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A Silent Revolution: From Sketching to Coding – A Case Study on Code-based Design Tool Learning

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ABSTRACT
Along with the information technology rising, Computer Aided Design activities are becoming more modern and more complex. But learning how to operation these new design tools has become the main problem lying in front of each designer. This study was purpose on finding problems encountered during code-based design tools learning period of designers, especially those influential factors. The research was based on two design protocol analysis studies. A pilot study was performed for research details adjustment. Three selected participants have been told to complete one sketching work with two different digital design tools. A 30 minutes teaching was performed on each participant. Processing was introduced for data analysis. We found digital methods can be used to performing design process analyzing. We construct a multi-scale analyzing structure for design process and we demonstrate the possibility of pure quantitative study of the design process.
Keywords: digital design tool, design protocol, case study, processing

INTRODUCTION

Shifting of Design Environment

We are living in the post-information age (Negroponte, 1995). Computers and computer-like mobile devices are filling our daily lives. To cache up with these digital era, the unbridled imagination, the purely visionary energy, associated with creativity is what design students seem to need to develop today (Wang, 2015). Despite of information technology booming, working environment of design industry has also been deeply changed. For decades, researchers were working on proposition building for varies design environments distinguished by physical space and working methods. Since 2002, discussion about the design environment shifting from real world to digital world has already began. A British research team from the department of Architecture performed a case study on 'electronic drawing board', and they suggested 3 document needs of the equipment which were: the device

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State of the literature

- In today's information age around the world, digital design tools have been widely used in the design of the production process, the dimensions of digital design have been added to the designer's toolbox.
- However, traditional digital design tools which developed by the programmers, using by the designers generates a great limitation on the possibility of designers' innovation.
- Design education on the code-based design tools is still in its infancy, regardless of the difficulty degree of such tools or the current scope of application, the differences between it and draw-based design tools are worth an exploratory research.

Contribution of this paper to the literature

- We perform an empirical study on design process between draw-base design tool and code-base design tool.
- We introduce a set of digital methods for design process analyzing.
- We construct a multi-scale analyzing structure for design process.
- We demonstrate the possibility of pure quantitative study of the design process.

reputedly helps in establishing and meeting needs to improve efficiency (speed), and establishes how the computer medium can be used effectively (accuracy), determining the best configuration of hardware and software to accomplish some task (succinctness) (Coyne, Park & Wiszniewski, 2002). After that, similar studies came out gradually. Ben Jonson discuss about the conceptual sketch in the digital age (Jonson, 2005), and two architectures research on the implications of rapid prototyping in digital design (Sass & Oxmanb, 2006). There're also people get interested in the impact that design tools have on reinterpretation during graphic design ideation activity (Stones & Cassidy, 2010), and the use of digital sculpting in conceptual product design (Alcaide-Marzal et al., 2013). In previous studies, the concern differences has slowly emerged – real world vs. digital world. Unlimited possibilities provided by the digital world placed in front of designers. Along with these possibilities, a lot of new design processes are differ from traditional design methods have emerged.

Transitional of Design Process

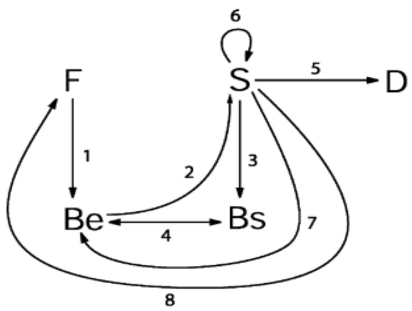
In order to perform design tasks in a new environment, design process made its own change accordingly. Digital technology have stimulate the designers to use new methods for design activities to get design information transporting fluently between real world and digital world, such as an integration of machines, material, and modeling process (Dortaa, Pérezb & Lesageb, 2008). In traditional design environment, designer choose design locations, chooses design materials and decides design tools. But things has changed in the digital world. From the Information Theory, Shannon told people the real world can be mapping into the digital world through bits. It was the same situation that designers facing at the beginning of 21st century (Shannon, 1948). The questions for designer have been changed from normal design problems plus digital information transforming. However, the benefits given by digital world

