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# The Design Cognitive Process Using Digital Instruments: an Enlightening Design Activity of Secondary School Pupils

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The French Curriculum for Design and Applied Arts presents a subject area stretched between artistic and technology education. It offers multidisciplinary approaches and practice shifts based on design projects that engender a digital skills development process. This—O-level—syllabus does not actually train design professionals. Rather, it develops pupils' design skills and requires the use of digital instruments to visually present and defend the design projects. We observed the design activity of several pupils in three learning situations (French high schools). We analysed pupils' intentions and preparations during the assessment tasks: artefacts they designed, statements they made on those artefacts, communications they organised to enlighten what they designed, etc. We based these analyses on interviews, slideshows and 3D graphic representations. The outcomes show the complex interaction between traditional and digital practices. It unveils the way pupils develop their creativity using and uttering peculiar ideas or tampering with teachers' requirements. It also demonstrates design skill development and knowledge acquisition: how pupils adapt the required tasks to the assessment criteria the teachers enunciate; knowledge they request to complete the tasks they must do; what kind of efficient activity (exploration, necessity, obligation) is involved in the design cognitive process when using computer-aided design.

*Cognitive processes. Digital skills development. Design Education. Social Constructivism. Computer-aided design.*

## 1. INTRODUCTION

### 1.1 Between artistic and technology education

The French curriculum of Design and Applied Arts (DAA) presents a discipline stretched between two historical affiliations: artistic education and technology education. Both refer to a constructivist approach to knowledge, that is to say, a practical teaching-learning situation which may generate questions from which pupils will build knowledge. The specific approach in artistic education is neither that of the practitioner nor that of the historian but that of a transversality which federates a set of approaches under a common question (Gaillot 1997). What is proposed in technology education is the incorporation of 'conduct research'; given that it allows the implementation of modalities of appropriation of representation and means of communication positioned as objects and problems of a technical nature (Laisney & Brandt-Pomares 2015). At the lower secondary level, for all pupils

11–15 years old, design education is engaged in artistic and technology education. The high schools' curriculum of DAA, called 'STD2A', offers multidisciplinary approaches and practice shifts based on design projects that engender a digital skills development process.

### 1.2 The STD2A requirements

The STD2A requirements refer to professional design activities to stimulate teaching-learning processes and situations. Pedagogical content encourages teachers to develop digital and drawing skills.

For the penultimate year, the requirements outline an approach to digital image processing, to develop greater autonomy of the pupil in the use of digital media at the service of their creative activity. The aim of this approach is to provide tools that allow the acquisition and processing of multimedia data to, on the one hand, communicate the studies and

projects carried out in the applied arts course, and on the other hand, to incorporate these tools within the design research process (MEN 2011, p. 3).

For the final year, the requirements consider drawing skills a prerequisite to any practice because it sharpens perception and observation. More than a tool, drawing must be considered a means of understanding the problems posed, conveying concepts, giving them form, expressing ideas and implementing a project (MEN 2011, p. 4).

## **2. THEORETICAL FRAMEWORK: DESIGN ACTIVITY IN PEDAGOGICAL SITUATIONS**

Design activity is examined in the STD2A design-learning context as a 'construction of representations' (Visser 2009). First, this perspective is based on the activity theory (Engeström 2001) and the constructivist approach to knowledge acquisition (Lebahar 2001; Vygotsky 1978). Then, this activity is also examined through the instruments in the design field within a reflective practice (Schön 1983).

### **2.1 The design task and design activity: representations at stake**

Lebahar (2007) states that the design task consists of assembling a representation, and that this task appears more as a composition of several problems, multifaceted and having different scopes. Concerning design activity, Dorst and Cross (2001) and Lebahar (2007) suggest that it is not seen as an activity reducible to a single and permanent coding of actions and operations. They analysed design activity to learn all the features and all the components. Lebahar (2007) proposes that design activity consists of organising tasks to design an artefact model which does not proceed from an existing model. Dorst (2006, p. 10) defines it as a co-evolution, a 'constant iteration of analysis, synthesis, and evaluation processes between the two-notional design 'space'—problem space and solution space'.

Moreover, design activity is based on situations, representations and task, and closely intertwines several types of interactions and several types of representations (mental images, operative pictures) whose role varies during the task and the purpose of which, is to conduct a programmed guide.

