Computer and traditional tools in design activity: Experimental study on students of architecture

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Abstract

The worldwide emergence of computer tools in the field of architecture has evolved along with the great advance in digital technologies, extending to the whole process of the project. A fact that we cannot generalize in Algeria: students and teachers hesitate to adopt these tools in architectural projects. Some prefer "traditional tools" (paper/pencil) especially in the early stages of design.

This paper presents the results of an experimental study aiming to know how and when the student of architecture uses computer tools during the design of his projects and how the used tools affect the method and the quality of design. The study is based on an exercise with a group of volunteer students from the Master of Architecture. At the end of the exercise, they filled-in a questionnaire to learn their opinions and choices.

The design outcomes were collected at the end of the experiment (texts, papers and digital files), and they were presented in a unified way and printed out before being distributed to the jury composed of teachers from the same department. During the experiment, observations were collected and annotated using an observation matrix. Based on this matrix, the design activity of each student was segmented and graphically presented via timelines. The latter showed difference between students regarding timing and order of the use of tools (computer tools and pencil). It was proved that most of them used both tools in back and forth. The results of the evaluation show that the design and quality of the project did not rely on the tool. More

specifically, the students' projects were not significantly affected by the adoption of computer tools.

Keyword: Architecture; Computer tools; Stages of the conceptual design; Design attitude; Observation; Experimentation.

1. Introduction

The use of digital in architecture has become widespread all over the world at educational and professional spheres. This tool which was once considered simply a means of drawing becomes a tool aiding in the design. However, students and practicing architects in Algeria do not share the same attitudes towards the use of such tool, even if the adoption of the computer in their projects is taking firm ground.

This paper explores the integration of the computer tools in students' architectural projects. It deals with the design process studied and analyzed through the experimental study, in an attempt to distinguish when and how the tool is integrated in the architectural design process.

Many research works have been carried out to investigate architectural design and have been focused on the sequence of the design process on the basis of protocol analysis. This method going back to 1960s along the introspection method used in psychology, is highly appreciated by researchers in their study of the designer's approach (Arrouf, 2012). Only the principle of segmentation of the design activity is taken from this method in the present work. This principle is adapted here by taking up this activity first on timelines before their segmentation into sessions or sequences.

This study is inspired by works already done in this respect like the research of Bilda and Demirkan (2003) that aiming to understand the designers' cognitive processes by comparing digital and traditional media. Another work of Blida and Gero (2005) questioned the need to use external representations in the early phases of design. The paper of Visser and Détienne (2005) dealt with the behavior of three architects working in collaboration during a meeting for

a project design. A similar work by Zhu et *al*. (2007) dealt with design quality (creativity, adaptability) of a final product achieved by using different tools: one sub-group was requested to carry out their project using CAD tools within a CAD laboratory. The second sub-group carried out the project using traditional tools within a traditional workshop.

However, our exercise, that was carried out in one of the faculty of architecture and urbanism's workshops, tried to ensure the usual work conditions for students allowing them to choose their working tools. The exercise highlights the design phase by observing how students make use of the computer, on one hand, and at what time they use it, at the other hand. In other words, the study lies in the extraction of key moments in the designer's activity; that is to determine the exact time or the exact phase during which the student resorts to the use of the computer. The focus is on the tools and not on the design process itself.

2. Methodology

To better understand the introduction of the computer tools in the design process and their possible impact on the design quality of projects, an exercise was designed and administered to a sample of volunteers who favorably answered a call for volunteers displayed at the department of architecture (workplace). In addition to the display, the call was also diffused through the students' group on Facebook. Contact with participating students was made possible through emails.

Data collection method differs from a study to another. For the work of Zhu et *al*., students had 8 hours of work during which they were requested to record the progress of each step by safeguarding a copy of their drawings or digital files. These students were interviewed at the end of the experiment. The work done by Leclercq et *al*. (2007) and consisted of observations of five professional architects using a screen tablet with an electronic pen. Results of this investigation were interpreted on the basis of an audio and a video record. Cameras were also used in the work of Blida & Gero (2005) and of Visser & Détienne (2005).

