On line course and learning scenarios for innovative design teaching

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Keywords: On line course, flipped teaching, design education, meta-cognition.

INTRODUCTION

Among professional activities, design is certainly one of the most rich and complexes; and so difficult to describe and to teach. The objective of this paper is to present the developments of an innovative design course, especially the recent use of an online course and of a detailed scenario of the entire course. From a description of design activity, a set of skills is derived, highlighting the role of meta-cognition. Then the course is presented, notably its recent developments towards flipped teaching. Results are the opportunities and effects of the online course and scenarios on the structure of the module and on the roles of teachers.

1 CONTEXT

1.1 Design model

Two major references structure design activity modeling. According to H Simon [1], design is the exploration by heuristic reasoning on an ill defined problem. The definition of the problem is completed and partly discovered during the exploration process itself. The designer's objective is to propose a satisfying solution taking into account internal and external constraints such as limited cognitive capabilities, means and time. According to D Schon [2], design is a "reflective conversation with the materials of the situation", notably the representations designers build and modify. Regularly, a designer must observe and analyze them in order to determine his next actions. Two types are distinguished by Schon. Observation 1 is the observation of the entire (representation of the) product under design whereas observation 2 is limited to the consequences of a modification. Schon also introduced the concept of framing – and reframing- notably at the beginning of design activity.

For modeling design, I consider three description levels [3,4]. At the lower level (elementary operations), designers consider and define product parameters and make inferences on these parameters. They also evaluate the product, or part of it, referring to technical requirements. This is a product viewpoint where the target performances, functions and affordances [5] of a product are deduced from its structural parameters. Opposite is abductive reasoning (heuristics / creativity): to imagine structural parameters from preexisting objectives. Here, it is important to note that new and contingent effects deduced from these structural parameters can emerge during design. Therefore, design problems are not only "ill defined" problems whose characteristics – especially the requirements – can (only) be discovered by the exploration of "the" solution space; but "wicked" problems whose definition depends on decisions taken on the proposed solution. At an intermediate description level, design is made of successive actions, each with a short term objective. Five actions are identified: framing the design problem (1), observing the entire product (2), selecting and analyzing a "local" problem (whose definition contains a restricted number of parameters – not all) (3), moving (4), and observing (and deciding) the local solution (5). The two observations correspond to Schon's model. The upper level for design description is that of activity management: how to manage the succession of design actions. At the very beginning, actions follow each other by ascending order. But very rapidly, a designer can choose to evaluate –or not- several technical options (iterations 5→4). He will also have to dynamically manage the co-evolution [6] between problems and solutions (iterations 5→2) and eventually reconsider product framing (iteration 2→1). Design activity management must consider both the consequences on technical decisions (among which contingency is critical) and the external constraints on the activity.

1.2 Design learning outcomes

Design skills are derived from the three-level activity model description. They must consider interactions between project management and technology analysis. From the lower level, a designer must be able to apply his technical knowledge for deductive reasoning: to calculate, to experiment, to apply optimization methods, to treat numerical data… Evidently, he must also be creative: to vary product parameters or to imagine new ones (a different structure, different performances, functions, affordances…). He will also have to represent solutions: to draw, to use CAD models… From the intermediate level, design skills mostly refer to (numerous) specifically developed methodological tools. Framing requires setting and detailing technical requirements: questioning user experience, identifying the need, describes functions and criteria… For action 2, a designer must be able to critically analyze how a system / product work and to identify its characteristics, its flaws and lacks as well as its potentialities: set structural control parameters, represent matter, energy and information flows and describe technical functions… For problem analysis, interesting concepts and tools refer to trade offs and contradictions and to ideal problem solving. Moves can be assisted by creativity tools and problem solving principles (and by representation and deductive tools – see above). Observation 2 (action 5) is an evaluation and can be structured by classification and comparison tools. For each tool, the learning outcomes must consider (at least) three objectives: knowledge of the concepts onto which they refer and description of the tool; its correct application; and the ability to adapt, transform or eventually "twist" the tool according to the situation and to the short term objective the designer defines himself. This last objective introduce critical thinking on the tool which is a meta-cognition applied to the means for action, including (self) observation of the action. From the upper description level, design skills refer to the management of an evolving situation where the evolutions come from both the project itself –see the notions of contingency and co-evolution – and form external constraints – “external” reframing, time, means and human management. Project management tools are not sufficient in such uncertain situations where agility and reactivity are necessary. A designer must be able to recognize the consequences of his actions and decisions, both on the product and on the process; and to (re)define next actions and project objectives. Therefore, meta-cognition in design is mobilized for the product itself (notably in action 2), for the means for action (design tools) and for the process management. Design is by essence a highly meta-cognitive activity [7].

