THE ROLE OF SKETCHING IN ENGINEERING DESIGN AND ITS PRESENCE ON ENGINEERING EDUCATION

A. Martin-Erho, M. Dominguez Somonte, M.M. Espinosa Escudero

ETSII-UNED (SPAIN)

Sketching is understood as a key factor for creative expression, the most effective visual thinking tools and so applied for design. It is considered the principal approach by which design engineers externalize their concepts and where the drawings provide visual clues for refinement and revision. Engineering Design researchers as well as professionals agree the value of sketching to enhance visual thinking and so creativity, but sketching presence in engineering education is so few. Even it is being displaced by computer-aided tools, as it means it is wrongly seen as an old drafting technique. Results means a lack of spatial abilities and problem-solving skills.

There is a decrease on class hours for graphical subjects in current engineering curricula. Moreover, Graphical subjects even pays more attention to metric geometry and CAD training, and so sketching practice is almost totally displaced by modern computer-aided tools. The feeling is that sketching is not valued as a powerful visual thinking tool and seen as an old drawing method, replaced by new computer drafting interfaces. We studied how sketching is valued at engineering schools by students and educators, about their opinions related on the importance of sketching, how they see as a creative tool and how they apply for courses, for teaching and learning.

It is very important that engineering colleges give students the value of sketching, as well of foster its use, to train the future design engineer “not only in the standard drafting skills, but additionally in the ability to represent concepts that are more abstract and best represented as sketches”. To foster creative problem solving, engineering schools should offer formal courses in sketching and drawing in support of design projects: teaching basic techniques in freehand sketching would help them generate quicker and more effective external visualizations of their ideas, and thus foster their creativity.

Keywords: sketching, engineering design, visual thinking, engineering education, creativity.
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10th International Technology, Education and Development Conference
7-9 March, 2016
Valencia (Spain)
WELCOME INTRODUCTION

Dear INTED2016 participants,

Welcome to this 10th anniversary of INTED!

We wish to express our most sincere thanks for being part of this inspiring forum of knowledge exchange. It is a pleasure to present a varied program with a wide range of sessions covering all aspects of learning, teaching and educational technology advances.

After 10 years, this edition has brought together nearly 700 delegates coming from more than 80 countries. This will create a truly international and multidisciplinary atmosphere that will promote the interaction with other colleagues with the same aim: to meet, learn and share ideas for a better education.

We hope that your participation in this conference will provide you with an opportunity to open your minds to other educational perspectives and explore new horizons.

Thank you very much for your contribution to these “10 Years together for Education”.

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THE ROLE OF SKETCHING IN ENGINEERING DESIGN AND ITS PRESENCE ON ENGINEERING EDUCATION

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Abstract

Sketching is understood as a key factor for creative expression, one of the most effective visual thinking tools and so applied for design. It is considered the principal approach by which design engineers externalize their concepts and where the drawings provide visual clues for refinement and revision. Engineering Design researchers as well as professionals agree the value of sketching to enhance visual thinking and so creativity, but sketching presence in engineering education is so few.

There is a decrease in class hours for graphical subjects in current engineering curricula. Moreover, these even pays more attention to metric geometry and CAD training, and so sketching practice is almost totally displaced by modern computer-aided tools. Our appreciation is that sketching is not valued as a powerful visual thinking tool and seen as an old drawing method, replaced by new computer drafting interfaces. We studied how sketching is valued at engineering schools by students and educators, about their opinions related on the importance of sketching, how they see as a creative tool and how they apply for courses, for teaching and for learning.

It is very important that engineering colleges give students the value of sketching, as well of foster its use, to train the future design engineer “not only in the standard drafting skills, but additionally in the ability to represent concepts that are more abstract and best represented as sketches”. To foster creative problem solving, engineering schools should offer formal courses in sketching and drawing in support of design projects: teaching basic techniques in freehand sketching would help them generate quicker and more effective external visualizations of their ideas, and thus foster their creativity.

Keywords: Sketching, engineering design, visual thinking, engineering education, creativity.

1 INTRODUCTION

Creativity is a required resource for design and therefore for engineering design. Even though, engineers are seen as creative professionals, as they have to solve many technical problems, also to innovate. To find these solutions, creativity is required.

