HOW TO SUPPORT REFLEXIVE PRACTICE ON THE USE OF METHODOLOGICAL TOOLS

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ABSTRACT
Our objective is to improve the training of future design actors in mechanical engineering. From the concept of reflexion on the materials of the situation (D. Schon), we propose, for conceptual design projects, to ask the students to build a graph representing the process they actually followed. The analysis of nine of these graphs shows a real coherence: the tools produce logical results and are connected. They also reveal the particular character of each process which is built during the activity of designing, refuting the idea of the existence of a generic process in innovative design. It is then possible to ask students to carry out a reflexion on their action and to give explicitly an account of it. This shows that process knowledge has not to be limited anymore to tacit (and individual) knowledge. It is possible to build some representation of the design process in order to share its comprehension. We consider that this aptitude is a key competence for future designers.

Keywords: conceptual design, design process, reflexion on action, methodological tools, training.

1 INTRODUCTION

Initially regarded as a problem solving activity, designing is now most modelled by a [problem-solution] or [function-structure] co evolution. N. Cross defines it as a bridging activity [1]. There was a "paradigm shift" in which the concepts of D. Schon largely contributed. Indeed, Dorst and Cross [2] consider that, for conceptual design in engineering design projects (our centre of interest), the concepts proposed by Schon constitute a very interesting complement of Simon's ones. Therefore, it becomes necessary to define teaching practices different from traditional projects work.

2 RELATED WORK

2.1 Schon's concepts

The concepts stated by D. Schon [3] are numerous and diverse: reflexion in / on action, visual reasoning and emergence, a process modelled by the interaction with drawings (seeing moving seeing), (re)framing of the problem... This pre-theory was recently completed with the concept of situativity: "the agent's view of a world changes depending on what the agent does" [4]. One of the consequences is that each process is built in the course of action (with path dependency) and cannot follow a pre-established methodology. Designers have a complete responsibility for the construction of the process they follow

2.2 Adaptation to engineering design

Recently, there was a real interest for the concepts of D. Schon in engineering. However, we must take care for at least two reasons. The first is due to the fact that most of these concepts remain vague [5]. For instance, we had do define the term of "(re)framing" as all the actions of construction of the problem and definition of its limits and of the objectives. The second reason relates to the fact that these concepts didn't emerge in the field of engineering design but in professional communities which use very largely the drawings (architecture and industrial design). Indeed, the observation of these objects allows the designer - beyond a help for the short-term memory - to find unexpected discoveries explaining the emergence of new parameters and problems [6]. For engineering design, Schon's concept of materials of the situation must be extended beyond the design objects by including the [problem-solution] duality, the methods and tools, and the project management [7]. Therefore, reflexive conversation can be conceived as the construction of a mental image of the situation at a given time (definition of the product and process, methods, tools, organisation …) allowing the designer to act on this situation: to collect elements of analysis, to imagine his future action and its consequences, to program it and carry it out. As it is based on observation and analysis, we can consider it as a first step useful for design knowledge building.

2.3 Methodological tools in situated design activity

Concerning tools, two attitudes have been opposed. On a first way, classical systematic design approaches advocate the adoption of a compulsory and rigid method in which each methodological tool has its pre-defined place. That strategy is well adapted to routine design, but can't offer the reactivity and adaptability required in innovative design, due to the great diversity of situations. In a second strategy, the designer has to decide himself the best way to act without any global procedure, and often without tool. Both result in unsatisfactory solutions [1]. The "right attitude" would be to choose tools and methods most fitting to the needs of the project in progress [8].

Not systematically used, the tools must ideally be assistances making it possible to guide the designers to a limited result with a controlled risk: the expected result must be higher than the investment. For these reasons, we often prefer to use only elements of methods (a graph, a tree, a series of questions, a definition...) rather than whole structured methods like Value Analysis or Functional Analysis. This lead to the concept of micro-tools initially suggested by Van Handenhoven and Trassaert [9] and applied to the construction of independent software tools [10]. The reflexion on the use of the tools meets here the reflexion on the construction of the design process: the tools become assistances for the construction of the points of view (function, structure...) and bridges between them.

2.4 Some corollaries for design education

Mobilizing the right tool at the right place must be considered as a competence: it is thus necessary to teach. To achieve this goal, learning through action is necessary and can take the form of students projects. In systematic design, the projects can be seen as opportunities of applying what has been seen during lessons and application exercises: the teachers expect students to follow the method taught, to use the multiple aids provided (with conformity) and to reach a result. The evaluation is little based on the design process (which is imposed) or on the knowledge acquired. However, effective learning takes place during these projects, but it is generally tacit, not formalized, and most of all little shared between the different students teams.