According to the social constructivist frame of knowledge, the relationship between subjects and knowledge is mediated in part by the objects they build and by the social interactions they have with other subjects (Vygotsky 1978).

### **2.2 The instrumented activity of the designer**

Beyond the operational design activity, the learning situation allows for the understanding of the constructivist process of design skill. In a training situation, the learner produces the conditions and the means of their future activity (Lebahar 2009). Lebahar (2007) has thoroughly analysed the design activity of designers and design students, and illustrated within the situation of complex interactions, where the designer enters a dialogue with a range of representations, tools or instruments that he uses to realise the design. Mediation by tools is at the heart of design activity, both for what it allows and by what means, what it makes possible, and what it limits (Engeström 2011; Rabardel & Béguin 2005). The tools help the subject to 'orient himself in the widening system of his connections with the world' (Leontiev 1978, p. 130). This is a necessity, the social essence of the subject.

So, to analyse data from a given context, to simulate, evaluate and communicate artefacts to the other subjects they work with, the designer establishes planned and external representations: diagrams, drawings, geometric objects, mock-ups, digital images, symbols systems, and so on. Representations are essential instruments to carry out the design activity allowing the modelling of shapes, features and achievements from an abstract design. Ochanine (1966) named these representations 'operative images'. They have two functions; first, they set a cognitive function, the designer can shape the desired data he collected, and the second is a regulating function, the designer uses the operative images as an artefact to act with the data.

Sketches made by designers during the design process play multiple roles for both designers and the design process (Purcell & Gero 1998). They serve as an external memory to augment the limitation of human cognitive abilities, as the medium that designers use to communicate with themselves and others, and as the triggers that enable designers to reason about a design problem (Schön & Wiggins 1992; Goldschmidt 1997; Gero & Mc Neill 1998; Suwa et al 1998; Bilda, Gero & Purcell 2006). They also enable the process of creativity (Bonnardel & Didier 2016, p. 84):

- A generative phase, in which mental representations, or 'preinventive' structures, are constructed;
- An exploratory phase, in which these structures are explored in ways that lead to insights and discoveries.

### 2.3. Digital tools: an enhancement of creativity and cognitive process?

Computer-aided design (CAD) tools as the name suggests are meant to be an aid to designers, however, professional CAD tools placed in the hands of pupils—who have a need for a tool that instructs them and that could provide instant corrective feedback—may slow down the design process and create a negative visual experience (Luh & Chen 2013).

Furthermore, if these digital technologies are taught in the STD2A curriculum, they are taught by teachers who do not have the required Technological Content Knowledge (TCK) (Tortochot 2015). As a result of not being appropriately informed on the use of digital tools, the pupil may lose sight of the objectives and requirements of the design process and focus primarily on the result of CAD representations (Tortochot 2013).

CAD tools and traditional tools, complement each other in supporting design activity (Lane, Seary & Gordon 2010). In the case of experimented students or professional designers, both digital and traditional instruments can also enhance creativity: original ideas or solutions adapted to the context (Bonnardel & Zenasni 2010). Creativity and all the appropriate instruments participate in the designer's individual cognitive process leading to the process of designing. Nevertheless, CAD tools may limit creative ability as pupils may not have the proficiency to manipulate a software program or they may be bound by the limits of the interface (Huot 2005).

This paper attempts to show the kind of cognitive processes pupils use in the design-learning field compared to experimented students.

## 3. INVESTIGATION

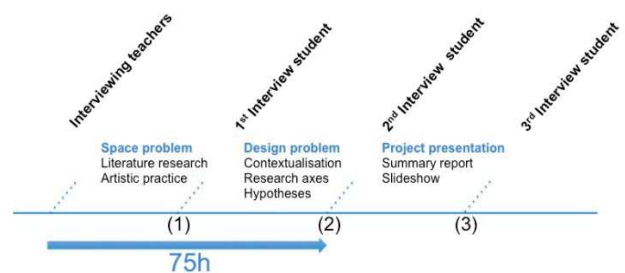
### 3.1. Design learning situation

The design activities of three pupils were investigated and analysed to observe how digital tools affect the design cognitive process, that is, the acquisition of design skills, design specific knowledge, and to explore how pupils decipher and handle project requirements and programme regulations. The analysis and investigation are based on the data collected as part of an on-going research, in which the goal is to observe a pedagogical situation through different theoretical objects (Lebahar 2009):

- planned organisation of the DAA teachers;

- productions the pupils made in various forms (drawings, commented drawings, photographs, texts);
- pupils' feedback on their own work.