Its teaching is classically done by PBL / Project Based Learning [8]. It is recognized to favor the acquisition of management and social skills. Meta-cognition is an interesting means for learning tools use and adaptation as well as design project management. Beyond practice, specific teaching actions should be imagined for it.

1.3 Context and pre existing course

The teaching module is part of program for industrial production management containing other modules dealing with functional analysis, project management, quality, classical problem solving methods, lean, 6 sigma... It particularly develops TRIZ [9,10] tools, and the management of industrial process design projects. Its volume is 28 hours of lectures, 24h tutorials (25 students) and 21h of practical work devoted to a design project in team work (4–5 students each; 3 simultaneous teams). Working in pairs mainly in home work, students are also asked to build a report by the application of the methodological tools given in the course to an existing product in order to analyze it. Meta-cognition is structured at the end of the projects by a list of questions project groups have to answer: on the methodological tools (conditions for use, limits, adaptation, and links between tools…), on the process (programmed or not, convergence/divergence phases, milestones, bottlenecks…), on representations (use of drawings, mockups, CAD…), and partly on the socio-cognitive character of the activity. Meta-cognition is also favored during the last third of the module with information delivered during an industrial conference, lectures on other methods (value analysis…), a critical synthesis of TRIZ world (history, claims, diffusion, actors..), exercises where the choice and adaptation of tools is asked for, a collective reflection on tools contributions and limits, and a final synthesis. As described, this teaching has been presented in SEFI 2010 [11]. The main results were the adaptation of teaching means to learning objectives especially for project management skills, the evolution of teachers' roles for students' reflection on action and results of the reflection asked on design projects. This reflection appeared nearly systematic and synthetic on methodological tools; but contrasted on the process and incomplete on the use of representations.

Between 2010 and 2013, several evolutions were introduced. Two modifications concerned design projects specification. In order to engage students to better reflect on representations, a lecture was introduced (use and roles of representations in design) and they are regularly encouraged to build physical representations showing the way a product work; i.e. not only static drawings or CAD models, but animations or films showing the product in interaction with other objects and users. Second, the information given for projects has been "calibrated" and the requirements for the formal halfway milestone modified in order to engage students to propose for it a first quite detailed solution (actions 1 to 5 – classical beginning of design activity); and then to experiment design iterations and to reflect on design activity during the second half. Both modifications improved the quality of the reflection on design process and representations. A second evolution concerns the documents for lectures. Their new structure was derived from the activity model. It is made of lectures presenting concepts on product description and on design process characteristics, and of methodological tools presentations. If the former structure focused on tools, the new one intends to present first design activity concepts then tools linked to concepts. Shorter sequences were also defined (30 to 90 minutes for a sequence). A third evolution concerned the tutorials on tools with the experimentation (in 2012) then the generalization (in 2013) of cooperative modalities. Students work in groups. They are first asked to produce a document where they apply a tool on a product or problem (depending on the tool main function). Then, they must improve (six "D tutorials" with a first application of a tool to Discover it) or evaluate (three "R tutorials" to Reinforce main tools mastering) a document produced by another group (same tool but a different product). Finally, a collective synthesis is made: impressions, advantages and limits of the tool (D tutorials); or evaluation of tool mastering (R tutorial). For each tutorial, guidelines were written. A fourth evolution concerns the reports on product analysis. During a tutorial at the end of the module, students are asked to cross evaluate other students' beta reports. Pairs of students are mixed up in order that each student sees several reports. Students highly appreciate this tutorial. Finally, a pedagogic plate form is used for the module description, examples of former students' reports, instructions and documents disposal. Except for tutorials instructions given just before each tutorial, all the information was given at the beginning of the module.

