A model for design activity in technological education

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Abstract

This paper discusses the design activities of students in secondary school in France. Computer Aided Design (CAD) tools are now part of the capacity of design professionals. It is therefore apt to reflect on their integration into the technological education. Has the use of graphical tools changed studentsôperformance, and if so in what direction, in phase of seeking solutions through a design activity in a situation of teaching and learning?

The influence of CAD tools on professional design activities has been the subject of much research, but little has focused on student activity. Thus, analysing student work through an experimental device, we ask that students produce more solutions without using CAD tools. Do CAD activities encourage the modeling of a particular solution? Does drawing by hand before CAD activities support the production of various solutions and define them more precisely? Through the analysis of solutions developed by students, including traces of their activity (sketches, digital files), we test our hypotheses. Finally, these studies contribute to the understanding the teaching-learning of design process by proposing a model for design activity in technological education.

Keywords: Technological education ï Modeling creative design ï Computer Aided Design ï Graphical tools

Context of the study

This paper completes a study published in 2014 (Laisney & Brandt-Pomares, 2014). It analysed design activities of students when faced with situations which require solving design problems. We focused on the role of CAD tools. More specifically, we considered the relationship between sketch realization (hand-drawing) and the use of CAD tools in the activity of students, especially in the early stages of research. Through analysis of drawings made by students as they use or do not use CAD tools, we aim to understand the creative process they employ.

The findings of this study relate to the fact that it is important to consider the introduction of these tools in promoting and facilitating the process of finding solutions. Our results confirm our hypothesis that hand-drawing ï as is the case for architects and designers ï favours a broader search for solutions. The introduction of a second phase, CAD tools, provides a model of the object that is enriched due to the assistance the tools provide to students. As such, CAD is required in the process of object design.

The scope of this research and its findings is contingent to situations, problems and specific tools. To complete these results, we propose to test new situations and new tools. These studies contribute to the understanding the teaching-learning of design processes by proposing a model for design activity in technological education.

Model for analysing teaching of design activity

Creative design, a model for design activity

The general model of the design activity borrowed from Lebahar (1983) identifies three main stages to describe the process of architectural design. This general model of the cognitive aspects of design assimilates this activity in ñresolution of badly defined problemsò (Simon, 1991) and is characterized by ñcreative designò. This notion of creativity develops through the mechanisms which it involves: exploration, generation of solutions and evaluation. But especially, this model takes into account an essential aspect of design activity, which concerns drawing in all its forms, including with the use of computing tools. The drawing is at the same time a representational medium and a tool of thought. More precisely, the sketch is considered as an integral part of creative design activities. It is defined as the dominating tool of thought for designers. Drawing is indeed seen by specialists in cognitive psychology (Goël, 1995; Schön, 1983) as a representation of mental activity, fixing the ideas in the first phases of design. But more than that, these drawn visual representations, which take several forms following the design phases, are recombined, modified and adapted. In Lebaharõs model, graphic intermediaries appear in each of the stages:

The architectural diagnosis; in this first phase the architect seeks to identify and define the problem to be solved with regard to the constraints. She is then in the phase of exploration and the result will be a first graphic ñbase of simulationò, a mix of notes and first drawings.

Research for the object through graphic simulation; from then on, the designer is going to work on generation of the solutions and their evaluation, in an incremental and iterative process. The drawing is going to be the privileged medium for this approach. It represents, as underlined by Lebahar, ñthe object in creation and the thought which creates itò.

The establishment of the model of construction; in this phase the designer defines precise graphic representations, intended to make clear the solution for the builders. It is the ñdefinitive decisionò concerning the whole project (plans, precise drawings with a specified scale, etc.).

