

# CONDUCTING VALUE ENGINEERING ANALYSIS AROUND A COMPUTER SUPPORTED COOPERATIVE WORK IN DESIGN PLATFORM

A. L. Guerra, T. Gidel, E. Vezzetti, A. Jones, and D. Lenne

*Keywords: potential of collaborative technologies, advanced and innovative design tools, design tactics and methods, new approaches to the design theories, handling design knowledge*

## 1. Introduction

The TATIN project [Gidel et al. 2011] of the *Université de Technologie de Compiègne* was launched in 2008. The aim of the TATIN project is to **improve the Preliminary Design (PD) process, through the introduction of computer-supported cooperative tools and an adapted design strategy.**

An interactive, multitouch, multi-user tabletop was conceived during this project. This family of devices is identified with the acronym CSCWD: Computer Supported Cooperative Work in Design systems (see [Grudin 1994] for a historical excursus on the origins of CSCW researches).

Starting from scratch, three aspects had to be considered for implementation of an interactive space:

- The hardware, HW (chassis, input and output device, connectivity, etc.),
- The software, SW (I/O management, framework, Graphical User Interface, etc.),
- The adapted design strategy (the scenarios and the workflows to be implemented via software).

To address this challenge a user-centred, co-evolutionary approach [Guerra et al. 2012], which will be presented in Section 2, was chosen.

Several Preliminary Design scenarios have been studied since the beginning of the project. Two main hypotheses have been demonstrated through **qualitative ethnographic descriptive** design observations.

1. **HP1:** The TATIN platform is an effective support tool for the Preliminary Design phases, in terms of **efficiency, usefulness and agreeableness.**
2. **HP2:** The use of the TATIN platform **fosters the cognitive abilities of designers** (derived from Wang et al. [2002], which talk about augmenting the capabilities of individual specialists and enhance the ability of collaborator to interact with each other and with computational resources). **Fostering the cognitive abilities of designers improves the Preliminary Design process.**

Section 3 presents the design observations we carried out and details the protocol for value engineering analysis through a comparative cross-sectional study. The results obtained are analysed in Section 4. The discussion of these results, and their comparisons with the results achieved through prior design observations can be found in Section 5. We conclude providing our plans for further development of the research.

## 2. Co-evolution of design strategy and CSCWD systems

We refer to co-evolution [Guerra et al. 2012] as the mutual influence throughout their design of the CSCWD system (hardware and software) together with the design strategy (differently from the co-evolution of problem and solution, such as in Maher et al. 1996). In Section 2.1 we defend our vision about (preliminary) design, which explains the reasons and the necessity of a co-evolutionary approach. In Section 2.2 we introduce our design strategy: the methodological circulation, while in Section 2.3 we trace the evolution of the TATIN platform toward its actual configuration.

### 2.1 Preliminary Design Process: the enactive approach

We see design as an iterative, heuristic, and holistic process, which remains in perpetual evolution throughout different design stages. It generally starts from a problem (either well or ill-defined), and passes through activities of conceptualization, framing, structuration, and planning (Preliminary Design). The design process ends upon the detailed study of the architecture and the components (Detail Design). While the design process progresses through these stages, designers switch alternatively between IW (individual-work) mode and TW (team-work) mode.

Our attention is focused on co-located collaborative meeting during the Preliminary Design phase. According to Shiba [1995], collaborative design promotes a more efficient construction of a shared vision, which makes the design team more effective. Usually co-located teamwork meetings involve a core-team, formed by 6 to 8 people, which work in apposite rooms. These rooms are equipped with tables and whiteboards. A “dictator-guided mutual” collaboration model rules this collaborative work ([Guerra et al. 2013] following [Maher et al. 1998]). During these co-located teamwork meetings, team members create and manipulate intermediary project artefacts from two categories:

- Intermediary artefacts that represent the project: activities, resources, planning, risks, and costs [Shen et al. 2002], [Gidel et al. 2005].
- Intermediary artefacts that represent the products: ideas, concepts, functions, drawings, sketches, and virtual and physical prototypes [Darses 1997].

These conceptual artefacts allow the team to maintain common vision and shared objectives. They ease the sharing of information and coordination that is vital to informed decision-making [Rogers et al. 2006], [Tory and Staub-French 2008]. The effectiveness of collaborative work therefore depends on the ability of participants to agree on a common set of representations to frame problem and solutions.