The design-learning situation is a summative test, called 'Multidisciplinary Project in DAA', planned in the senior year for a duration of 75 hours. This test is organised in the classroom by the teaching team (a real project-based-learning). The pupils' written, graphic, oral productions are evaluated in three stages successively (Figure 1): the preparatory phase and research project (1) and its realisation (2) are assessed by their teachers and the project presentation (3) is evaluated by an external jury.



**Figure 1:** The multidisciplinary project and the different stages of the research

The project is always structured in five stages:

- At the beginning of the project, each teaching team proposes a topic.
- According to the teachers' requirements, pupils must engage at the same time both a literature research and an artistic practice.
- Then each pupil defines a space problem: his personal analysis of the topic allows him to point out a question.
- The space problem becomes a design problem: each pupil chooses a design field, makes clear a context and infers some requirements, as specifications and constraints induced by his design problem.
- The pupil seeks assumptions to resolve it.

### 3.2 Participants

Three participants from an existing corpus of nine pupils were selected for this communication. The three participants of this study are from three different schools located in south France; Diderot, Hemingway and Mistral. The topics proposed by each teaching team are 'Parade', 'Around the Time' and 'Experience of Fragility' respectively. Of the three schools that participated in this study,

Hemingway is the only school not equipped with digital material.

### 3.3 Materials

All the productions of the three participating pupils were documented via photography. These productions included three phases of work: phase one—exploration of the theme; phase two—development of production; phase three—presentation of the production. Only the productions from phase one and phase two were used in this communication. A pair of interview transcriptions for each of the three participating pupils were used; these included one interview at the end of phase one and a second interview at the end of phase two.

### 3.4 Methodology

The pupils design activity was explored using empirical methods—observation of recorded documents (photography of pupils' production) and analysis of transcriptions from interviews. The interviews were semi-structured; this is to say that each participant was asked a different set questions relative to their individual works. Additionally, each interview varied in length.

In the first instance data from the participants' productions—writings, photography, collages, weaving, sketches, design solutions and design synthesis—were used to observe and gain insight into the creative and cognitive process in design activity, choice of tools in design activity and the influence of digital methods versus traditional methods on the development of graphic design skills. Following this, the transcriptions from the interviews of the three participants were analysed. The entire interview transcriptions were not reproduced on this paper, only the sections considered to be relevant were included here. In order to synthesise and show only the essential, all the representations were not used.

## 4. OUTCOMES

### 4.1. Pupil 1 (P1), Diderot School, topic 'Parade': 'traditional tools to be better understood'

The productions of P1 in phase one, shown in Table 1, display a vigorous, cognitive process in the design activity of preparation and research. This is identified by coordinated assemblage of pictorial and textual elements, decoding of references via sketches as seen in Table 1(iii) for example, and quantity of production. With regards to the choice of tools, P1 has not used digital tools in this initial phase, favouring collage, lettering and sketching (observational drawing as grasping

perceptual skills, according to STD2A requirements).

Table 2a and 2b display the productions of P1 in phase two. Again, a vigorous, cognitive process in the design activity is displayed in this phase which includes contextualisation, exploration of axis and establishment of a hypothesis. This process is identified by the quantity of production, recorded thoughts and concepts in written form and use scenarios that are sketched ('expression drawing' [thought through form], according to STD2A guidelines), as seen in Table 2b(i). During this phase, P1 used both digital and traditional methods in their design activity.

The first interview with P1 conducted after the productions in phase one were completed, reveals that P1 sought to be understood. Their solution to this cognitive design problem was to accumulate a large amount of graphic and textual material. Excerpts from this interview are displayed in Table 3.

The interview reveals that P1 reflected on their productions and assimilated design specific knowledge; for example, they identified why a heuristic map is useful to them (to construct 'preinventive structures') and explained how sketches helped them to decode the work of other artists ('analytical drawing' as study and understanding of reality, according to STD2A requirements). P1 expresses a clear idea of what the objectives of phase one were. Concerning the choice of tools, P1 identified that they used a digital tool because they had a precise model and the representation was clearer when they used the digital tool as compared to drawing.