Rabardel and Weill-Fassina (1992) work on the implementation of graphics systems allows us to consider the analysis of graphics intermediaries involved in all three stages of Lebaharõs model in a triple point functionally, semiotic and cognitive. The graphics are intermediate semiotic objects embedded in complex tasks that are functional to the task at hand. For example the shapes, the size, the subject, the structure or the function are among the aspects of the object useful for the designer action. This action raises various transformations operated on the subject (manufacturing, assembly) as well as mental operations of treatment of the information inherent to the resolution process of design problems. So, the drawing is a tool, an instrument which the subject uses to solve design problems. Design is so considered as a creative process of an object by progressive elaboration of a mental representation and a graphical representation of this object by the subject.

The role of the graphic tools

Lebahar (1996, 2007) studied the place of the tools of CAD ï in particular where articulation enters traditional drawing ñby handò and modeling by means of CAD software. ñWhitefield showed, by comparing the works of industrial designers drawing by hand, in those produced by designers using a CAD system, that the first ones tended to investigate several possibilities of alternative solutions (strategy in width), while the second, more concentrated on their operations of modeling on computer, more got into detail and developed only a unique solution, during all the process (in-depth strategy)ò (Lebahar, 2007, free translation, p. 146). According to Lebahar, ñstrategy in widthò is rather connected to drawing by hand, while the in-depth strategy depends on the implementation of a CAD system.

Other research on the use of CAD software by industrial designers (Asperl, 2005; Bonnardel, 2009; Bonnardel & Zenasni, 2010; Chester, 2007) shows that most CAD software do not really support creativity and are after all only a range of ñcomputing techniquesò. First of all at the cognitive level, their methods of construction of a digital model tend to impose choices on the user and do not base themselves on the indistinct data of the design initial phases; this is reflected by the fact that the designer is forced at an early stage to handle specific geometric entities. The systems do not know how to manipulate vague, indistinct data characteristic of the problem-solving stage. At the contextual level, meanwhile, the modes of representation and interaction paradigms they offer do not place the user in an optimal context for creation.

We underlined the importance which holds the drawing in the design first phases as the "freedom" which it infers in the generation of the solutions to a problem, essentially thanks to an intuitive relationship with the designer. He goes away nevertheless in quite a different direction for the CAD software.

At this stage, these studies show that while CAD tools are sophisticated, it is still beneficial to incorporate hand-drawings in the design activity, and especially in the teaching of technology.

From the point of view of the teaching-learning processes, Martin (2007) shows the contribution that can be made to schools by computing tools which aid the learning of drawing. The use of a digital tool can help the children while they copy a model, but does not improve their capacity to use their own internal model. At middle school level, Pektas and Erkip (2006) show the necessary level of ñfamiliarizationò with CAD tools to favour pupilsô commitment in the design task, as well as the role of the representations. All these works agree on the fact that on one hand, the computing tools must be adapted to the teaching-learning process, and on the other, it is important to take into account the representations in every stage of the process.

To conclude, this study is interested in the development of design activities by pupils within the framework of technology education, which traditionally centers on the use of tools (Brandt-Pomares, 2011). We propose to use a model built by considering a ñgrey areaò in which the use of traditional design or CAD tools will help the process of finding solutions for pupils of middle school. This ñgrey areaò corresponding to this particular time that students spend to use one drawing tool or another, we intend to understand. We think that creativity could be expressed through the variety of solutions developed by pupils.

At the methodological level, we propose to analyze the student activity. The analysis of the activity has been described in many studies (Engeström, 2005; Leontiev, 1972; Vygotski, 1962). Itôs a way to look at what the teacher asks the students to work through and it offers insights to students and what pupils *actually* do.

Methodology

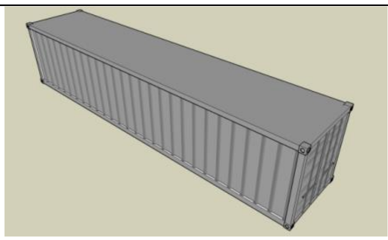
Our hypothesis is that use to drawing ñby handò favours the shaping of a bigger variety of solutions, while the use of the CAD tool particularly favours the deepening of a solution. As a result, the order in which the pupils would be advised to use these tools would also have an influence. Preceding CAD activity with an activity without recourse to computing tools should end in the production of valid solutions with regard to the constraints, more numerous, more varied and defined, with more precision at the end of the process. We therefore formalize the following three operational hypotheses: the pupils produce more solutions when not using the CAD tools (H1); the CAD favours the modeling of one solution in particular (H2); drawing by hand prior to the CAD activity favours the production process of solutions, several possibilities and more detail (H3).