However, in the current study, and in order to put students at ease, the record of progress is made though observation and photo taking. Data collected through observation is completed by questionnaires administered to participants. Other studies opted for free interviews like the work undertaken by Bendeddouch (1998).

The experimental study is made up of a design exercise made by volunteer students for whom an appropriate space work was ensured (Figure 1). The design problem to be solved has been prepared to offer students more freedom and it consists of a project with few constraints. The choice concerning feasibility: content and student's level was made in collaboration with some teachers at the department. Some of them were participated in the evaluation of students' outcomes in this exercise.

The proposed variants are as follows:

- 1st variant : individual dwelling ;
- 2nd variant : rest area and motorway service;
- 3rd variant: automobile show room.

Participants received the content of the exercise and the different variants in hard and digital copy (CD) before starting the exercise (stage 2 in Table 1). The form of the output was not specified, but according to the documentation offered to the participants, it has been indicated that the output consisted on any document justifying their project in the form they are used to. The explanations given to students stipulate that the design work could be stopped once the product is sufficiently communicable.

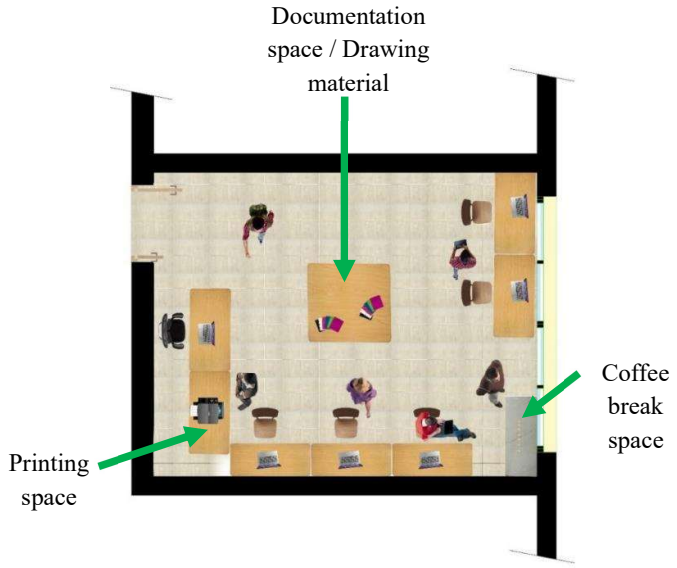

Figure 1. Plan view of the workshop devoted to the experimentation.

The experiment is made up of six steps as explained in the following table:

Table 1. Experimental steps.

Step	Objectives	Supports	Average duration	Observations
1	Presenting the research context and the exercise objectives.	Verbal	10 mn	
2	Explaining variants : - The design problem to be solved ; - Checking comprehension	A file delivered individually to students: programs, sites … (paper and CD)	15 mn	
3	Explaining questionnaires administered to students	Printed questionnaires	10 mn	To be taken back at the end of the exercise
4	Explaining the task: observation, notes and photos taking, while ensuring students are at ease.	Verbal	10 mn	
5	Exercise	Laptops, paper, tracing paper, felt-pens, pencils, color pencils, magazines, electronic and paper documentations.	In average : 4 hours and 38 minutes	Lunch break at 12h.00 or 12h.30 + Coffee break as fits the student
6	Taking back the documentations, the digital files and the questionnaires and thanking the participants.		20 mn	

3. Résultats

3.1 The observation

The objective being to collect information through the observation of the students' working attitudes, an observation grid had been devised in advance, adjusted and filled on the spot in a chronological order. Time consumed, working manner, supports used and duration of the different phases form the data of this grid. Note taking was done according to a timing variance of 10 to 15 minutes (maximum) depending on the context. In parallel with students working, photos have been taken (Figure 2).

Figure 2. Photos of the exercise.

For each student, a timeline was drawn to represent the student's activity. Axes, thus, represent graphically progress in time of the design activity (in a chronological order) and is made up of a sequence of tasks each defined in terms of its beginning, end, and the support used in its execution. It is important to note that the process is made up of a non linear combination of steps (switching back, moving back and forth, for example), but our choice is made on the linear in relation to time.