In the second interview, which takes place after phase two, P1 used analogue representations to describe an interactive event. P1 stated that their motivation for not using digital tools was that they felt it was what the production was requiring. P1 identified that they are most comfortable with watercolour and asserted that the choice of using watercolour is not because they felt more at ease with this method but rather because their ideas may be better understood than if they used a crayon.

### 4.2. Pupil 2 (P2), Hemingway School, topic 'Around the time': 'wasting the time doing small things'?

The productions in Table 4(i) and (ii) of P2 appear to have respected the requirements of phase one of the STD2A project as P2 has exploited the use of multiple artistic methods. As a result of their cognitive and design activity P2 has created clusters of information—image and text—on a collection of boards. Table 4(ii) shows the first page of a collection of boards identified as specifications.



These specification boards contain mainly textual elements with some highlighted words and a reference to colour choices. There was no use of CAD tools in this phase of preparation and research.





Table 4(iii) and (iv) display the productions of P2 in phase two. During this phase, P2 used both digital

tools and traditional methods (sketching, lettering, manual composition and fine art techniques) in their design activity. The text elements in these productions contain some highlighted words. Clusters of information—image and text—can be identified. All board titles are generated with CAD software as well as the poster propositions and the contextualisation of the artefact.

Table 1. Photographs of some productions of P1 from Phase one

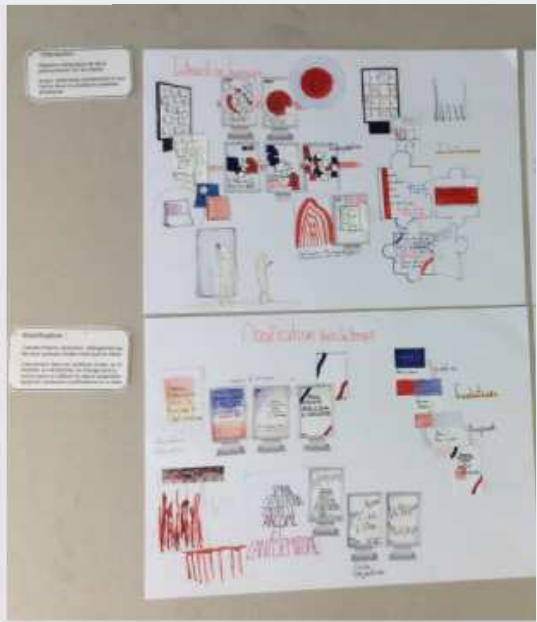
	Productions	Analysis
i		<ul style="list-style-type: none"> <li>• P1 uses words as an instrument of mediation in this initial stage of design activity.</li> <li>• P1 creates order on the support: a title area can be identified to the top; to the left, a handwritten text describing the theme; and to the right, a significant area of the support is used to display words that show their connection by their alignment. Some of these words are circled or highlighted with a different colour.</li> </ul>
ii		<ul style="list-style-type: none"> <li>• P1 has created a collage of diverse images and text.</li> <li>• P1 has outlined or coloured some elements of the collage in red.</li> <li>• P1 has used mainly figurative images in this collage.</li> <li>• P1 has used a majority of black and white images in this collage.</li> </ul>
iii		<ul style="list-style-type: none"> <li>• P1 has used sketching as a mediation instrument in this design activity.</li> <li>• P1 has used words as a mediating instrument in this design activity.</li> <li>• P1 has demonstrated an association of sketches and words by proximity.</li> <li>• P1 has pasted the pictorial elements onto the support and all text is composed by hand.</li> <li>• P1 has highlighted some words on this support.</li> <li>• P1 has created groups of handwritten text and image on this support.</li> </ul>
iv		<ul style="list-style-type: none"> <li>• P1 has created clusters of handwritten text and pasted images on this support.</li> <li>• P1 has created links between the groups with red lines.</li> <li>• P1 has made some distinctions in the handwritten text using size and colour as discriminators.</li> </ul>