Research plan

To test our hypotheses, we proposed a plan in which the pupils are requested to solve a ñclosedò problem. The teachers ask their pupils to fit out a space in house. The following instruction was given to the pupils: ñYour work consists of proposing solutions to fit out a house by respecting the constraints of the specificationsò.

It should be noted that teachers, agreed to participate in the experiment, were asked to intervene as little as possible and avoid guiding the actions of pupils. The specifications given to students are as follows in table 1:

Use a container (12m x 2,5m x 2,6m)



Sleep area	Be quiet Two places to sleep
Eat area	Prepare meals Eat meals
Wash area	Clean oneself, WC To be out of sight
Work area	Be quiet An office
Circulation area	Able to move between different areas

Table 1: Specifications

We analysed the productions realized by more than 300 pupils (aged 12) in France confronted with a design task. Table 2 presents the distribution of the tested population.

Middle school	1	2	3	4	5	6
Nb of divisions	1	2	3	2	2	4
Nb of pupils	27	35	59	42	43	100
Sweet Home 3D	Prior experience			No prior experience		

Table 2: Tested pupil population

Similarly, classes are divided into two groups, A and B, which are balanced (no group level) and correspond to those established by the teacher who has responsibility within the institution.

Table 3 presents the three working modalities corresponding to what the pupils had to make during two 50-minute sessions.

Sessions	Group A	Group B
1	Modality 1 ґby handò	Modality 2 ґSketchUpò
2	Modality 3 ґfreedom of choiceò	

Table 3: Plan of the experimental device

We want to implement tools already used by teachers, which are recommended on the various sites of academic resources for technological education in France. Sweet Home 3D software, based on features inspired by traditional ñintuitiveò design, seems to offer a quick route to learning.

During the first session (modality 1), group A has to realize the design task by exclusively using the traditional method of drawing ñby handò. Meanwhile, group B (modality 2) has to realize the same task by exclusively using the Sweet Home 3D software. During the second session (modality 3) both groups (A and B) are again confronted with the same task; that is, they have to pursue their research to find solutions, but this time they have the freedom to choose the graphic representation tools. To verify the impact that the pupilsô familiarization with the software could have, we shall test two populations of pupils: those who ñknow itò, because they have already used it within the framework of teaching realized by the teacher during the previous sessions, and those who ñdiscover itò.

Data and analysis indicators

The pupils made their graphic productions in the conditions of an ordinarily functioning middle school technology course of technology in the middle school, in class and with their usual teacher. At the end of sessions 1 and 2 and for each of modalities 1, 2 and 3, all the written and digital files produced by the pupils were collected.

We coded the various solutions according to the distribution and the choices to fit out these areas. From the choices made and their combination, we can determine all the solutions to this problem. Indeed, there are five solutions at least for the choice of distribution, four solutions to fit out the sleep area. Altogether, there are only twenty solutions. Illustration 1 proposes an example of a solution.

Illustration 1: Solution (to the left) and production (to the right)

Concerning the first hypothesis, the indicators are the numbers of productions and solutions represented by the pupils according to the tool used. Every paper or computer file developed by the pupils will be called a production, whatever its state of elaboration; that is, for example, even if it is a simple sketch or an incomplete digital model. Any production will be considered as an eligible solution; that is, a possible solution to the problem posed. An eligible solution is not necessarily at this stage a finalized solution to the problem. The numbers of productions and solutions so found during the three modalities of the experimental plan will allow the comparison between both groups A and B.