We share the vision of a co-evolution of problem and solutions along the design process [Maher et al. 1996]. From the realm of unknown, through a sequence of divergent and convergent cognitive activities (creation and focus), problem and solutions co-evolve to reach a level of concreteness at the end of process [Dorst et al. 2001]. As designers explore this “problem/solutions” space, their quest is to identify satisfactory [Dorst 1996] or adequate [Cross and Clayburn Cross 1995] solutions, according to the criteria imposed by the project ecosystem.

Several design strategies are followed during exploration of the problem/solutions space. A design strategy is the cognitive approach, which emerges from the collective intelligence of a design team exploring the “problem/solutions” space. This collective intelligence is greater than the simple sum of the individuals [Woolley et al. 2010]. A design team behaves as a single cognitive entity (collective intelligence), but at the same time, it behaves as a collage of individuals. These individuals are cognitively influenced in different ways by the interactions they have with the surrounding ecosystem (natural objects, artefacts and other cognitive beings). We identify as Enactive Design this cognitive feedback-based exploration of a design team’s collective intelligence, through the perception-action interaction with the ecosystem [Lenay and Steiner 2010] of each designer.

The term strategy is used to underline the effectual aspect of the design process [Sarasvathy 2001]. The path to reach a satisfying design solution is not known in advance [Guerra et al. 2013]. Following this paradigm, we based our research work on a co-evolutionary approach. While keeping a holistic view on all components that compose our design problem (system and design strategy), we engaged in an iterative design loop driven by user feedback from numerous evaluations. This co-evolutionary approach allowed us to better frame our problem and to focus on the most satisfying solutions according to our ecosystem.

## 2.2 A design strategy for CSCWD system: Methodological circulation

The design strategy emerging from the above-presented design vision is called Methodological Circulation (MC). MC is an evolution of Focused Creativity first proposed by Gidel and Romon [Gidel and Romon 2009]. Focused Creativity is in turn inspired from the union between Herbert Simon and Allen Newell's problem solving theory [Newell and Simon 1972], design thinking [Brown 2009], [Plattner et al. 2010], and effectual approaches [Sarasvathy 2001]. This design strategy aims to ease, thank to a design toolbox, the cognitive effort needed in the feedback-based exploration of the "problem /solutions" space.

Idyllically the computer supported-tool is a design toolbox that contains all the design methods among which design teams are free to circulate. That is to choose the most adequate one (e.g. brainstorming, FAST, TRIZ, ...) according to the current project goal and situation, which is unpredictable a priori. The possibility of an easy shift from one method to another, while allowing the reuse of data produced using the previous methods, is a critical success factor for both our hypothesis.

## 2.3 Improving preliminary design through the use of Computer Supported Cooperative Work in Design platform: TATIN and TATIN-PIC

The Preliminary Design phase is the most impactful in terms of performance and costs [Paulson 1976]. MacLeamy [2004] explains that the optimum project plan calls for high initial efforts in the Preliminary Design phase for a more effective, cost-efficient design process. As a consequence, Preliminary Design is the phase where improvements have a major flywheel effect on the whole design process outcome.

Preliminary Design activities, such as:

- framing of the problem (e.g. functional and value engineering analysis),
- generation and exploration of new concepts (e.g. brainstorming),
- structuring the project (e.g. PBS, WBS, Gantt and PERT analysis), and
- identification of possible menaces (e.g. risk evaluation and FMExA),

just to mention some, are performed in teams, using paper-based supporting tools (paperboards, boards, brown paper, post-its, notes, and sketch, to cite some). Wang et al. [2002] defend the interest in experiencing a significant paradigm shift. Preliminary design needs to *adopt a more pragmatic and aggressive approach through collaboration, supported by artificial intelligence, and fuelled by information technologies*. However, only few research prototypes are available (Wang et al. 2002).

Wang et al.'s proposals explain the interest for the introduction of computer-supported tool.

TATIN is the first version of the CSCWD platform research prototype developed at the *Université de Technologie de Compiègne*. TATIN project aims to enhance the Preliminary Design phase (that as said above has the major flywheel effect on the whole process), through the introduction of computer-supported cooperative tools. TATIN-PIC is the evolution of TATIN.