Figure 1. The evolution of design process research

is obvious and easy to see. First, the digital world separated the space. Designers can thinking in a marvelous space which is total different from real world. They can watch their design in the sky such as architectural design, and take a look inside of the design objects such as the central processing unit (CPU) design. Second, the digital world split the time. In real world, sometimes design project constrained by design object's physical properties. So design cycle was constrained in the same way. In digital world, physical constrains temporally disappeared. Designers can doing design activities that cannot be doing in real world such as copy & paste. So the design process was changing accompany digital technology rising in two ways – atoms to bits and bits to atoms. The former, was widely used by today's designers in their concept design stage (Goldschmidt, 2004). The later, was adapted by designers for their prototyping stage (Gershenfeld, 2007). In order to fulfill these new design process requirements, new design tools appeared apparently.

Transform of Design Tools

Design tools are part of designer, just like the painter cannot painting without their brush. In the nineteenth century, the Romantic Movement in the arts glorified human imagination by identifying it as a power of the mind to imitate the divine act of creation, as described in the Book of Genesis, and ever since that time imagination and creativity have been consolidated, accepted, and promoted as a highly desirable standard of intellectual activity. (Wang, 2015) The graphic design process was found to involve very characteristic uses of drawing. While changes in technology have brought about changes in this use, drawing is still seen to be an important part of the process and a fluid use of drawing is a crucial ability for graphic designers. Although also subject to change, the educational sector, particularly in Scotland, retains a profound interest in the development of drawing ability in student designers and, while the characterization of a complex and individualistic human activity like drawing remains somewhat controversial, practitioners and educators alike retain an interest in drawing as an essential form of designedly activity. (Schenk, 1991) Since Software Company like Adobe supplying the digital tools such as Photoshop and Illustrator, designers achieved the ability to drawing in the digital world. Many studies were performed on challenging the differences between real world sketching activities and digital sketching activities or semi-digital activities (design with digital device like sketching pad). Little work exists on the difference between normal digital sketching tools and coding design tools.



Be = expected behaviour → = transformation

Bs = behaviour derived from structure ↔ = comparison

D = design description

Figure 2. The FBS Framework (Gero, 1990)

LITERATURE REVIEW

There is clear theoretical construction process of designer's design behavior studying. Since 1990, Gero suggests the design process as a goal oriented purposeful activity. The metagoal of design is to transform requirements, generally termed functions, which embody the expectations of the purposes of the resulting artifact, into design descriptions. (Gero, 1990) Goldschmidt followed and give out the Design Representation Theory (Goldschmidt, 2004). He suggests that design representations can be separate into meta-elements and these elements can be study with specific ways. After a ten years research, Goldschmidt give out the Linkography to show how design representations can be studied (Goldschmidt, 2014).

FBS Structure

For Gero, design begins with a description of the world and some behaviors and attempts to produce causal dependencies between them. The existence of design is because the world around us does not suit us, and the goal of designers is to change the world through the creation of artifacts. Designers design by positing functions to be achieved and producing descriptions of artifacts capable of generating these functions. In this sense, design is the opposite of the traditional scientific explanation. (Gero, 1990).

There are three classes of variables describing different aspects of a design object in FBS framework, Function (F), Behaviour (B) and Structure (S). Function (F) variables describe the teleology of the object, Behaviour (B) variables describe the attributes that are derived or expected to be derived from the structure (S) variables of the object, Structure (S) variables describe the components of the object and their relationships. Connections between the function, behaviour and structure of a design object coming from the designer's experience. In order to fulfill the function, designer need to translate it into specific behaviours, and all these