Concerning the second hypothesis, the indicator is the state of elaboration of the models represented by the pupils of both groups A and B, in three modalities. It will take into account the dimensional respect through manipulation of the scale of representation, the presence of decoration elements and material texture and the deepening of a unique solution deducted from the number of solutions developed by pupil.

Finally, concerning the third hypothesis, the indicators are of two kinds: the variety of the solutions developed in three modalities and graphic tools chosen and used in the third (free) modality between the sessions 1 and 2 for groups A and B. The variety of solutions will be measured with regard to the diversity of the proposals.

Results and data analysis

Number of productions and solutions

Each production by a pupil is identified as the result of a work which ends in the realization of graphic. The productions retained as solutions include only the graphic tracks which represent a structural organization of distribution (Illustration 2).

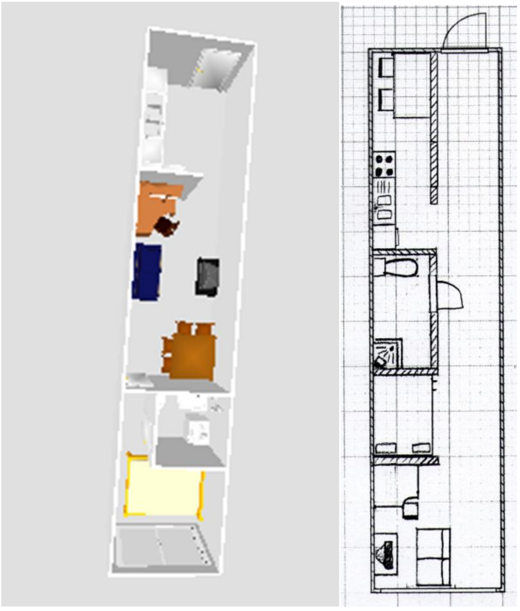


Illustration 2: Solution with Sweet Home 3D (to the left) and by hand (to the right)

We counted the number of ñsolutionsòproduced by the pupils. The number of productions and solutions developed by all the pupils at the end of the first session appear in tables 4ï 6.

Session 1	Nb of pupils	Productions	Solutions
Group A	157	251	214
Group B	149	154	128

Table 4: Number of productions and solutions elaborated

The analysis of the number of productions and solutions confirms our first hypothesis, according to which the pupils produce more solutions without using the CAD tools. Indeed, on one hand table 4 shows that the pupils in group A realize more productions and solutions than the pupils in group B, while on the other, tables 5 and 6 show that this difference is not due to any pupils in particular but to a general tendency which concerns the majority of the pupils. The pupils in group A are capable of developing mainly more than a production (or solution) while the pupils of the group B do not rarely propose it any more of one.

Session 1	1 production	2 productions	+ 2 productions
Group A	70	83	4
Group B	142	6	0
Total	212	89	4

Table 5: Number of productions developed by pupil

Session 1	1 solution	2 solutions	+ 2 solutions
Group A	85	60	3
Group B	122	3	0
Total	207	63	3

Table 6: Number of solutions developed by pupil

Our methodological precaution, with no level group, is confirmed by statistical test. Confirmatory tests show, as seen in table 4, that both groups are equivalent in terms of constitution (Khi2 = 0.028; Ddl = 1; p<0.05). More than that, we think it is not the groupõs composition that influences the number of productions and solutions, but the role played by the graphic intermediaries in the tasks. Nevertheless, we observe in tables 5 and 6 significant differences (Khi2 = 94,888 and Khi2 = 59,671; Ddl = 2; p<0.05) which we attribute to the task and the fact that in one case the pupils use the traditional method of drawing ôby handö, while in the other they use CAD tools.

Difference between knowledge and discovery of the software

In order to look to the effects of pupilsô level of familiarization with the software, we differentiated the population into two groups: those with prior experience of CAD and without. Table 7 give the number of productions and solutions developed by the pupils in group B at the end of the first session.