TATIN platform is composed of a tabletop. TATIN tabletop uses two HD video projectors positioned side by side to render the final double full-HD 83-inch image (1920 pixels x 2160 pixels and 1.60 x 1.40 m). The input device of the TATIN platform is based on the LLP (Laser Light Plane) technology. Infrared lasers augmented by linear filters are used to create a laser plane flush with the top surface of the table. Users' fingers, when touching the surface, disrupt the laser plane. Two infrared sensitive cameras beneath the table are responsible for tracking the fingers illuminated by lasers. Then, image-processing algorithms from Community Core Vision (CCV) are applied to the camera images to determine the position of different contact points on the surface of the table and transform them into software events. The results of our own design observations [Gidel et al. 2011] corroborated the previous scientific findings [Rogers and Lindley 2004]. Both studies point out that a vertical surface is needed to better support convergent thinking, while creativity is better supported by the horizontal tabletop. The lack of a vertical surface was the origin of the TATIN-PIC project (an improved version of TATIN), namely the introduction of a vertical board. The TATIN-PIC vertical display has a screen size of 2.05m by 1.15m, and the screen resolution is Ultra HD, with 2730 pixels by 1536 pixels. The input device technology follows the principle of the plane flush disrupted by the contact of fingers, with solely one difference: instead of lasers we used an infrared overlay frame. The TATIN and TATIN-PIC platform are shown in Figure 1.



**Figure 1. (left) TATIN tabletop – (right) TATIN-PIC platform**

The design toolbox on the platform currently contains the following design methods: brainstorming, causal analysis, functional analysis, risk analysis, problem framing, project planning, SWOT analysis, business model analysis, and flowcharts to represent the structure of different solutions.

### **3. Design Observations and Protocol**

In Section 3.1 we present our evaluation paradigm. Section 3.2 highlights the different design observations performed along the TATIN and TATIN-PIC project. Moreover, it contains our reasons for evaluating value-engineering activities. Section 3.3 describes the protocol of the design observation proposed in this article.

#### **3.1 The need of a common framework to evaluate CSCWD systems**

Buisine et al. [2012] propose that measuring the usefulness of interactive tabletop systems is a key issue. According to them, the best mean to evaluate the usefulness is a “paradigm evaluation”, or comparing the fulfilment of the same task on a tabletop system and on a given control condition (such as pen-and-paper). Furthermore, Buisine et al.’s article states that to get an “increasingly detailed picture of user experience in tabletop interface use (e.g. effectiveness, usability, pleasantness of interaction, etc.)” ethnographic studies or user need analyses should be used.

There is no general consensus around the possibility of comparing environments such as interactive tabletops and their traditional counterpart [Huber 1990], [Nunamaker et al. 1991]. We assume that in term of user experience evaluation, such comparison is nomologically possible. [Guerra et al. 2013]

Although we share Buisine et al. [2012] evaluation-paradigm approach, we would argue against considering usefulness as the main criteria for evaluating CSCWD systems. A system can be useful but neither efficient nor agreeable in use. We analysed our project according to the DRM framework proposed by Blessing and Chakrabarti [Blessing and Chakrabarti 2009]. The Research Clarification stage led us to conclude that there is a lack of common framework for evaluating CSCWD system. To fill up this gap, we started a series of descriptive studies, based on a simple Initial Reference Model (IRM),. Our IRM is composed of three factors: usefulness, agreeableness, and efficiency as detailed in HP1. Our design observations can be defined with the following adjectives:

- Qualitative: studying things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them, according to Denzin and Lincoln’s definition [Denzin and Lincoln 1994];
- Descriptive: cross-sectional study according to Blessing and Chakrabarti’s [2009] definition of Descriptive Study I;
- Ethnographic: realistic context of observation with a minimalist intervention of the experimenter, concurring Buisine et al.’s [2012] definition.

#### **3.2 Design observations during the TATIN and TATIN-PIC project**

Three design observations have been conducted from June 2010 to June 2013, reflecting the principles presented in Section 3.1. While the hypotheses did not change, the protocol evolved according to the co-evolution of the system and the methodology as explained in Section 2.