Consequently, we will consider that a teaching taking into account the recent contributions of the modelling of the activity mentioned above must have several characteristics. It must be based on situations representative of a "true" design problem, i.e. an ill defined problem, with uncertainty and multiple solutions not even known to teachers, and open enough to allow some evolutions of the problem domain. The use of the elementary methodological tools must be systematically evaluated in comparison with the situation. The construction of the process is progressive and students are responsible for it under the teachers' advises. A reflexion on action must be strongly suggested so that it is effective in order to lead to knowledge acquisition. Lastly, this acquired knowledge must be formalized and shared with other students. On this last point, we refute an assertion of D. A. Schon (design is not teachable, but learnable): process knowledge has not to be limited anymore to tacit (and individual) knowledge; it is possible to build some representation of the design process in order to share its comprehension.

3 TEACHING EXPERIMENT

3.1 Context

The context of this work is a course entitled Process and Product Innovation. It counts for the validation of a master degree in Manufacturing Management and Engineering (see http://www.utbm.fr/). Now, it comprises a volume of 26 hours for lessons, 28 hours for exercises and 21 hours for projects with teachers (plus extra home work). The objectives of lessons and exercises are to understand basic concepts (design fixation, function/structure duality, creativity, value and cost...) and to learn the methodological tools. These tools mainly come from Functional Analysis (questioning the need, interactions diagram, criteria identification, flows diagram, functional tree) and from the theory of inventive problem solving TRIZ [11] (multi screen, Ideal Final Result – IFR -, laws of evolution, problems modelling in "technical" or "physical" contradictions or in substance field models, problem resolution tools (contradiction solving principles and standards). We do not prescribe any global process including those two methods: the tools are presented as relatively independent, even if they can logically follow each other. During projects, we also suggest students to consider other tools and to understand the concept of tool as "what can be used for..."

In this article we shall mention only the work done during projects. The students work by group of 3 to 5. Their objective is to propose a new product or an improvement of an existing product. The choice of the subject is free, and in fact the majority of the subjects are proposed by the students. They can be problems encountered or even treated during previous training periods in industry or having to meet a need for an industrialist. They can also be proposals coming from their personal concerns, typically on sport or leisure products.

3.2 Reflexion on action via the construction of graphs

In order to help the students for their reflexion, we asked them to build a representation of their design process at the end of their project in a form common to all, and to present it. The process is seen as a sequence of tools producing results, and it is on the basis of already achieved result that one (other) tool can be called. A "result" can be information (a list of criteria, a geometrical model), or an effect on the group or the project: for instance, a CAD model reveals a conflict between the geometry and one of the other performances. The form of such a graph was given and we asked students to represent

the process such as it was held, with possible junctions (a tool produces several results...), dead ends (a tool does not produce "anything" or its production is not used), or loops.
The objectives of our study are:

- To test an affective appropriation of such a process representation by the students.
- To reveal similarities and differences between groups in order to show students the non predictable character of innovative design projects and their responsibility in the process definition and management.

3.3 Results and analyses

The results presented here refer to the session of spring 2006. Nine of the thirteen groups of students delivered a graph likely to be exploited. The four other groups either returned a basic graph revealing an absence of reflexion (one group), or produced an analysis - even not very detailed - with graphical supports that did not met our requests. Among the nine graphs selected, the number of posted tools ranges between 7 and 18 and the number of results ranges between 8 and 25. An example of graph is given in figure 1.

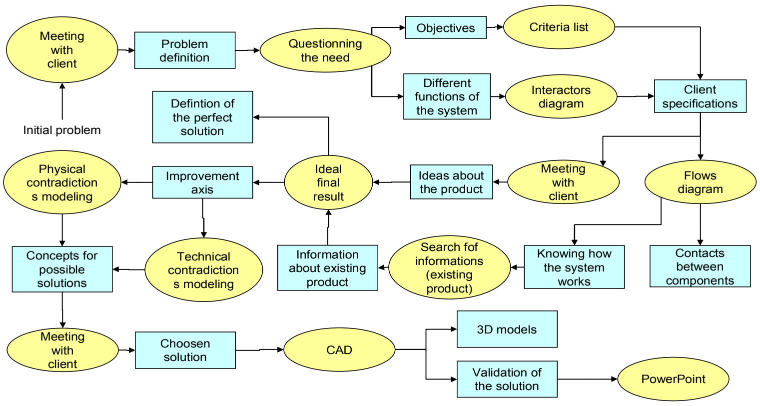

Figure 1: Example of effective paths between tools (ellipses) and results (rectangles)