Some remarks emerge following a first reading of the timelines:

- All the suggested variants were equally dealt;

- The students did not have the same attitude towards the work; each student had his own preferences, except one student (S4) who worked with computer tools for the whole process. All the rest of the students started working on paper / tracing paper with a pen ;
- The software used were: SketchUp, AutoCad and Google Earth (Google SketchUp). SketchUp is the one preferred by most students for the volume. As for AutoCad, it was reserved for spatial repartitions and finalization of the drawing before submitting it;
- 4 students out of 9 (working with a computer) used AutoCad alone and did not produce 3D drawings (Example of S10) or made hand volumetric (Example of S3, S7 and S9) ;
- 5 students out of 9 (working with a computer) used AutoCad and SketchUp and produced 2D and 3D drawings (with the help of softwares) ;
- The flowcharts were drawn by hand only on a white paper or a tracing paper ;
    - S9 : ébauche de volumétrie (non poussée)
- The design is made on a two-dimension plan:
    - For the whole process, as for example S10 ;
    - The volume comes at the end of the process, whether it is produced with a software (S2) or by hand (S3, S7)
    - S9 : a draft volume (a basic one)
- A back and forth work between 2D and 3D is observed in :
    - S4 ;
    - S5 and S8: hand 3D sketches then with the help of a software.

3.2 Analysis of the design activity

The reported activity of each student on timeline was segmented into sequences or sessions according to the used tool; each change in tools mark the beginning of a new sequence. Table 2 sums up these sessions with a more detailed temporal division to quantify the hourly volume related to:

- Working with computer ;
- Working with the pencil on a tracing or white paper;
- Readings: this session covers all what is related to available documentation on student's own laptops or internet search of documents and images;
- Others: covers all useful tasks such as digitization of the site (for students' preferring a vectorial plan), volume of the site, printing, text typing, …

Time allotted for each session was quantified as well as milestone tasks were identified on these axes aiming to locate –with relation to the design activity- at which time:

- The first recourse to the computer was done;
- The first lines were drawn out on white/tracing paper.

This information is summed up in the same table, which specifies the time and the percentage of the elapsed time.

Two cases are reported :

- The work of the student who came for the work without bringing her laptop (S6) was not taken into consideration in this part.
- The student S7 had a technical problem with AutoCad and decided to continue working on paper. The quantification of this work is presented in the table below but not taken into account when calculating the averages.

Table 2. Segmentation of the design activity into sessions and the design activity milestones.

Work	**Variant choice**	**First lines on paper**	**Session (s) of work with pencil/paper (mn, %)**	**First recourse to computer**	**Session (s) of work on computer (mn, %)**	**Readings (mn, %)**	**Others (mn, %)**	**Total working time**		**Projet chosen**
S1	at 10h.00	at 10h.55:	80	at 12h.10:	145	55	40	320	5h and	Rest area and

		after 55mn		after 2h10mn					20mn	motorway service
		17,19 %	25,00%	40,63%	45,31%	17,19%	12,50 %	100%		
S2	at 10h.00	at 10h.55: after 55mn	65	at 13h.00: after 2h30mn	110	30	55	260	4h and 20mn	Individual dwelling
		21,15 %	25,00%	57,69%	42,31%	11,54%	21,15 %	100%		
S3	at 10h.00	at 10h.25: after 25mn	125	at 13h.20: after 2h50mn	55	5	35	220	3h and 40mn	
		11,36 %	56,82%	77,27%	25,00%	2,27%	15,91 %	100%		
S4	at 10h.00	None	0	at 10h.35: after 35mn	270	10	35	315	5h and 15mn	Rest area and motorway service
		-	0%	11,11%	85,71%	3,17%	11,11 %	100%		
S5	at 10h.10	at 10h.50: after 40mn	35	at 12h.45: after 2h05mn	180	50	25	290	4h and 50mn	Automobile show room
		13,79 %	12,07%	43,10%	62,07%	17,24%	8,62 %	100%		
S7	at 10h.10	at 10h.10: after 0mn	150	at 12h.45: after 2h05mn	75	40	0	265	4h and 25mn	Rest area and motorway service
		0%	56,60%	47,17%	28,30%	15,09%	0%	100%		
S8	at 10h.10	at 10h.10: after 0mn	70	at 11h.20: after 1h10mn	190	0	15	275	4h and 35mn	Automobile show room
		0%	25,45%	25,45%	69,09%	0%	5,45 %	100%		
S9	at 10h.10	at 10h.40:	125	at 13h.10:	125	30	10	290	4h and	