Session 1		Nb of pupils	Productions	Solutions
Group B	(No prior experience)	94	98	78
	(Prior experience)	55	57	51
Total		149	155	129

Table 7: Number of productions and solutions developed by group B

Proportionally, the number of productions and solutions realized by pupils in group B who discovered the software and those who know it is of the same order.

Main results

For a ôclosedö design problem, the exploration phase of the search for a solution grows rich by using drawing ôby handö. Indeed, the use of traditional drawing in the early stages of finding solutions allows pupils to rough draw solutions to design problem. The pupils are all capable of producing drawings which allow the expression of their ideas. The results of the experiment tend to show that the use of traditional drawing before CAD tools are used allows the pupils to develop quantitatively more solutions. The Sweet Home 3D software seems to be considered early in the process of finding solutions. We note nevertheless that in this case, the exploration of a range of possiblities is reduced and the pupils aim at only one solution. The general model of the design activity proposed by Lebahar (1983, 2007) is interesting to understand the design activity of architects and designers. However, it is not fully efficient to analyse the design activity of pupils in a context of teaching and learning in the classroom. We therefore propose a new model (Illustration 3) adapted from Lebahar to better understand the design process in the context of technology education in secondary school. This model includes CAD tools and the drawing by hand.

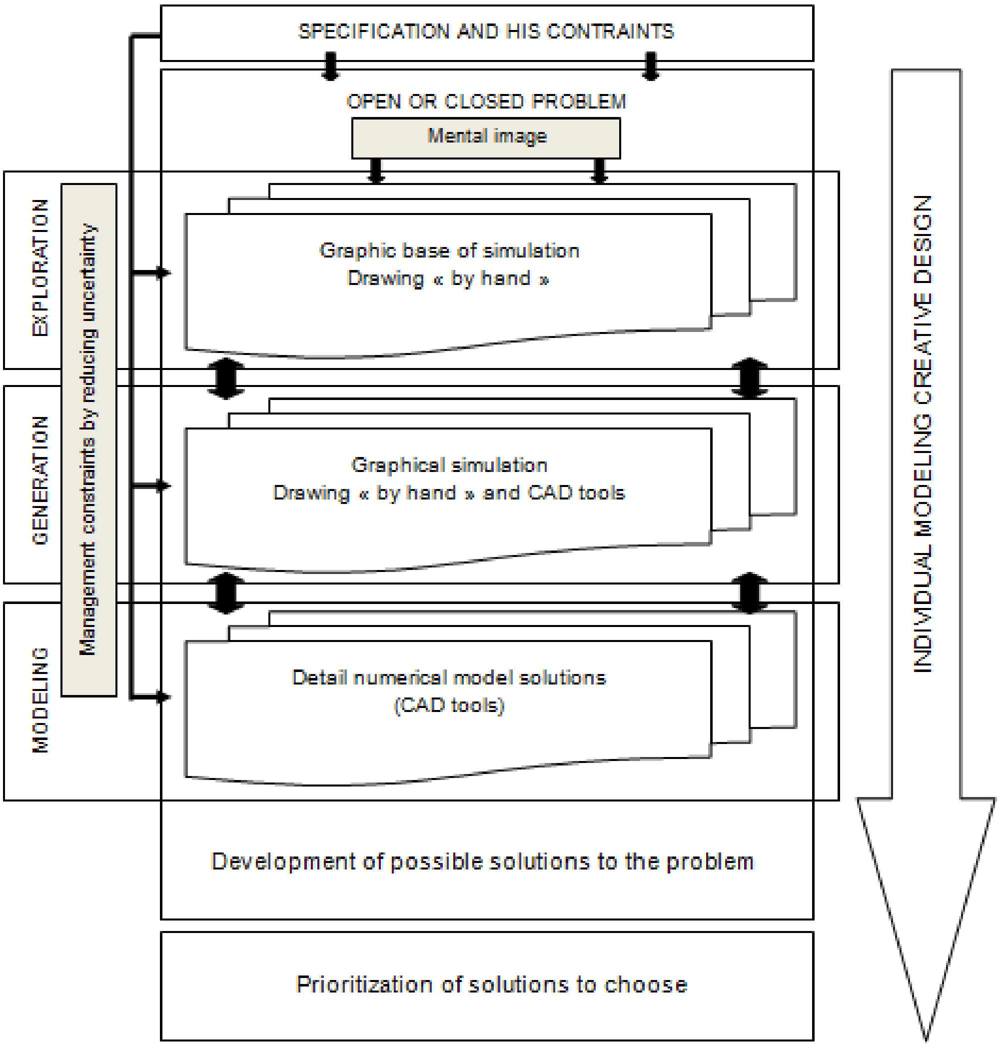


Illustration 3: Individual modeling creative design

Considering all our results (Laisney & Brandt-Pomares, 2014), we propose to complete Lebaharôs model by including the role of graphic tools in the design process. This helps to understand better the ñgray areaò in which it is both the use of traditional drawing "by hand" and CAD tools that can help the process of finding solutions for pupils.

Bibliography

Asperl, A. (2005). How to teach CAD. *Computer-Aided Design and Application, 2*(1). doi: 10.1080/16864360.2005.10738395

Bonnardel, N. (2009). Design activities and creativity: from the analysis of cognitive factors to creative design support. *Travail Humain, 72*(1), 5-22.