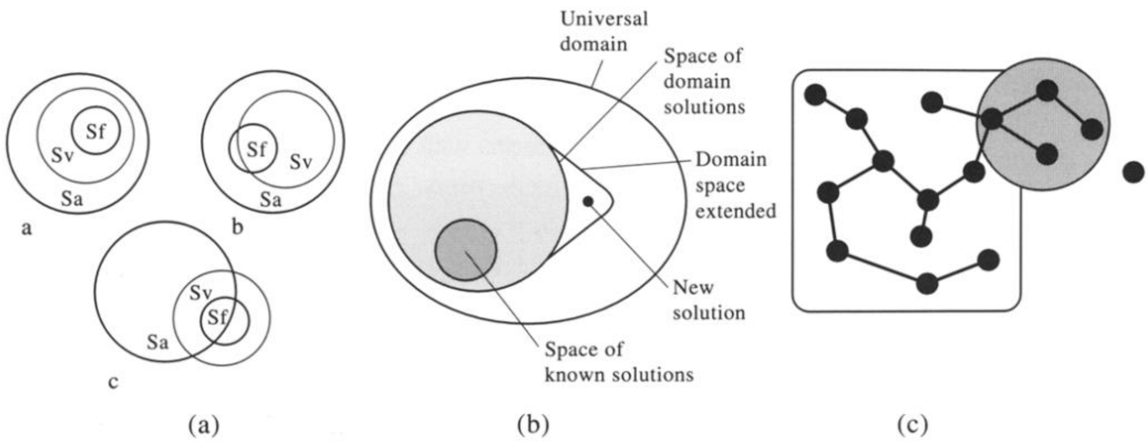


Figure 3. Illustrations of extended problem space (a) Habraken II (b) Rosenman and Gero 13 (c) Takala (Goldschmidt, 1997)

behaviours belong to a structure, there is no establishing connections between function and structure. Besides three classes, eight processes depicted in the FBS framework are claimed to be fundamental for all designing. They're Formulation (R→F, and F→Be), Synthesis (Be→S), Analysis (S→Bs), Evaluation (Be↔Bs), Documentation (S→D), Reformulation type 1 (S→S'), Reformulation type 2 (S→Be), Reformulation type 3 (S→F (via Be)). In this paper, we focus on main structure of the FSB model (three classes), detailed processes will be discussed according to specific situations.

Design Representation

The discussion of design expression arises from the difference in the problem structure. The design problem has been divided by Goldschmidt into two parts, one is the well-structured problem and the other is the ill-structured problem. For Goldschmidt, well-structured problem specifies the initial state and the goal state, it can also use the stop rules to achieve the goal, and operators of such problems are derived from the known algorithms. The ill-structured problem is quite different, one or more of these constituents is either unknown or incoherent. The initial state is usually vague, and the goal state either unknown or ambiguous, neither stop rules nor algorithms for operators are specified in advance. The solver of an ill-defined problem must generate and represent a great deal of additional information that he or she 'imports' into the problem space in order to construct states, including the initial and goal states, and in order to construct a path or paths that connect them. It is therefore unlikely that problem spaces for well- and ill-structured problems are similar, nor can we expect to find similar search mechanisms within them. (Goldschmidt, 1997) In order to reduce the interference term and reduce the probability of occurrence of intermediate variables, this paper used well-structured problem for study.