Note: the complete module in UTBM uses all these modalities. But part of it is also used for diffusion in other engineering schools: in ESTA (Business and engineering) and in ISAT (automotive engineering). In ISAT, concentrated on 6 days, I teach only TRIZ tools including D tutorials to 100 students: 20 hours for each student.

2 INNOVENT-E PROJECT.

InnovENT-e [12] is a french IDEFI program. Its objective is to develop, label and promote formations based on a skills reference frame for innovation generation and management, especially for SME and / or abroad development. These formations should be accessible for students involved in an initial higher education program as well as for long life learning. Learning modalities can be full distant or hybrid learning.

In this frame, lectures on concepts and tools presentation were transformed into an online resource. And the entire course has been described in elementary components, each describing students' activities: a scenario.

2.1 Creation of the online course.

The creation of an online course is seen as a process leading to an online course a student can consult at his own pace, from a resource still existing; here, the preexisting powerpoint support for lectures to which we added explanations, recorded then typed. It began in mid 2013 for a first use in spring 2014 semester. Its consultation is given on a web site (html format). Its presentation is illustrated by numerous visual supports and a tree detailed structure for a rapid access to each content. Links between notions have been explicated at the end of the 2014 session, both with a detailed glossary of terms and with the addition of a sub section at the end of each section. Such links appear necessary in a domain where the vocabulary is still under construction and can vary according to the viewpoint / methodological tool. Nevertheless, there are few videos and the interaction with the student is limited to multiple choice questionnaires at the end of each section. Students are given a full access to the entire online course at the beginning of the module and we regularly recall them for its consultation. Moreover, the resource is fully accessible during the tutorials. Now, the main stake is not the contents or the interaction offered during its consultation, but its use and its interactions with other learning modalities.

2.2 Learning scenarios.

Flipped teaching has been qualified as both undervalued and promising [13]. But it requires students to change their learning culture [14] and to adapt their activities. Especially, time management must be redefined … and such difficulties were effectively reported by students for the 2014 session. Learning scenarios, built for the 2015 session, appear as a way to specify to students how to work. The objective was the creation of a detailed and structured base of information containing for each sequence (elementary learning activity) the description of an objective, the learning modality (ies), the resources, the documents students must consult, build, exchange and give at the end of the activity, the time, the evaluation(s) and the actions of the teacher. Except for the last point, all the information is explicitly given to students. Moreover, the pedagogic plate form is automatically built from the scenario.

The existing practice and documents largely prepared the writing of learning scenarios. Some very few lectures had to be subdivided. For tutorials, the existing frames, instructions, guidelines for tools use and evaluation, and presentations of products and answers were completed in order to become self sufficient: a quite easy work - even though cumbersome. The successions of activities were also thought and applied; they had simply to be explicitly written. For projects, the description of teachers' activities was prepared by the reflection on teacher's roles and by a practice of note taking and sharing among colleagues. Writing learning scenarios was the opportunity to write down information initially private or given verbally; and to detail it. Learning outcomes were also detailed up to each activity. Moreover, with this description, I was able to define sub modules. Each one is a succession of activities aiming to reach one unique learning outcome.

3 RESULTS

Results affect all the activities of the module, except project, kept unchanged.