One important subject related to creativity and design is visual thinking [1]. Hsu and Won [2] considers the use of visual thinking models as “the closest way to humans of thinking and reasoning”. McKim [3] demonstrated through experimental studies that visual thinking is key to all design domains. Goldschmidt [4] explains visual thinking from the design perspective as the process and reasoning behind the creation of ideas or form in design. By visual thinking, a designer is able to combine items, assemble and handle mechanisms and components, and actuate devices that already does not exist. A great amount of design information is conceived, recorded and communicated by visual language. Many properties of an object that a designer thinks about cannot be reduced into a verbal description, which always has ambiguities. By a visual process, designers can appreciate shape, proportions and interrelations between items that made and object.

The use of visual techniques is understood as one of most effective design problem solving mental processes. These techniques can be schemes, concept and mind maps, and most commonly sketches.

A sketch can be previously understood as a drawing made in an informal way, and approximated dimensions and details. On the other hand, an engineering drawing is a detailed description of an engineering system of a design, with exact dimensions.
Sketches, far from simple and rough drawings, are pictorial representation that fully defines one concept, design or idea. In addition apart of represent these ideas, sketches are also used to find these. Cross [5] suggests that designers create drawings during early design stages not to communication ideas, but as a “thinking aloud” process. McKim [3], suggested the term “idea-sketching” related to the property of visual thinking to give birth to ideas. Sketching are also applied help analyzing problems visually, “a medium for graphic thinking in the exploratory stages of architectural designers work” [6].

Sketching is a quick, easy and effective tool for design tasks, a common and a recurrent tool for facing design problems [7]. According to Goldsmidt [4] research on the process of sketching [4], designers creates visual displays to “let induce images of the entity is being designed”. Although there are authors that does not think sketching necessary for design [8], other believes that sketching is basic, an activity linked to design, “impossible to separate” [9]. Johnson [10] considers sketching a way to quickly make provisional drawings, helping on creating an efficient sense of spatial and relational information and so, in opposite to non-sketching trends, he sees it as a necessary tool for design.

1.1 Types of sketches

Sketching allows information to be represented in various forms, as well as working in various levels of abstraction, used to start analysing a design problem to refine ideas, previous to detailed design stage. Many sketches are generated for the designer’s own use: to capture ideas, to externalize thoughts and mental images, and to construct a visual understanding.” In other cases, Sketches are mainly developed for communication, for tackle design problems in groups. According to what sketches are drawn for, they can be categorized. One most cited classification of sketches is done by Ferguson [11], who identifies thinking sketches (to support individual thinking processes), talking sketches (to communicate with others), and prescriptive sketches (to represent the sketched idea) Other is storing sketches, which mentions sketches drawn to keep valuable ideas [12].

1.2 Characterisation of sketches (Nature of sketches)

Sketching has the ability to simply represent ideas or concepts, “graphic metaphors” of real objects or future designs [13]. To achieve this, sketches possess several properties that shapes it as a creative tool. One most important is its capacity to quickly externalize ideas [14]. Since sketches can be made more rapidly than formal drawings, they allow for more facile manipulation of ideas. Being a quick mean of graphic representation, sketches works as an extended memory for the visual images in the mind of the designer, letting easy manipulation. Apart of express previous mental models, sketches allows to develop new ideas and work with design variants. As sketches are not fully defined, they are ambiguous, lets re-interpretation, giving to designers to find new solutions. Goel [15] also shows the symbolic nature of sketches. Designers use a lot of standard symbols and idiosyncratic geometric forms as placeholders for concepts [16]. These symbols of sketches may be also common, depending on who is making these sketches: designers, engineer or architects [17].

1.3 Role of sketching in engineering design

It is agreed that visual thinking is basic for engineering. As Lipson and Sliptani remarks: “It is interesting to watch how an engineer, when given a design problem, instinctively reaches for a pencil and paper.” [18] Therefore sketching is an activity involved on engineering tasks and so on engineering design stages [13] [14]. Engineers always start to analyze a problem by paper and pencil, which gives visual clues for finding the possible solutions. In the case of Engineering Design, Sketching is involved on several stages, since definition of the problem, to find concept solutions, to analyze and evaluate, as well as to communicate.