The first design observation studied a single session of co-located work, in which only one activity of divergent thinking (brainstorming) was performed [Gidel et al. 2011]. In the second one, the platform was improved allowing the observation of two sessions of divergent and convergent thinking (creation of the tasks and organising the planning), which are two components of the same design activity

(project planning) [Guerra et al. 2013]. These studies highlighted (concerning to our general hypotheses):

- HP1: the agreeableness users perceived while performing preliminary design activities around the platform, [Gidel et al. 2011]
- HP1: some encouraging clues of its efficacy (30% gain of time compared to a pen-and-paper counterpart), [Guerra et al. 2013]
- HP2: positive feedback concerning Methodological Circulation, the proposed design strategy, and
- HP1&2: corroborating evidence that the contributions of the participants in term of speech-time and gestural behaviours are more balanced if the preliminary design activity is performed around TATIN-PIC platform [Gidel et al. 2011]. This is a first step to prove the usefulness of the platform and its positive impact on designers' cognitive abilities: according to Woolley et al. [2010], collective intelligence is enhanced by an equitable repartition of the speech-time in a group.

Those design observations, despite being rich in term of results, lacked in duration and diversification of the design activities studied. In response to this, we wanted to test different design activities performed throughout several sessions of co-located collaborative work. Therefore, we observed 13 sessions of value engineering activities (Functional Analysis, Technical Systems Functional Analysis, Causal Analysis) over a period of 6 month. Table 1 shows a synthesis of those observations.

**Table 1. Summary of the design observation along the TATIN and TATIN-PIC project**

<b>Year</b>	2010	2012	2013
<b>Platform</b>	TATIN	TATIN-PIC	TATIN-PIC
<b>Preliminary Design Activity</b>	Brainstorming	Planning	Value Engineering
<b>Number of sessions observed/ number of pers. per group</b>	1 / 6	2 / 5	13 / 5
<b>Number of subjects observed/ ordinal of the session</b>	48/1 <sup>st</sup>	20/1 <sup>st</sup> , 20/2 <sup>nd</sup>	54/1 <sup>st</sup> , 20/2 <sup>nd</sup> to 13 <sup>th</sup>
<b>Reference</b>	Gidel et al. 2011	Guerra et al. 2013	Current article

### 3.3 Protocol and experimentation

The protocol was designed to compare the results of value engineering sessions conducted in the control condition (CONTROL condition) on conventional tables supported by single-users PCs and paperboards, to value engineering sessions on the TATIN-PIC platform (TATIN-PIC condition.)

The observations began with a total of 54 testers for the first session. For the remaining session, we allowed teams to decide to continue the longitudinal study on their volition. This meant that sessions 2 through 13 were conducted with only 20 subjects. Each session was composed of two time-slots of 2 hours each. In each time slot, one group of 5 people worked on TATIN-PIC condition and one group of 5 people worked on CONTROL condition. All the subjects were young engineering practitioners aged from 22 to 29, almost equally distributed between females and males. Two senior experts (more than 15 years of experience in the domain) evaluated the results of the different groups. Full-HD video cameras (4 for TATIN-PIC condition and 3 for the CONTROL condition) were positioned to cover the workspace. Their position was also chose to minimize their visibility for the users, to avoid bias produced by the Hawthorne effect [Mayo 1945]. High quality audio was captured through directional microphones.

A questionnaire for the subjective assessment of the user experience was given to each participant at the end of the first three sessions. The questionnaires were different according to the conditions but addressed the same criteria. In each of the questionnaires, participants were asked to evaluate criteria on a Likert scale of 7 points. We are aware of the criticisms in favour of a 10-point scale [Cummins and Gullone 2000], [Dawes 2008]. The main reason for our choice is that the works we want to compare our results with, for instance, Buisine et al. [2012] use a 7-scale point. Adding written

comments on each criteria evaluated was also possible. All the experiments were conducted in French and therefore results have been translated in English by the authors. At the end of the 13 sessions, design teams on both conditions, were interviewed during a 30-minute semi structured focus group.

## 4. Results

Inferential analyses were performed by the means of ANOVA. The option of considering Likert's scale as an interval scale, instead of an ordinal one, is still controversial [Jamieson 2004]. According to Kuzon Jr. et al. [1996] via Jamieson [2004]: *"the average of fair and good is not fair-and-a-half; even when one assigns integers to represent 'fair' and 'good'."* However, we believe that in a descriptive qualitative study, if a value between 'fair' and 'good' is found, it is possible to explain the feeling this value symbolises (i.e. something greater than 'fair' and lower than 'good'). To determine the exact quantity of 'fair' and 'good' is out of the scope of this research.