		after 30mn		after 2h30mn					50mn	
		10,34 %	43,10%	51,72%	43,10%	10,34%	3,45 %	100%		
S10	at 10h.10	at 10h.10: after 0mn	80	at 12h.45: after 2h05mn	170	10	40	300	5h	Individual dwelling
		0%	26,67%	41,67%	56,67%	3,33%	13,33 %	100%		

RQ. In order to facilitate the reading and comparison of data, the minimal and the maximal values are identified in two different colors for each column.

The following points are remarked on the basis of the table:

- Total time of the exercise (without taking into consideration the lunch break, breaks for personal reasons, and the student S6) ranges between « 3h and 40mn » and « 5h and 20mn » with an average equal to 4h and 42mn ;
- Sessions :
    - The total of sessions allotted for the work with the computer took between 25% and 85,71% of the total time of the exercise, with an average equal to 52,40% ;
    - The total of sessions allotted for the work done with the pencil took between 0% and 56,82% of the total time of the exercise, with an average equal to 26,57%;
    - Readings took between 0% and 17,24% of the total time of the exercise, with an average equal to 8,51% ;
    - The other tasks « Others » took between 3,45% and 21,15% of the total time of the exercise, with an average equal to 12,52% ;
- The milestone tasks:
    - With the exception of the work S4, the rest of the participants resorted to the work by hand, using the pencil before moving to the computer ;

- The time taken to move to the pencil varies between 0mn (valid for the 3 variants) and 55mn from starting up the activity, with an average percentage equal to 9,23% of the total time for the exercise ;
- The participants resorted to the computer after a time varying between « 35mn » and « 2h and 50mn » from starting up the exercise, with an average percentage of 43,98% of the total time allotted for the exercise.

4. Discussion

4.1 Design attitudes

For the entire project design phase, the participants have adopted the following work attitudes:

- Use of paper/pencil only : A1 ;
- Use of Computer tool only: A2 ;
- Use of pencil at the beginning of the project and computer tool at the end : A3 ;
- Back and forth between the pencil and the computer, but always ending with the computer: A4

4.1.1 Attitude A1 : « Paper architecture »

This attitude called « *paper architecture* » (Porada, 2001-2002), is based on work done by hand on white/tracing paper. Proponents of this attitude are convinced that hand drawing is an architect's traditional talent. Coordination between the hand and the brain seems the ideal for the detection of problems and the simulation of solutions.

Le travail S6 a été totalement produit selon cette attitude de travail, quoique l'étudiante a réparti son rendu en deux phases : la « *phase 1* » : des croquis à la main en 2D et 3D avec du texte, puis vient « *la phase 2* » qui –selon elle- concerne « *le développement des espaces intérieurs (les plans) et les croquis à main levée (passer à l'échelle) qui sera réalisée avec l'ordinateur* ». En se référant à sa propre citation, nous pouvons classer son attitude « réelle/habituelle » en A3.

The work of S6 was totally done adopting this working attitude, although the student divided her work into two phases: the « *phase 1* » : 2D and 3D hand sketches with the text, then comes the « *phase 2* » which–according to her- concerns « *the development of interior spaces (the plans) and the free hand drawings (moving to the scale) which will be made with the computer* ». According to her own explanation, her "reel/usual" attitude can be classified in A3.

4.1.2 <u>Attitude A2 :</u> « Computer for the whole process »

In our experiment, we have noted just one participant adopting this attitude: S4 (rest area and motorway service). The participant did not draw any line on the paper and did not print any drawing. He resorted to the computer after 11,11% of the exercise time had elapsed, taking thus the highest percentage of the session of work on computer with 85, 71%.