Sketching has been a frequent subject of research in architecture as well as industrial design. In the case of engineering, Ferguson [11] analysed the role of sketching in engineering as well as Ullman [13] who studied the importance of drawing (both formal drafting and informal sketching) in the process of mechanical design. Yang [19] explored aspects of sketching skills in engineering design performance and made a comparative study between brainstorming, morphology charts and sketching for concept ideation in the engineering design context. Yang [20] Other studies are made on solitary engineering sketching [21].
1.4 Sketching at engineering education

As sketching is basic for engineering design, it must be a skill required for future engineers and so to be taught at engineering colleges. Ullman [13] remarks the need of training engineers in the skill of sketching to represent concepts. According to the Engineering Design Graphics Division of the American Society for Engineering Education (ASEE), freehand sketch engineering objects is the second more important skill for graphical communication to be learnt for engineering students [22]

According to that, it should be clear the agreement of engineering teaching community about the value of sketching skills for current and future engineers. However, as some authors remarks, presence of sketching in engineering education is so few.

Although they are essential for engineering activities, some authors warns the unusual presence of teaching sketching skills[23] [24]. The question is that engineers taught for drafting but not for sketching, as Ullman et al. noted t in the 1990s, even more, Linsey observed that engineers “are not taught to draw” [24] In addition, Yang [19] says that engineering students traditionally are assessed on their mathematical and verbal abilities and less by their visualization skills. Mataix [25] showed a decrease in class hours for engineering graphics subjects in current engineering curricula. We reviewed engineering programs on some engineering colleges in Spain and confirmed that sketching practice is almost totally displaced by modern computer-aided tools: Graphical subjects even more attention to analytical geometry and to CAD training. In the case of USA; M. Yang [19] reports a similar scenario: “ Many engineering undergraduates in the United States are instructed in drafting and computer-aided design CAD, but rarely in sketching”.

As a consequence of that, engineering graduates limits their capacity to analyze design solutions [23], as well that a negative effect on spatial abilities, visual spatial reasoning and then visual thinking problem-solving skills: “New engineers often have inadequate experience in making sketches by hand in order to effectively communicate visual information. Graphical skill on engineers are focused on CAD, which is adequate for detail design task but not for other involved with creative activities. CAD. Graduate engineers have also great CAD knowledge but a poorer ability to generate, develop or communicate technical ideas. Veisz [26] showed a lack of ideation capacity for designers which uses CAD at all project design stages. The negative effects on graduate engineers having a poor knowledge of engineering basics, non-verbal tools and “the art” of engineering is warned by Ferguson as to have “mediocre engineers”[11].

2 EMPIRICAL STUDY

As some authors remarks, this scarce of sketching at engineering Education, displaced by CAD suggests that sketching is seen just as an old drafting technique [27], replaced now by these computer aided design tools, and therefore is not valued as a powerful visual thinking tool [23].

In order to review that, we studied how sketching practice is valued at engineering schools by students and educators. We asked students as well as educators to participate in this survey, consisting in answering 15 questions related on the importance of visual thinking for engineers, the importance of creativity in engineering education, value of sketching, and its use for courses, for teaching and for learning. This questionnaire was placed on a Google Docs site and link to fill on-line this questionnaire was sent via email to teachers and students.

3 RESULTS

Responses of teachers as well as students was received mainly from universities from Spain as well as from United States, United Kingdom, Russia, Austria Finland and Japan. 67% of responses were received by teachers and 33% by students. Subject of teachers was various, from structural, systems design, Machine design, to chemical engineering, and to remark 42% of teacher’s subject was engineering graphics.

3.1 Importance of Visual thinking for engineering Design

96% of responses agreed that visual thinking is basic for engineering that shows both students and educators agrees the value of visual thinking for engineers: 83% of responses revealed to be visual
thinkers, and 17% verbal tinkers. This proportion does not depend on their role at university: 86% of students said to be visual thinkers as well as 82% of teachers.