These data are then critically analysed with our field notes. For each session separately, we present the data and the related ANOVA analysis in Section 4.1. Section 4.2 provides the limits of the current study. We conclusively provide a general analysis in section 4.3.

### 4.1 Subjective analysis of value engineering sessions

The questionnaires from the first three sessions captured the user's subjective assessment of value engineering activities performed on CONTROL condition and on TATIN-PIC condition. The variables measured are among others: effectiveness of the tool, involvement of the subjects, agreeableness, confidence in results, etc. Tables 3, 4, and 5, summarize the observed variables values. We checked if the distribution was normal by confronting median and mean, and considering an absolute asymmetry degree as acceptable if minor than 2. Standard deviation and standard error on the mean provided useful information, which are discussed in 4.2. Finally, a T-test is performed to check significance through p-value ( $p < 0.05$ ,  $p < 0.01$ ).

**Table 2. Comparison of subjective criteria between the TATIN-PIC condition and the CONTROL condition – Session 1**

	CONTROL condition			TATIN-PIC condition			DOF	P Test	Significance
	Mean	$\sigma$	se	Mean	$\sigma$	se			
Involvement in method	5.15	1.31	0.29	5.28	1.38	0.37	1/33	p=0.94	no
Tool Effectiveness	5.04	1.12	0.24	4.92	1.25	0.35	1/32	p=0.56	no
Group productivity	4.8	1.12	0.24	5.78	0.70	0.18	1/33	P<0.01	yes
Confidence in results	5.62	1.07	0.23	6.46	0.66	0.18	1/32	p<0.01	yes
Report generation	4.62	0.91	0.32	3.00	1.15	0.58	1/10	p=0.06	no
Time management	3.42	1.12	0.24	5.07	1.07	0.29	1/33	P<0.01	yes

**Table 3. Comparison of subjective criteria between the TATIN-PIC condition and the CONTROL condition – Session 2**

	CONTROL condition			TATIN-PIC condition			DOF	P Test	Significance
	Mean	$\sigma$	se	Mean	$\sigma$	se			
Involvement in method	5.11	1.54	0.51	6.2	1.38	0.37	1/17	p=0.08	no
Tool Effectiveness	4.11	1.8	0.61	5.1	1.25	0.35	1/17	p=0.20	no

Group productivity	5.7	1.6	0.53	4.8	0.70	0.18	1/17	p=0.19	no
Confidence in results	5.67	1.73	0.58	5.7	0.66	0.18	1/17	p=0.96	no
Report generation	2.5	0.71	0.32	1.67	1.15	0.58	1/6	p=0.30	no
Surface Circulation efficacy	4.56	1.51	0.50	5.5	0.98	0.30	1/17	p=0.13	no
Time management	n.a.	n.a.	n.a.	4.4	1.50	0.48	1/9	n.a.	no

**Table 4. Comparison of subjective criteria between the TATIN-PIC condition and the CONTROL condition – Session 3**

	CONTROL condition			TATIN-PIC condition			DOF	P Test	Significance
	Mean	$\sigma$	se	Mean	$\sigma$	se			
Involvement in method	3.78	0.97	0.32	5.50	1.8	0.37	1/17	p<0.01	yes
Tool Effectiveness	5	0.50	0.17	3.60	2.45	0.78	1/17	p=0.11	no
Group productivity	3.9	1.53	0.51	5.40	1.07	0.34	1/17	p=0.03	no
Confidence in results	3.56	1.51	0.50	4.40	1.71	0.54	1/17	p=0.27	no
Report generation	4.71	0.76	0.25	3.20	2.28	0.72	1/12	p=0.22	no
Surface Circulation agreeableness	4.00	0.81	0.41	4.90	1.52	0.48	1/12	p=0.18	no
Time management	4.11	1.70	0.56	4.60	1.07	0.34	1/9	p=0.47	no

#### 4.2 Limits

We would like to critically highlight the limits of this study to provide a correct value to our findings,. Almost no results have a statistical significance according to T-Test,. This is due to the small size of the participants, worsened by a poor answer-rate to some questions. Moreover, software bugs biased the final results. When the system worked properly, scores were extremely positive, on the other hand, they turned extremely negative in case of bugs. Rather than choosing to dismiss the entirety of these subjective results, we chose to carefully complement them with our field notes and videos, which helped us understand the context of the results. Though questionnaires are a fast and useful means of analysis, they are not able to have the same descriptive power of a video recording or of an interview. Due to time constraints, all the data, particularly the videos, have yet to be fully analysed. We are currently in the process of coding the videos to measure the speech patterns of teams using TATIN-PIC platform. This will allow us to measure the equity of speech time among participants, and is one of the ultimate goals of our TATIN-PIC platform.