4.1.3 <u>Attitude A3 :</u> « Computer tool = drawing table »

This attitude is that of the participants using the computer after having formulated a clear idea of what they wanted to do, as the example of the works of S2, S3, S5 and S8. These participants decided everything on the paper before using the computer for one time: in **one session**. In these cases, the computer is considered as a drawing table or "*a modern drawing table*" (Guena, 2010) for the projects conceived in a traditional way, giving, therefore, a clear separation between the two sessions (the first devoted to pencil and the second to the computer tool).

The first recourse of participants to the computer comes after consuming half of the time (percentages vary between 25,45% and 77,27%, with an average of 50,88%). This attitude is very noticeable for S3 (individual dwelling) who resorted to the computer after using more than 2/3 of the exercise time (77,27%). This is confirmed (for this participant) by the considerable amount of time allotted to the work with the pencil and the paper which is equal to 56,82% (the highest percentage of participants), whereas the work with the computer received 25,00% (the lowest percentage of participants). Among participants adopting this

attitude, this was the only case for which the paper session has exceeded the computer one (the S7 is not taken into consideration).

It is noteworthy that even if the participants start with the pencil /paper, the session devoted to the work with the computer represents a higher percentage than the one devoted to the work with the paper. Among the four participants adopting this attitude (A3), the amount of time used in the work with the computer ranges between 25,00% and 69,09% with an average equal to 49,62%. However, the amount of time used in the work with the pencil/paper ranges between 12,07% and 56,82% with an average equal to 29,84%.

The work of S7 can be classified in A3, up to the technical problem that occurred after consuming 75,47% of the time allotted for the exercise.

The attitude A3 is, thus, the most adopted by the participants in the experiment.

4.1.4 <u>Attitude A4 :</u> « The back-and-forth »

The participants adopting this attitude: S1, S9 and S10 work on the paper until they reach a better definition of their project, at this time they shift to the computer, then shift back to pencil/paper. This back-and-forth movement is generally marked by the printing of plans. It is important to note that even if some participants had printed once, they placed the tracing paper many times, like the work of S10 (individual dwelling). This work reflects at best the back-and-forth movements where working sessions with the computer and those with the paper were multiplied.

It is to be noted that for the participants adopting a back and forth attitude, the total amount of time devoted for sessions related to the work with the computer is the highest. It ranges between 43,10% and 56,67%, with an average equal to 48,36%. The lowest percentage (43,10%) is that attributed to S9. This work represents an identical amount of time concerning working sessions with the computer and those with the paper/pencil. This participant resorted to the

computer after using half of the time: 51,72%. The other two participants opting for this attitude represent almost identical percentages: 40,63% and 41,67%.

This experimental study shows that the great majority of participants conveyed attitudes mixing between the work with the pencil and the use of the computer.

4.2 Stages of design

The architectural design is one of the most critical phases in the project process. The most important ideas emerge during this phase and continue to developed and revised till the end of the process. According to Lebahar (1983), this phase itself is divided into two steps: ***design and production***. The first step corresponds to the creative part of the process through the search of forms and the problem solving, while the second step corresponds to give a form to the project. These two stages (times) are also called: conceptualization and instrumentalization by Bourbonnais (2014).

According to the observation of the design activity, we may conclude that with the exception of the work of S4 (using the computer for the whole process), the participants used the computer tool for the production stage, even if they were adopting attitudes shifting between the two tools (Table 3). The pencil was used for the first stage « conception/conceptualization » the stage of ideation, which generally addresses "poorly defined" problems (Quintrand et *al*. 1985). Free hand sketch, that considered as "a *projection of thought*" (Leclerq et *al*. 2007) seems to be ideal in order to respond to the blurred and abstract aspect of this stage. As a result, the computer was discarded for the second stage "production / instrumentalization.

Table 3. Working attitude and stage of the computer use.