From these graphs, two analyses were made.
For the first one we observe the productions made by the use of the different tools. We count only the sequences observed in more than one graph. The results are not surprising and they reveal some interactions between product and design process.
Most of the tools appear able to deliver their "nominal" production, like for instance a definition of the ideal final result (IFR), or some functional criteria.
Some of them have an extra influence on the process following, for instance:

- Questioning of the need is not only used to identify the need (4 occurrences), but also to start the project (5), and to describe the product (3) to be designed ;
- The interactions diagram is used to start the project (2), to delimit the system (2), to produce a list of criteria (3), and to draw up the list of functions (4) ;
- The flows diagram makes it possible to identify the flows going through the system (5), thus allowing to better understand how it realizes its functions (2) ;
- The use of TRIZ resolution tools produce solution concepts (5) ;
- Building a geometrical model with CAD software produces of course 3D models (5), but also new problems (2) to be solved.

Finally, certain tasks are identified as very useful for the project, even if they don't belong to formalized tools:

- The search for information, makes it possible to know the product (6), to find solutions (3), even to make decisions (2) ;
- The contacts with the "client" are useful to begin the project (3), to know the product (2), then to make decisions (4) ;
- Evaluation is used, but little (2), and to make decisions ;
- A free search for solution is also effective to find solutions (3).

The second analysis is based on the identification of paths linking tools (table 1).

Table 1: Sequences of tools: a number in a box xy indicates the number of paths from a tool in line x to a tool in column y.

	Search for information	Contact with client	Questionning the need	Interactions diagram	Criteria identification	Flow diagrams	Functionnal tree	Ideal Final Result	Triz multi screen	Triz problem modelling tool	Triz problem solving tools	Comparison / evaluation	Schemata, concepts	CAD	Search for solution (free)	End of project
Initial problem	1	2	6	1				1					1		1	
Search for information	X	1	1			1	1	1					1	1	1	
Contact with client	1	X	2		1			1				1		1		1
Questionning the need	1	2	X	7	1			1	1							2
Interactions diagram	2	1		X	5	1			1	1		1			1	
Criteria identification		1			X	3	1					1		1	1	
Flow diagrams	1					X	1	1		1			1	1		
Functionnal tree	1						X	1		1				1		
Ideal Final Result	1							X	1	3			1	1	1	
Triz multi screen	1								X	1					1	
Triz problem modelling tools	1	1						2		X	3				1	
Triz problem solving tools											X		3			
Comparison / evaluation												X		1		1
Schemata, concepts					1	1	1	1		1		1	X	3		
CAD		1	2							1				X		5
Search for solution (free)												2	2		X	

Students classically start their projects with a questioning of the need and they end it with a CAD modelling of the product they propose. We can explain it by the place of the first project meeting in the course, and by the deliverable we asked (including a geometrical description). Apart from these observations, the highest frequencies relate to the two methods taught (Functional Analysis and TRIZ), and to a logic for geometrical modelling (drawing, then CAD). But on a total of 121 sequences, 83 are not mentioned more than twice! This result reveals the differences between the graphs more than their similarities: the students gave sights of their processes which differ very appreciably between the groups. If an overall logic exists from the definition of the need to a proposal, one can refute the idea of the existence of a generic process for all the groups (there are "not" two identical processes).

4 CONCLUSIONS.

In this article, we proposed to help the reflexion on action of students in a Master degree course in mechanical engineering by asking them to restore the effective course of their project in a graph connecting the different elementary methodological tools used and the results that each one produced.

This teaching experiment shows that it is possible to spark such a reflexion. Each group of students can give the path followed, evaluate the critical issues, and wonder about the relevance of the choices - as proposed, such a graph is already an aid for a presentation of a design process, and a good support for discussion. But some collective learning is also effective: by observing the graphs (and the associated comments) made by other groups, each student can perceive similarities and differences which can possibly be explained by some specificities of the project, or/and by different choices. The analysis carried out after the session produced results conform to the concept of situativity: each process is different (but one must notice that it is based on few data).

A first evolution in progress consists in introducing the graphs at the very beginning of the projects (instead of at the end of the session). This change aims to move from reflexion on action to reflexion in action; these graphs constitute a considerable contribution for the exchanges between students and teachers during the project.

A next issue could be to evaluate the aid provided for procedural knowledge building on the use of methodological tools. We consider that the required competency is not only the ability to use a tool according to its own rules, but also includes the ability to call / choose the "best" tool for the current situation: to call a tool, to evaluate its potential contributions, to gather the right information for its use, to use it with a critical sight in order to evaluate its results, sometimes divert it or give it up. Until now, this knowledge acquisition was only tacit, individual, and hard to evaluate; a representation of the effective process is a useful medium to build explicit - then sharable - knowledge.

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