#### 4.3 General results analysis

With acknowledgement to the previously exposed limits, we present the trends that emerged from questionnaires (user's interpretation), the field-notes and the videos (our interpretation). Users perceive activities performed around the TATIN-PIC platform as more time-efficient throughout the different sessions (though in session 2 none of the subjects in the CONTROL condition answered the

question). Because the results from session 1 are significant ( $p < 0.01$ ), this suggests that the digital platform is more efficient, according to HP1.

Users are more involved in the activity when using TATIN-PIC platform, as shown by Table 3,. Because subjects are more involved we determine that the system is useful and agreeable, as related to HP1. We suppose that this is due to the playfulness of the interaction (attested in [Gidel et al. 2011]).

When users had to shift between different surfaces (vertical paperboard and horizontal table for CONTROL, and interactive tabletop and vertical interactive board for TATIN-PIC), they found this action easier, more agreeable, and more efficient on the TATIN-PIC platform. “*We don’t have to re-copy everything and we can move the post-its with a single gesture*”, said subject A3 during session 2. “*Fast transfer helps not to lose focus on the activity*”, said subject A8 during session 2.

On the other hand, the perceived effectiveness of the TATIN-PIC platform does not differ compared to CONTROL condition. We explain this by the frequent software bugs (see 4.2) we had in some sessions. User experience is greatly affected by this kind of event. “*We had to restart 5 or 6 times the activity due to system failures. What a nightmare!*”, said subject A6 in session 3. This lowers the efficacy of the system, in contrast with HP1.

These software problems affected the platform’s ability to create automatically minutes meeting that could be re-used in the following sessions. This feature hardly worked properly along the whole design observation. This explains the worst score (of the entire observation) of the TATIN-PIC platform compared to CONTROL condition. “*We were not able to save and export the work of this session due to a bug!*”, said subject A3 in session 3. This too, lowers the efficacy of the system, in contrast with HP1.

A greater personal involvement, together with a better confidence in the results in the TATIN-PIC condition, is interpretable as a sign of a better collaboration pattern. This has to be considered as an improvement of the cognitive abilities of the designers, in term of collective intelligence, according to HP2. We hypothesize that this behaviour is promoted by two supposed “properties” of the TATIN-PIC platform: the more equitable repartition of time speech (which is not yet proven for this observation as stated in 4.2) and the manipulation of open intermediary objects [Guerra et al. 2013]. Moreover, the two experts evaluated more favourably the results produced on the TATIN-PIC platform. On a scale to 0 to 20, the average judgement was of 19 (groupT1(18), groupT2(20)) for the TATIN-PIC condition and 14 for the CONTROL condition (groupC1(12,5), groupC2(15)).

## 5. Conclusions and future work

The TATIN and the TATIN-PIC project were launched with the goal of improving the Preliminary Design process. A platform consisting of an interactive tabletop (TATIN) was integrated with an interactive vertical board (TATIN-PIC), enabling us to conduct a series of design observation. We compared co-located collaborative Preliminary Design activities performed on pen-and-paper based traditional settings and on TATIN-PIC condition. Our previous analyses showed a positive impact on the motivation and the satisfaction of the users. Users expressed their appreciation for the agreeableness of the platform. Collaboration was improved thanks to a more equal time speech distribution among participants, obtaining better results at the end of the work session [Gidel et al. 2011].

We extended the temporal window of our design observation by following 13 sessions of value engineering analysis. We proved that it is possible to conduct a preliminary design process in its entirety on a CSCWD platform. Even with all the limits listed in 4.2, this is the first study with such results in our knowledge.

According to experts, users performed better on TATIN-PIC than CONTROL. This, together with the previous results, shows that working on TATIN-PIC is, for sure, not worse than CONTROL condition, and eventually (when the number of bugs is limited) even better. TATIN-PIC effectiveness is suggested by a greater perceived productivity, time management, and motivation, in line with our previous findings [Gidel et al. 2011], [Guerra et al. 2013].