Work	Working attitude	The stage at which the computer is used	Observations
S1	A4	Production / Instrumentalisation	
S2	A3	Production / Instrumentalisation	

S3	A3	Production / Instrumentalisation	
S4	A2	Conception / Conceptualisation + Production / Instrumentalisation	
S5	A3	Production / Instrumentalisation	
S6	Non identified	Production / Instrumentalisation	A participant who came without her laptop and expressed her desire to take part in the experiment
S7	Non identified	Production / Instrumentalisation	A technical problem with AutoCad which occurred after consuming 75,47% of the time devoted for the exercise.
S8	A3	Production / Instrumentalisation	
S9	A4	Production / Instrumentalisation	
S10	A4	Production / Instrumentalisation	

4.3 The evaluation: Computer tools / architectural quality

The evaluation of the design quality was ensured by an examination board made up of teachers from the same department, who have experience in teaching workshop. The works submitted by the participants were first treated in order to unify their products and prepare printing in the same format. The unified printing in A3 format was submitted to the teachers of the examination board with a text explaining the general context of the exercise and the evaluation grid. Criteria that constitute the latter were set in collaboration with some teachers evaluators. A working session was devoted for each member of the examination board to explain the exercise, its objectives and the evaluation mode. The evaluating teachers were free to add any further comments.

The examination board has evaluated the architectural quality of the works on the basis of the product: A3 drawings submitted in the absence of the designer as the drawing means to be an instrument of research and clarification of ideas and a tool for representation the conceptual idea, like the research conducted by Lebahar (1983).

In order to facilitate the reading and the interpretation of the results, the appreciations of the teachers were converted into a 1 to 5 scale. The evaluation results are shown in Figure 3.

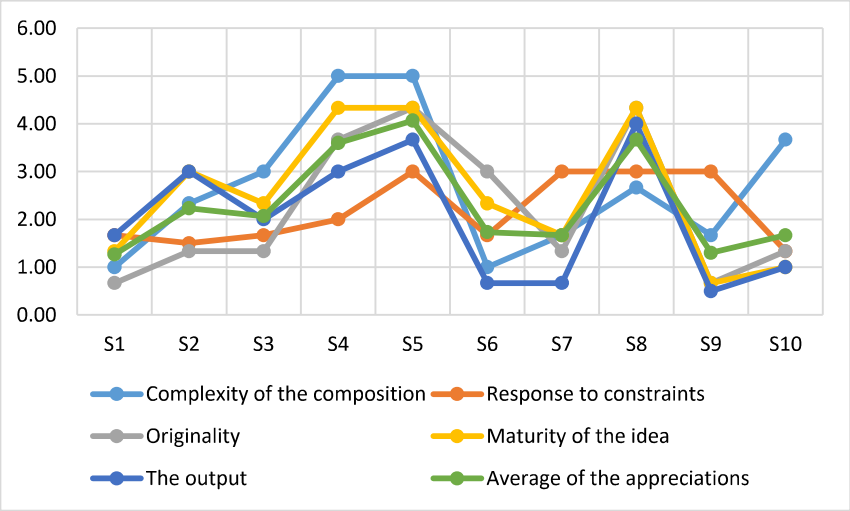

Figure 3. Evaluation of the participants' works by the members of the examination board

The average of the appreciations attributed to each work was calculated and ranked in Figure 4 presenting two graphics (left: a ranking according to participants' order, right: according to best works)

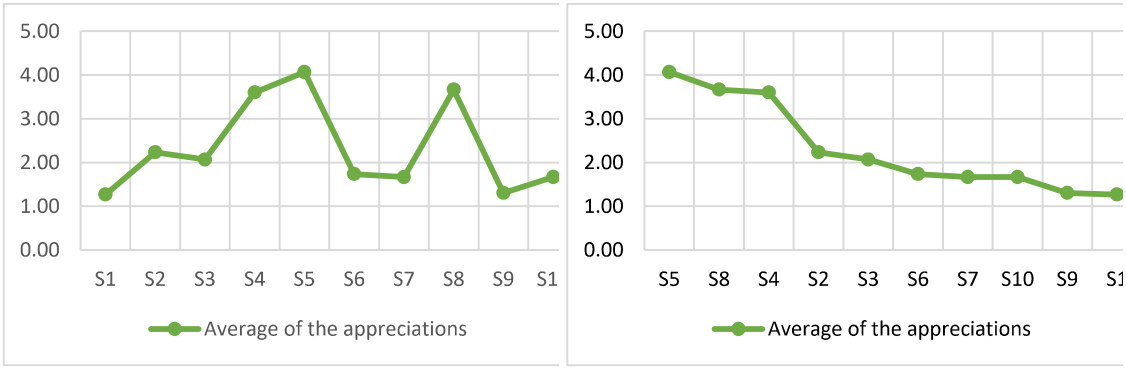

Figure 4. Global appreciation and ranking of works

The projects that convinced the most the members of the examination board are in order: S5, then S8 and S4 (which have nearly the same averages).