**Table 2a.** Photographs of some productions of P1 from Phase two

	Productions	Analysis
i		<ul style="list-style-type: none"> <li>• On this board, P1 has constructed representations using pasted images, handwritten text and painted elements.</li> <li>• On this board, P1 is manipulating handwritten text, pasted images and painted elements in each instance of representation.</li> <li>• For the handwritten text, P1 manipulates size, colour and position.</li> <li>• On this board, P1 presents a contextualisation of the representation, which appears to be executed with CAD.</li> <li>• The board also includes an informative sketch which indicates with an arrow the mirror.</li> <li>• The representations on the bottom right of this board appear to have been executed with CAD.</li> </ul>
ii		<ul style="list-style-type: none"> <li>• On this board, P1 has constructed representations using CAD to compose the image elements and in some instances the text elements, however, they have also used handwritten elements.</li> </ul>
iii		<ul style="list-style-type: none"> <li>• P1 has used a mix of CAD and traditional tools on this board. For example, colour samples in the top right of the board are represented with watercolour and on the bottom right, coloured pencils.</li> <li>• P1 manipulates colour, images and handwritten text in the various instances of representation. Manipulation of size and position is seen here.</li> </ul>
iv		<ul style="list-style-type: none"> <li>• P1 has used a mix of CAD and traditional tools on this board.</li> <li>• P1 appears to have chosen one image from the previous board and manipulating this image by adding or subtracting from it.</li> <li>• The third image from the bottom right and the second image from the left on this board show that P1 continues to mix CAD and traditional tools.</li> <li>• P1 shows a progression of activity with directional arrows which connect the three images in the top centre of the board.</li> </ul>



**Table 2b.** Photographs of some productions of P1 from Phase two

	Productions	Analysis
i		<ul style="list-style-type: none"> <li>• P1 has executed an organisation of images, colours, words and collages to describe functionality.</li> <li>• P1 uses sketches, handwriting, and colouring techniques such as marker, coloured crayons and watercolour.</li> </ul>

**Table 3.** Analysis of excerpts from Interview one with P1

Interviewer	P1	Analysis
<i>This choice to put a lot of photos was motivated by what?</i>	<i>I wanted it to be understandable in fact I wanted to put a lot of photos because they were plenty of direction so</i>	<ul style="list-style-type: none"> <li>• Being understood appears to be important to P1.</li> <li>• P1 appears to believe that accumulation and size can accomplishing “understanding”.</li> </ul>
<i>And these are the words you put in bold?</i>	<i>It is these notions I want to bring out</i>	<ul style="list-style-type: none"> <li>• P1 is aware of “emphasis”</li> </ul>
<i>The heuristic map was a request from your teachers, do you find it a useful tool?</i>	<i>Uh... yes to choose direction</i>	<ul style="list-style-type: none"> <li>• P1 acknowledges that a heuristic map is useful.</li> </ul>
<i>Ok and it really helped you in</i>	<i>Uh ... yes a little because otherwise I would have stayed, I would have gone everywhere</i>	<ul style="list-style-type: none"> <li>• P1 identified why they think the heuristic map is useful.</li> </ul>
<i>Ok and the layout, arranging the photos in this way was it also the request from your teachers?</i>	<i>No no it was I who chose</i>	<ul style="list-style-type: none"> <li>• P1 chose how to structure their concept boards in phase one.</li> </ul>
<i>Ok and sometimes there were images that did not show it enough or ...</i>	<i>Yeah but the teachers also said it did not show it enough</i>	<ul style="list-style-type: none"> <li>• P1 acknowledges that some images were not correct.</li> </ul>
<i>Ok. Did the remarks they made help you? How did it happen? Did you have any specific questions to ask them?</i>	<i>Um ... not necessarily specific but just to check if I was not going a little everywhere otherwise it is ok</i>	<ul style="list-style-type: none"> <li>• P1 appears to be concerned mainly with staying within the boundaries or following the rules.</li> </ul>
<i>You were able to associate them with sketches and texts. What was your purpose for the sketches?</i>	<i>To pick out the principles that emerged and to find the way in which the artists denounced something</i>	<ul style="list-style-type: none"> <li>• P1 explained that their sketches were used to help decipher the work of other artists.</li> </ul>
<i>What do you think were the objectives of the first phase?</i>	<i>Uh ... to find concepts and principles to find a clear context</i>	<ul style="list-style-type: none"> <li>• P1 is aware that the goals of phase one of the project were to discover notions and principles concerning the theme in order to propose a clear context.</li> </ul>

