSSE modeling strategy is a fast way to use parametric 3D CAD for non-engineering majors (or novices), as well as a system verified by actual teaching as a way to enhance learning efficiency.

(3) After the completion of experimental lectures, five strategic models are currently designed as Web-based teaching material. In addition to its application in parametric 3D CAD teaching, they can also serve as student after-school learning material.

This research applied performance time measurements to evaluating learning efficiency. Figure 11 and Figure 12 are the results from Test1 and Test2 from control group and experimental group. These figures also include AutoCAD grade.

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