3.1 Information delivery: Lectures and online course

Since the course is accessible online, lectures in the classroom were limited: to the introduction and synthesis (with students' active participation), lectures on technical functional analysis and Value Analysis, a synthesis on TRIZ "world" and the industrial conference. For the 2014 session, the use of the online course for home consultation was variable and low: Students declared an average of 5.6 hours- ald 12 to 14 for initial presence lectures. But they also regularly consulted it during tutorials and project. During the second half of the session, I introduced a short sequence (10 minutes) at the beginning of each tutorial to remind orally an abstract of knowledge concerning the tool studied: underlying hypotheses, main features, how to use it and instructions for the tutorial. In ISAT (Autumn 2014), I also tried short sequences where students consult the online course during tutorials hours. In this context where the concentration of the course on few days restrains possible consultations on evenings, this modality was quite efficient. For the UTBM 2015 session, I added a short video in order to remind information before tutorials and each online section is embedded in its corresponding sub-module scenario.

3.2 Tutorials to discover then apply methodological tools

Keeping the same number of hours in presence with students, the online course gives additional time during "lecture" sequences. Incidentally, two sequences were used for answers to individual questions (projects and reports on a product analysis). But the main use of this time was to propose to students activities aiming to discover tools: in fact tutorials in a large classroom - 56 students. Five tutorials are now given this way, among which a new one. These D tutorials are possible when the scenarios are fully formalized, with documents describing the instructions, the product, and a procedure to use the tool. Examples (products) must be simple, needing few technical additional explanations. The objective is limited to a first application on the tool, finally with little reflection on it. The teacher controls time and activities with some limited individual assistance. This is "mass" instruction, efficient relatively to its limited objectives. It is relayed later during R tutorial hours with few students (and also during projects and reports), to reinforce the mastering and engage reflection.

3.3 Reports on product analysis

A similar reorganization for tutorial hours was then possible. As soon as some activities were transferred to lecture hours, it was possible to reinforce tutorials on functional analysis and to introduce new activities. The reports on product analysis were initially made nearly entirely off course with the single late tutorial for cross evaluation of beta reports. There are now regulated by two additional tutorials where the teacher assists and checks the progress of the work. Therefore, the use of online courses was the means by which the module was restructured with domino effect modifications. Moreover, less time for lecture speeches means more active students and new activities. An indicator is the estimated time a student spends simply listening - the teacher or other students working on the blackboard. The percentage decreased before the introduction of online course and tutorials structured by detailed scenarios since cooperative tutorials were still used in 2013 but this decrease was drastically accentuated…. Should an ideal course be one where teachers never speak to all the students? A more reasonable objective could be, when the teacher takes the floor, to voluntarily limit his speak to few minutes.

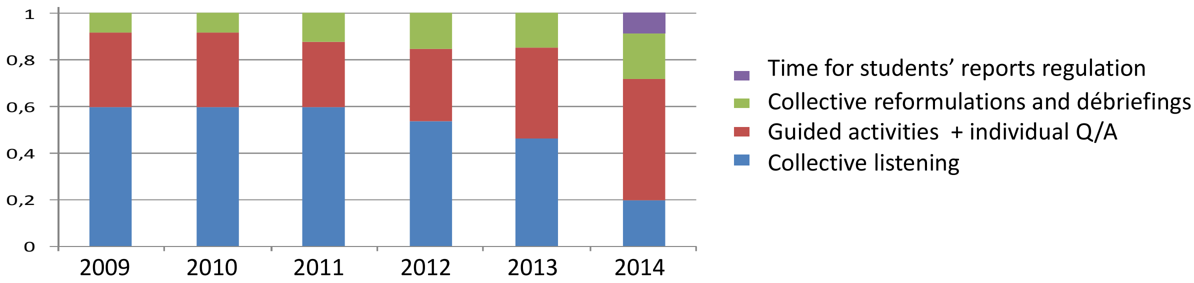

Fig. 1: Evolution of the percentages of time students spends in different types of activities during lecture and tutorial hours.