Apart from sketching valued by educators, we wanted to know if they apply other visual thinking tools for engineering education, such as mind maps. 75% agreed that Mind Maps are useful, and 4% one of responses that they disagreed. 21% left of responses said they didn’t know Mind Maps. This proportion keeps equal when analysing teachers (76% agree, 6% disagree, 18%) and students (71% Agree, 0% “Disagree” and 29% “Don’t know”).

### 3.2 Importance of creativity in engineering education

As well as we wanted to see how teacher value visual thinking for engineering, we wanted to know how they value creativity for engineering: We asked teachers is they applied any creative method at classes, in order to solve any engineering design problem.

57% of students applied some creative method at classes and 43% did not responded. 29% of teachers said to apply at classes and 71% responded that they don’t or did not responded. Half of teachers that taught graphic expression responded to apply any creative method at classes. It is interesting to remark that there were some responses that wrote sketching and mind mapping as a creative methods.

### 3.3 Value of sketching

All responses by students as well as teachers disagreed with the affirmation that sketching is not necessary because of CAD tools availability (“Sketching is not important as we have modern CAD applications”). About the affirmation “Working with sketches will help to perform engineering tasks in a creative manner”: 100% of responses agreed to this question, which contrasts in the other hand with the response of how creative methods they used at classes, being a minimum what they applied or consider sketching as a creative tool.

We obtained same results from the question of that Sketching enhances spatial abilities, having a 100% of agreement from both students and educators about the value of sketching to enhance spatial abilities. (This results has to be analysed comparing to how sketching is really applied at classes)

Almost all of students (86%) answered to be skilled on sketching practice. Some of them who answered not to know how to sketch also answered to be verbal thinkers.

Student and teachers applies sketching according to its role in engineering design, which confirms that they value it properly. The value of sketching as a creative tool by students and educators is confirmed by 100% them uses sketches for ideation tasks (Help to find ideas/design solutions). It is important to say that the same proportion of students and educators applies sketching to analyse an engineering problem (Students 83%, teachers 87%). The most expected common function of sketches, to transmit ideas to others. Is applied by students less than teachers: (Students 67%, teachers 87%). It is logical as teacher’s uses sketches as their educational role. All responses disagreed with the affirmation that Sketches were just for draw, which confirms how students and teachers value adequately the role of sketching. In the other hand, 75% of students and teachers that uses CAD apply sketches as a previous step for CAD modelling, which agrees with a proper use of each tool according to design stages. Students 83% keep ideas for further reference and only 47% of teachers does it. Reason may be because these ideas are already known or they don't need, as they know.
3.4 Sketching in engineering education

We wanted to know if, teachers applied sketching, regarding that all teachers answered that sketching is a valuable tool for creativity and spatial abilities. 94% of teachers applied sketching at classes, which confirms how educators value this method. According to previous response, sketching is practiced at classes, but it is not enough included in most of engineering programs, as an explicit subject. Only 61% of responses said that sketching is included in any engineering course. In the other hand, we got the full agreement of student and teachers that sketching should be an important subject to teach/learn at engineering education, with 100% of students and teachers agreeing that.

4 CONCLUSIONS

Some of results rejects our previous hypotheses about sketching at engineering education environment is not adequately valued and it is seen as an obsolete drawing method. Both students and teachers values and so applies sketching properly. Presence of sketching on engineering programs, as it is shown by results, is more than expected. The relation of visual thinking and engineering was also confirmed. It is interesting that engineers apply creative methods, and in cases Sketching and Mind Maps are considered as creative tools.
This study is considered as a first approach of the problem. We are aware of some limitations of this study. Further research shall be necessary to confirm how graduated students apply sketching to real engineering design tasks.

Although sketching is not adequately included on engineering curricula, this practice is present on engineering schools by the efforts of educators. This shows a trend, according to future engineering needs, that must be into consideration for future engineering educational programs, in order to give students the value of sketching, as well of foster its use, to train the future design engineer in sketching skills. Our suggestion is that engineering schools should offer formal courses in sketching and drawing in support of design projects: teaching basic techniques in freehand sketching would help them generate quicker and more effective external visualizations of their ideas, and thus foster their creativity. In that case, exploratory case studies on sketching syllabus, courses implementation or applying sketching by Problem-Based Learning shall also be required. We encourage researchers to approach and study this proposal to found optimal solutions to this question.

REFERENCES