**Table 4.** Photographs of some productions of P2 from Phase one & two


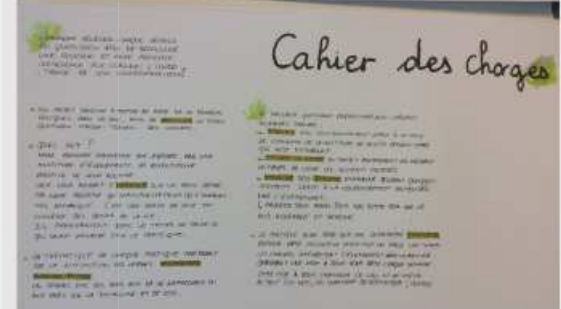



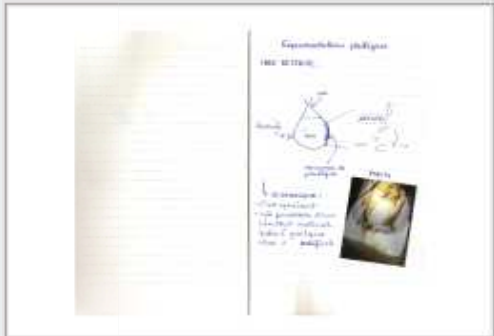


	Productions	Analysis
i		<p><b>Phase one</b></p> <ul style="list-style-type: none"> <li>• P2 has organised this board, grouping related handwritten elements with material or pictorial elements.</li> <li>• Base on the text, the weaving work seen on the left was used as an instrument of mediation between P2 and themselves, as well as a mediation tool between P2 and the problematic of the project.</li> <li>• The organisation displays the progression of this mediation.</li> <li>• On the right half of the board P2 displays a selection of images—which marks a relation outside of themselves—that they have chosen to associate with the project.</li> </ul>
ii		<p><b>Phase one</b></p> <ul style="list-style-type: none"> <li>• P2 uses words as instruments of meditation in this stage of design activity.</li> <li>• P2 has composed this board in two columns of handwritten text.</li> <li>• P2 has some highlighted words in the text.</li> <li>• This first board of specifications includes; the problematic, the what, the why and the how.</li> </ul>
iii		<p><b>Phase two</b></p> <ul style="list-style-type: none"> <li>• P2 uses both CAD and traditional tools on this board.</li> <li>• The board has instances of handwritten and computer generated text, sketches and computer generated images.</li> <li>• P2 has created clusters of information on the board.</li> <li>• P2 has highlighted some of the words in red.</li> <li>• On the top right, there is a progression of form with regards to the booth with a corresponding handwritten text which is a realisation of internal cognitive activity.</li> </ul>
iv		<p><b>Phase two</b></p> <ul style="list-style-type: none"> <li>• On this board, P2 shows a contextualization of the booth and poster. This manipulation was done using CAD. The title which was pasted on the board was also formulated with CAD.</li> <li>• P2 has made a spelling error in the title.</li> </ul>

Table 5. Photographs of some productions of P3 from Phase one & two

	Productions	Analysis
i		<p>Phase one</p> <ul style="list-style-type: none"> <li>• Here on this board P3 has organised the photographs of experiments they conducted with light and plastic bags. These photographs are accompanied by text which is a realisation of their thoughts as well a mediation tool of the object.</li> <li>• On the bottom right of the board, P3 displays a reference image—a relation outside of themselves—they have chosen to associate with results of the experiment.</li> <li>• P3 has used CAD to compose the board.</li> </ul>
ii		<p>Phase one</p> <ul style="list-style-type: none"> <li>• This image displays the first page of P3's journal which was made after the experiments.</li> <li>• P3 has made a sketch with some identifying arrows, some handwritten points under a title "I Note" and a photograph which is pasted in the journal.</li> <li>• The sub-title on the page reads "RETAINED IDEA"</li> </ul>
iii		<p>Phase two</p> <ul style="list-style-type: none"> <li>• The title on this board reads "Sooth by ..."</li> <li>• P3 has organised a collection of options of what is identified by the text above the main image as "a 3D environment conducive to daydreaming".</li> <li>• P3 has used CAD to create these environments.</li> <li>• The text at the bottom is a realisation of their cognitive process it reads "BUT: I must add movements (birds which leave when there is noise, ..."</li> </ul>
iv		<p>Phase two</p> <ul style="list-style-type: none"> <li>• P3 has organised this board to show the project in context. This is done by using a sequence of images and a corresponding text which describes the key moments.</li> <li>• P3 has used CAD in these representations.</li> <li>• P3 has included a realisation of their thoughts at the bottom on the board.</li> </ul>