3.4 Evolution of the roles of teachers.

The questioning of teachers' roles was engaged before the Innovent-e project [11]. What appears new is the formalization of learning scenarios where the activities of both students and teachers is asked for. With the disposal of an online course, a teacher looses a large amount of his mission of information diffusion. Nevertheless, it is still necessary to give back such information, often to summarize or reformulate, and also to give or recall a context, illustrate on examples and make links to future lectures, activities or concepts. During tutorials, a teacher must understand and interpret questions, explain, propose alternative representations… and keep time while following the progress of the classroom. These regulations are particularly important when students deepen they knowledge and mastering of methodological tools. When closing tutorial sequences, the role moves to animation and synthesis of multiple viewpoints, and to draw perspectives. For the project and the realization of reports, the roles of the teachers are quite unchanged: to build a project situation by the choice, construction and adaptation of a subject, to adjust the requirements (both technical and related to learning), to suggest and question the choice and adaptation of tools, to help when necessary, to question the process management and then to control as much as possible the experimentations associated to the learning objectives. For these roles, the teacher mobilizes his meta-cognitive abilities in order both to act on students' learning and to pilot their learning processes: above all, a teacher is a reflective practitioner (and also a lifelong reflective learner) [2].

3.5 Structure of the module.

With the complete formalization of learning scenarios, ten sub modules were drawn. Six correspond to TRIZ tools and are built on a same pattern: online courses on concepts on product and/or design activity, then tutorial to discover and to master TRIZ tools (for 3 of them). The other sub modules (introduction, project, reports and reflection) combine meetings with teachers, document exchanges, pair evaluations, project milestones, collective syntheses, self evaluations…. The formalization of learning scenarios helped to further explicit and detail the structure of the module and most of all to give it modularity.

3.6 Formation of colleagues.

The preparation of the online course (end of 2012), then its realization (end of 2013 and 2014), were also used by two colleagues to discover by themselves the design and TRIZ concepts and tools I use in this course. Both – in ISAT and in ESTA – help me during sessions with students - this was necessary due to the number of students involved. Working together with same bases (the online course), written scenarios and complete documents for each tutorial helps the appropriation of concepts and practice sharing to teachers themselves. Both colleagues could now deliver the six TRIZ discovery tutorials and control design and concepts acquisition for the six tools, following a same process and reaching similar objectives… after (only) two sessions.

4 CONCLUSIONS

The modifications of the design module due to the Innovent-e project consisted in the introduction of an online course (2014) then the formalization of learning scenarios (2015). They follow a series of transformations which concerned successively design Project Based Learning, the creation of lectures and tutorials, the realization of reports by students, a definition of the way teachers follow the progress of projects, the instrumentation of the reflection asked to students and cooperative means for tutorials. As other teaching tools, online courses and learning scenarios offer opportunities and means for transforming and adapting teaching modalities, teachers' (and students') roles and finally to transform learning processes. Their impacts are largely perceptible. Due to online courses, time was reallocated and the activities reorganized. Students spend more time on higher cognitive activities: to discover by themselves, to test and to reflect on the tools and on their activity. Similarly, I – and my colleagues – give more and more importance to the preparation and control of students' activities, and to the observation, adjustment, evaluation and validation of their learning. Activities also tend to become shorter (by segmentation and diversification) and so the course more dynamic. Modularity increases, giving the opportunity to better tune other contexts, in other schools and for lifelong learning. These tools also favor the rapid formation of colleagues, sharing not only the contents but also documents, learning scenarios and teaching practice. Nevertheless, if such sharing appears now easy when the objectives are limited to tools discovery, the meta-cognitive objectives for design activity management involve project application and reflection on them and appear less easy to formalize.

The perspectives of this work are now its dissemination and adaptation; and its test in real distant learning conditions.

ACKNOWLEDGMENTS

Thanks to Pierre Alain Weite (UTBM), Steve Bossard (ISAT) and Daniel Schlegel (ESTA) for our common teaching actions, their questions and their implications. Thanks to Innovent_e project managers and engineers in pedagogy: Solene Meignen, Zedjiga Aidrous, Marion Mezerai, Hamid Le Fleurier, Paula Caterino.

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