We plan to exploit all the videos to verify if the TATIN-PIC platform generates a more equitable repartition of speech-time even in value engineering analysis, and if this has a direct link with the



collective intelligence of a group as verified by Woolley et al. [2010] on traditional supports. We are willing to share our data to collaborate with everyone interested in this research field.

Since the observation here presented, we improved our platform in terms of hardware and software. We are now re-conducting a new round of experimentation designed to overcome the limits we highlighted. Our goal is to achieve a sufficient level of reliability to test the CSCWD platform in a real industrial setting, in order to be able to provide industry-related feedbacks for the community.

In conclusion, subjects familiar with traditional design tools, then trained to use the CSCWD tools, found the latter slightly better than the former, despite software bugs that negatively influenced user's perception. The interest of TATIN-PIC platform is clearly understandable, especially considering a wide range of possibilities in the digital realm, e.g. pro-active personal agents to facilitate information research and the retrieval, creative and decision-making supporting tools, multimodal interaction and so on. The next step will be to evolve toward an industrial prototype, which can be used for real industrial observations.,

## Acknowledgement

The TATIN-PIC project is co-funded by the European Union and the region of Picardy, which we thank. We want to acknowledge also Professor Jean Paul Barthes and Doctor Claude Moulin for their precious help.

## References

- Blessing, L., Chakrabarathi, A., "DRM: a Design Research Methodology", Springer Berlin, 2009.
- Brown, T., "Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation", Harper Business, New York, 2009.
- Buisine, S., Besacier, G., Aoussat, A., Vernier, F., "How do interactive tabletop systems influence collaboration?", *Computers in Human Behaviour*, Vol. 28, No. 1, 2012, pp. 49-59.
- Cross, N., Clayburn-Cross, A., "Observations of teamwork and social processes in design", *Design studies*, Vol. 16, No. 2, 1995, pp. 143-170.
- Cummins, R. A., Gullone, E., "Why we should not use 5-point Likert scales: The case for subjective quality of life measurement", *Proceedings of the 2nd International Conference on Quality of Life in Cities, Singapore, 2000*, pp. 74-93.
- Darses, F., "L'ingénierie concurrente: un modèle en meilleure adéquation avec les processus cognitifs de conception", In Bossard, P. Chanchevrier, C. and Leclair, P. (ed.), *Ingénierie concurrente, de la technique au social*, Economica Paris, 1997, pp. 39-55.
- Dawes, J., "Do data characteristics change according to the number of scale points used? An experiment using 5 point, 7 point and 10 point scales", *International Journal of Market Research*, Vol. 51, No. 1, 2008.
- Denzin, N. K., Lincoln, Y. S., "The discipline and practice of qualitative research", *Handbook of qualitative research*, Vol. 2, No. 2000, 1994, pp. 1-28.
- Dorst, K., "The design problem and its structure", In Cross, N., Christiaans, H., Dorst, K. (ed), *Analysing Design activities*, John Wiley, Chichester, 1996, pp. 17-34.
- Dorst, K., Cross, N., "Creativity in the design process: co-evolution of problem-solution", *Design Studies*, Vol. 22, No. 5, 2001, pp. 425-437.
- Gidel, T., Gautier, R., Duchamp, R., "Decision-making framework methodology – An original approach to project risk management in new product design", *Journal of Engineering Design*, Vol. 16, No. 1, 2005, pp. 1-23.
- Gidel, T., Kendira, A., Jones, A., Lenne, D., Barthès, J.-P., Moulin, C., "Conducting Preliminary Design around an interactive tabletop", *Proceedings of the 18th International Conference on Engineering Design – ICED11, Copenhagen, 2011*, pp. 366-376.
- Gidel, T., Romon, F., "Dedicated Collaborative Space opened to all opportunities but focused on innovation target. The UTC innovation centre case", *Proceedings of 4th Conference on Designing Pleasurable Products and Interface – DPPI09, Compiègne, 2009*.
- Grudin, J., "CSCW: History and Focus", *Computer*, Vol. 27, No. 5, 1994, pp. 19-26.
- Guerra, A. L., Gidel, T., Vezzetti, E., Kendira, A., "Co-evolution of design methods and CSCWD systems to improve the preliminary design process", *Proceedings of the 19th Colloque CONFERE – CONFERE12, S.Servolo, Venice, 2012*.
- Guerra, A. L., Gidel, T., Vezzetti, E., Kendira, A., Jones, A., "Co-evolution of design tactics and CSCWD systems: Methodological circulation and the TATIN-PIC platform", *Proceedings of the 19th International Conference on Engineering Design – ICED13, Seoul, 2013*, pp. 315-324.