The first interview conducted after phase one discloses that P2 wanted to experiment as much as possible, for example, they describe 'yes, I removed all the punctuation to observe that if one does not take the time to read the punctuation one does not really understand the text'. P2 is conscious of the choice of tools and methods they have used, for example, they identified photography as a means of accessing details, and described how one can capture different points of view with the camera that are not possible with the human eye ('... photography is not really the human eye, either we zoom, or make a wide angle, ...'). P2 also mentioned that photography was an area they want to pursue in the future. During this first interview, P2 described how process is important and demonstrated that they reflected on the method of working ('... I felt like I was wasting my time doing small things ... but perhaps the small sketch where I would have taken my time will have more value than if there were quantity, ...').

In their second interview—which was conducted after the completion of productions in phase two—P2 described how they '... don't know how to do it well by drawing ...' while referring to communicating their intentions and explained how they used the method they consider themselves best at, which is photography. They went on to say '... if I knew how to draw better, I would have done more sketches ...'. In this interview, P2 indicated that they liked working directly on Photoshop, not using any initial sketches. They also disclosed that they had already decided from the beginning what they wanted to do for phase two of the project, and this made phase one difficult.

#### **4.3. Pupil 3 (P3), Mistral School, topic 'Experience of Fragility': 'ideas came by themselves little by little'**

Table 5(i) and (ii), presents the digital documentation of the artistic research of P3 through photography and descriptive text. This documentation includes comparative references to existing works or matter as for example in Table 5(i). The productions define the context of the project using text and image. Table 5(ii) presents a page of the journal. The pages of the journal appear to recap the process that led to the results. The fifteen pages of the journal contain mainly handwritten text with two pages having images and sketches.

Table 5(iii) and (iv) displays the productions of P3 in phase two. Table 5(iii) shows a contextualization of the project executed with CAD tools. Table 5(iv) demonstrates what is described as an interactive scene (movement and sound) via 2D imagery. The journal page displayed in Table 5(ii) contains handwritten notes and pasted images.

In the first interview with P3, they revealed that the research they did themselves allowed them to remember things better. P3 stated that they did not do much sketching as they thought it was not a wise choice for this project. They also stated that putting things on paper didn't really help them progress in their research. When asked about what appeared to be conclusions of the artistic experiments, P3 described how they reflected on their work as such; 'it is advice not that I give myself, but in taking photos, I tell myself, and when I go to write well I say I must'. P3 stated that the artistic research did not have a relation to the subject. They stated that '... an important point was to move from the artistic experimentation which is just visual artistic research to something concrete ...'.

In the second interview, which took place after phase two, P3 stated that they did not have a work flow and that their ideas came by themselves little by little. They also stated that they already had an idea of what the final image would look like before they began to make the CAD representation. When asked why they had not done any sketches in phase two, P3 replied that since there were working with space, it was not wise to do sketches because that would mean sketching the space each time. They went on to say it was faster to work with the CAD program when working with spaces. When asked if they had a priority in the project, P3 replied that the results of the project were important to them, whereas for other pupils it was the process. They stated that the purpose of recording things is to have a footprint. They went on to say that if the protocol did not stipulate they had to write, they would not have written and that they realised when they would have had to talk about the work, that writing would help them to remember the important points.

## **5. GENERAL DISCUSSION: VIGOROUS COGNITIVE PROCESSES**

The design cognitive process is conditioned by different assessment stages pupils must navigate. Table 6 provides an overview of design activities intertwined with traditional or digital tools, productions and interviews. Furthermore, the discussion underlines in what way exploration, necessity and obligation are the main activities observed in pupils' design learning.

### **5.1. Following the guidelines or a way to explore tools**

P1 has worked mainly with traditional tools. Based on their preference for watercolour one could argue that this is perhaps why they have worked predominantly this way. However, the results imply that this use primarily of traditional tools in the second phase, was what the project dictated and it



was not a personal motivation. And in the first phase, it was motivated by the project guidelines which stipulated the use of a fine arts practice. Nevertheless, it may be constructive to suggest that the digital technique of photomontage used in the CAD representations were influenced by all the previous collage work. Was P1 trying to replicate a

traditional technique in a digital format? If the answer is yes; why?