Bonnardel, N., & Zenasni, F. (2010). The Impact of Technology on Creativity in Design: An Enhancement? *Creativity and Innovation Management, 19*(2), 180-191. doi: 10.1111/j.1467-8691.2010.00560.x

Brandt-Pomares, P. (2011). Technological Education : The issue of Information retrieval via the Internet. In c. Benson & J. Lunt (Eds.), *International Handbook of Primary Technology Education ; Rewiewing the past twenty years* (pp. 151-166). Birmingham: Sense Publishers.

Chester, I. (2007). Teaching for CAD expertise. *International Journal of Technology and Design Education, 17*(1), 23-35.

Engeström, Y. (2005). *Developmental work research: Expanding activity theory in practice*. Berlin: Lehmanns Media.

Goël, V. (1995). *Sketches of Thought*. Cambridge, MA, USA.

Laisney, P., & Brandt-Pomares, P. (2014). Role of graphics tools in the learning design process. *International Journal of Technology and Design Education*. doi: 10.1007/s10798-014-9267-y

Lebahar, J.-C. (1983). *Le dessin d'architecte : simulation graphique et réduction d'incertitude*. Roquevaire: Éditions Parenthèses.

Lebahar, J.-C. (1996). Simulation activity of CAD draftsman during a design task. *Travail Humain, 59*(3), 253-275.

Lebahar, J.-C. (2007). *La conception en design industriel et en architecture. Désir, pertinence, coopération et cognition*. Paris: Hermès-Lavoisier.

Leontiev, A. N. (1972). *Activité, conscience, personnalité* (2eme ed.). Moscou: Editions du Progrès.

Martin, P. (2007). *Instrumentation, créativité en éducation artistique : Le cas de l'utilisation des outils de création numérique à l'école.* (Doctorat), Université de Provence, Aix-en-Provence. Available from Atelier National de Reproduction des Thèses, Lille

Pektas, S. T., & Erkip, F. (2006). Attitudes of design students toward computer usage in design. *International Journal of Technology and Design Education, 16*(1), 79-95. doi: 10.1007/s10798-005-3175-0

Rabardel, P., & Weill-Fassina, A. (1992). Fonctionnalités et compétences dans la mise en oeuvre de systèmes graphiques techniques. *intellectica, n°15*.

Schön, D. A. (1983). *The reflexive practitionner : how profesionals think in action*. New York: Basic Books.

Simon, H. A. (1991). *Sciences des systèmes Sciences de l'artificiel* (Réédition de 1969 ed.). Paris: Dunod.

Vygotski, L. S. (1962). *Thought and language*. New York: Wiley.