- Huber, G. P., "A Theory of the Effects of Advanced Information Technology on Organisational Design, Intelligence, and Decision Making", *Academy of Management Review*, Vol. 15, No. 1, 1990, pp. 47-71.
- Jamieson, S., "Likert Scales: How to (Ab)use Them," *Medical Education*, Vol. 38, No. 12, 2004, pp. 1217-1218.
- Lenay, C., Steiner, P., "Beyond the internalism/externalism debate: the constitution of the space of perception", *Consciousness and Cognition*, Vol. 19, 2010, pp. 938-952.
- Maher, M. L., Cicognani, A., Simoff, S. J., "An experimental study of computer mediated collaborative design", *International Journal of Design Computing*, Vol. 1, 1998.
- Maher, M. L., Poon, J., Boulanger, S., "Formalising Design Exploration as co-evolution: A Combined Gene Approach", In Gero, J. S., and Sundweeks, F. (ed.), *Advances in formal Design Methods for CAD*, Chapman and Hall London, 1996.
- Mayo, E., "Hawthorne and the Western Electric Company. The Social Problems of an Industrial Civilisation" , Routledge, 1945.
- McLeamy, P., "Collaboration, integrated information and the project lifecycle in building design, construction and operation. WP-1202", *The Construction Users Roundtable*, 2004.
- Newell, A., Simon, H., "Human problem solving", Prentice-Hall New Jersey, 1972.
- Nunamaker, J. F., Dennis, A. R., Valalich, J. S., Vogel, D. R., George, J. F., "Electronic Meeting Systems to Support Group Work", *Communications of the ACM*, Vol. 34, No. 7, 1991, pp. 40-61.
- Paulson, Jr., B. C., "Designing to Reduce Construction Costs", *Journal of the Construction Division*, Vol. 102, No. 4, 1976, pp. 587-592.
- Plattner, H., Meinel, C., Leifer, L., "Design Thinking: Understand – Improve – Apply", Springer Berlin, 2010.
- Rogers, Y., Lim, Y., Hazlewood, W., "Extending Tabletops to Support Flexible Collaborative Interactions", *Proceedings of the 1st IEEE International Workshop on Horizontal Interactive Human-Computer Systems – Tabletop 2006*, IEEE Computer society, Adelaide, 2006, pp. 71-78.
- Rogers, Y., Lindley, S. E., "Collaborating around vertical and horizontal large interactive displays: which ways is the best?", *Interacting with Computers*, Vol. 16, No. 6, 2004, pp. 1133-1152.
- Sarasvathy, S. D., "Causation and Effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency", *Academy of Management Review*, Vol. 26, No. 2, 2001, pp. 243-288.
- Shen, C., Lesh, N., Vernier, F., Forlines, C., Frost, J., "Sharing and building digital group histories", *Proceedings of the 7th ACM conference on Computer-Supported Cooperative Work – CSCW 02*, ACM Press, New Orleans, 2002, pp. 324-333.
- Shiba, S., "Les outils du management de la qualité: guide pédagogique", *Mouvement français pour la qualité, bibliothèque Qualité*, Nanterre, 2005.
- Tory, M., Staub-French, S., "Qualitative analysis of visualization: a building design field study", *Proceedings of the 2nd conference on Beyond time and errors: novel evaluation methods for Information Visualization – BELIV 2008*, ACM Press, Florence, 2008.
- Wang, L., Shen, W., Xie, H., Neelamkavil, J., Pardasani, A., "Collaborative conceptual design – state of the art and future trend", *Computer-Aided Design*, Vol. 34, 2002, pp. 981-996.
- Woolley, A. W., Chabris, C. F., Pentland, A., Hasmi, N., Malone, T. W., "Evidence for a Collective Intelligence Factor in Performance of Human Groups", *Science*, Vol. 330, No. 6004, 2010, pp. 686-688.

MSc. Ing. Andrea Luigi Guerra, PhD Student  
 Université de Technologie de Compiègne/Unité COSTECH  
 Telephone: +33 06 95667654  
 Email: andrea.guerra@utc.fr