Tableau 4. Characteristics of the best works.

Work	Variant	Work attitude	First lines on paper (after consuming … of the exercise time)	First recourse to computer (after consuming … of the exercise time)	Session (s) of work with pencil/paper	Session (s) of work on computer	Stage of the use of computer tools
S5	Automobil show-room	A3	13,79%	43,10%	12,07%	62,07%	Instrumentalization
S8	Automobil show-room	A3	0%	25,45%	25,45%	69,09%	Instrumentalistion
S4	Rest area and motorway service	A2	/	11,11%	/	85,71%	Conceptualization et instrumentalization

These three first works:

- Received the highest percentages in terms of sessions with the use of the computer. They are in the following order : S4, S8 and S5 ;
- Reflected at best the back-and-forth work between 2D and 3D ;
- Presented a use of both softwares: AutoCad for the 2D and SketchUp for the 3D.

It appears –in our humble opinion- that these three works are those reflecting a better use of the tools: the use of the computer alone or of both tools. We may conclude that according to the evaluation made by the jury, the architectural quality does not depend on a specific tool but rather on **the intelligent use** of the tool(s) chosen.

5. Conclusion

The experimental study is an opportunity to closely verify the students' design attitudes and the use of the computer during the design stage. The results of this study showed that the

majority of the participants mixed between the use of the computer and the use of the pencil/paper (using both tools):

- The computer is kept to the end to digitalize the plans already done on paper, creating thus a clear separation between the two uses. In this attitude, the computer is an alternative to the drawing table and has the objective of digitalizing the plans produced in a traditional way;
- A permanent work back and forth between the two tools. Sometimes the students make use of a paper output to work and improve the project with the hand and /or bring modifications before opting for the final solution.

We have noted that for the majority of the students using both tools, whatever the attitude they adopt, the computer is reserved for the second stage of design. The use of traditional tools known as « *analogue* » or « *manual* » (Dortaa et *al*., 2008) are preferred for ideation, whereas the computer tools are devoted to the production stage: "*CAAD tools are viewed as production tools rather than as another design tool*" (Zhu et *al.*, 2007).

Up to the current work, the computer tools are considered as a graphical medium: « *In spite of the advanced features that have been designed for the CAAD tools, most of their utilisation is mainly concentrated on the later stages of design, as a graphic medium for drawing, modeling, rendering and simulation*" (Zhu et *al.*, 2007).

This study confirms that architecture students of Constantine prefer varied choices as regards the design tools, but the majority stick to traditional methods as they start with a free hand sketching, preferring its abstract aspect. In 1985, Quintrand explained that the problem is in the tool, and it is only the second time of the design that can accommodate the computer. Leclerq et *al.* (2007) presented that the computer tool is not made for the design phase. Bourbonnais (2014) confirmed that it is not enough developed to assist the architect in the

design. In Algeria, we are currently living the same situation, although our students are attracted by the technology and do their best to be up-to-date with softwares and training.

The evaluation of participants' works brought to light other factors among which the use of the computer which appears to be not a priority. Other research works have already proved that there is no clear difference in the quality of works produced in the traditional way and those produced with the help of CAAD (Zhu, 2007). We deduce from this evaluation that an intelligent use of the chosen tool is necessary, and a wrong comprehension of the tool limit the quality of the product (the architectural project). However, in our universities, the computer tool (as we have not yet reached the stage of digital technologies) is not used to help in the design. It has not taken its real place and its use is not pushed the great potential of simulation …..

This brings us to the question about the mastery of the tool that is not only about having enough knowledge of software and digital technologies, but also the mastery of the chosen tool.

Acknowledgment

We would like to express our sincere gratitude to the students who volunteered in the experiment.

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