The project of P1 has a digital counterpart which is interactive. However, P1 chose to represent this interactivity on an unanimated sheet of paper. Why did they not use another mode of representation

**Table 6.** Cognitive and design activity of the 3 participants in phase 1 and phase 2

Activity	P1				P2				P3			
	Phase one		Phase two		Phase one		Phase two		Phase one		Phase two	
	PRD	INT	PRD	INT	PRD	INT	PRD	INT	PRD	INT	PRD	INT
Reflexion	•	•	•	•	•	•	•	•	•	•	•	•
Writing	•	•	•		•		•		•		•	•
Lettering	•	•	•		•		•					
Composition	•	•	•	•	•		•		•		•	
Fine Arts	•		•	•	•	•	•		•			
Sketching	•	•	•			•	•	•		•		•
Photography					•	•	•	•	•		•	
CAD			•	•		•	•	•	•	•	•	•

PRD = Production    INT = Interview    CAD = Computer-aided design

that would display precisely what the results would be? Another question that comes to mind; is the choice of tools for representation accountable for quantity in production and the vigorous, cognitive design activity process?

**5.2. The necessity of CAD tool against facts**

The theme of P2’s project—take time—appears to have motivated the choice of techniques—mandala colouring, linocut, pointillism and so on—in phase one. A personal preference for photography and a declared inadequate skill in drawing, appear to have motivated whether they used or did not use these methods and their associated tools. The clusters of content of image and text reveal that P2 is reflecting on the project through visual and written content

As mentioned in the results of the productions of phase two, P2 has used CAD to produce the board titles. In Table 4(iv), a spelling error in the board title can be observed. This error invokes several questions: is this provoked by the use of the CAD tool? Even so, P2 has executed multiple steps of design activity that should have allowed them to revise the error—typing, printing, cutting and pasting. Is it that P2 expected the CAD tool to automatically do the right thing? Did the student’s cognitive process go into snooze mode and give automatic acceptance to the CAD tools output?

The communication of P2 is somewhat contradictory. During the interviews, they suggest that the approach and process of the project are important, yet, they declared not to have taken into account what the teacher’s instructions were as

they already knew what they wanted to do. Furthermore, in the second interview they revealed that they already knew what the outcome for phase two was going to be and therefore had to make their productions in phase one correspond; this made phase one difficult. Also, P2 talked about sketching in the first interview but there are no signs of sketching in the phase one productions.

**5.3. CAD-oriented project as an obligation**

The productions of P3 show that they worked mainly with CAD. The interviews reveal that they did so because they thought that the CAD tool was the appropriate choice, as they were working with space and they thought that working with CAD would help them to work faster. Is P3 equating working faster to working better? How is it then, that a CAD-oriented project does not take advantage of CAD tools to demonstrate the interactive elements of the project? P3 also mentioned in the interviews that they liked to work with Photoshop. Perhaps this preference is what motivated their choice of tools.

It can be suggested that P3 appears to have assimilated some design skills as they stated at the end of interview two, how they could see the utility of writing and recording progress.

**6. CONCLUSION**

The analysis shows, on the one hand, the pupils’ motivating factors and points of interest in CAD and traditional tools. P1 uses the digital tool as a tool of exploration and combines it with handmade



sketches, writing and watercolour techniques. Their activity shows an iterative and divergent design process that is nevertheless structured by a method that they have appropriated. P2 uses the CAD tool as a tool of necessity, to palliate their difficulties of representation in drawing which is an obstacle to their design activity; in this case, the 'magical' CAD tool has a regulating function that shapes their operative images (Ochanine 1966) or 'intentional drawings' (MEN 2011). Using the CAD tool is an obligation for P3 as it seems the better tool to simulate, evaluate and communicate the final state of the artefact representation (Lebahar 2007). Dialoguing with their teacher, and writing, seem to be more efficient than sketching, to reason about the design problem. On the other hand, the effectiveness of CAD in design tasks unveils exploration, necessity and obligation as main generative and constructive design cognitive process phases (Bonnardel & Didier 2016) within an obvious co-evolution of problem and solution spaces (Dorst 2006).

The observed and analysed design activity questions the role of CAD in a design cognitive process during a non-vocational training situation. The results partially explain the pupils' motives and their goals (Leontiev 1978). To further validate these findings, research must first be refined and secondly, extended to additional design learning situations (for instance, other certification levels or learning groups).

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