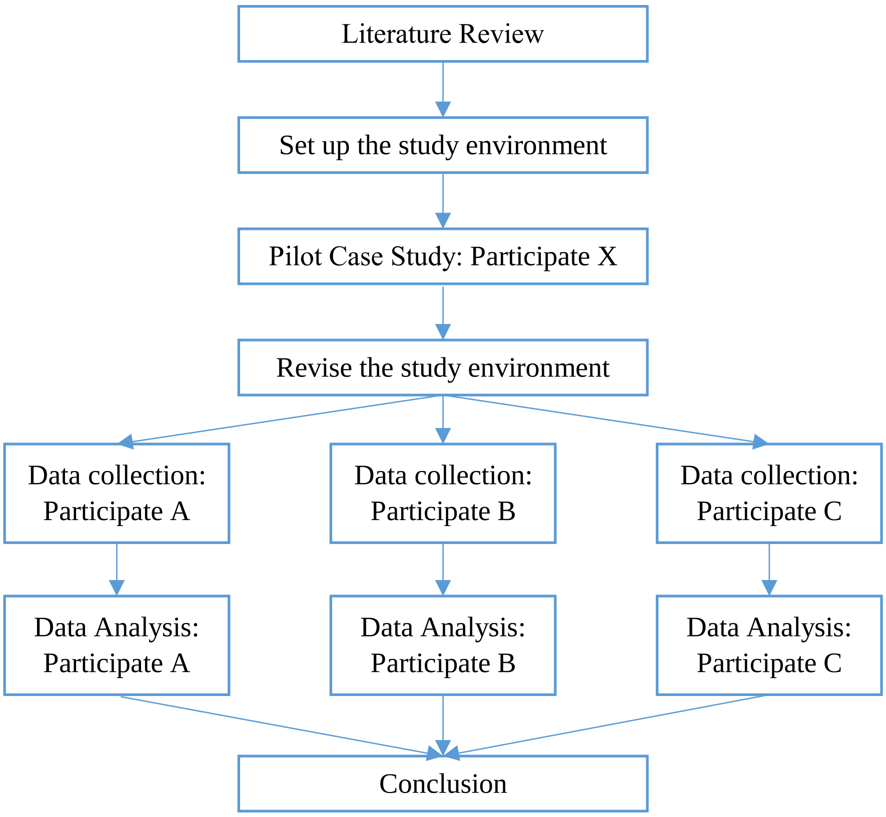


Figure 4. Case Study Procedure

In addition to define the well- and ill- of the problem structure. Goldschmidt also discuss different design representations in problem space. He separated them into four major representations: internal representations, external representations, conceptual representations and figural representations. This article follows his problem classifications to interpret the experimental data. In order to adapt to the attributes of the design tool itself, and to achieve the quantify research objectives, this paper adopts internal representations and figural representations.

Design Protocol

Traditional, to performing a protocol analysis is to obtain verbal materials from a participant and using qualitative methods to analysis them. Earlier studies have shown that protocol analysis is an effective method that can be used to perform design process analysis. Under the leadership of Gero, Tang (2010) and Lee (2010) studied the differences in the design process between the traditional plotting environment and the digital drawing environment. In this study, they combined the FBS model with protocol analysis and found that there was a

Table 1. Basic experiment environment

	Basic Requirement	Actual Situation
Experiment Location	General lab in design school	Design lab in College of Design
Experiment Computer	PC or Notebook with i3 CPU or higher	A public experiment computer Participants' respective laptops.
Experiment Platform	Normal operating system which can run Adobe Creative Suite on it	Mac OS Microsoft Windows
Experiment Software	Adobe Photoshop Adobe Illustrator Processing	Adobe Photoshop CC 2014 Adobe Illustrator CC 2014 Processing 2.0
Participants	Normal design student volunteers	Four volunteers

significant difference between the design process in traditional media and the design process in digital media. However, since their experimental design was based on a pen-and-paper pattern, they were unable to escape the real-world sketching constraints even when they used a 21.3-inch LCD Wacom tablet. Common design tools in software form, was born with two built-in properties in the very beginning: the first is the keyboard - mouse pattern, the second is the limited classification of the design function. Although the sketching function of external devices is added in the later versions, the essential properties of these tools have not been changed radically. Therefore, this article takes this situation as the starting point of study.

In addition to the contrast of design process between real-world and digital world, other researchers use protocol study on scale issues of design process in recent years. Through the activity theory, they setup three levels design process. This paper adopts this multiscale design process analysis method to classify the design process, expecting to find the relationship between different scales with information visualization method.

EXPERIMENT

Set Up Experiment Environment

There are four stages in this study: pilot study, first case study, design tool teaching and second case study. In the pilot study, variables that are not suitable for experimentation need to be identified and then modified or stripped. The design process was recorded in the first and second case studies, and the recording was done by screen recording software. Prior to the second case study, participants were given a 30-minute teaching about processing to calibrate the differences in experience due to different educational backgrounds. The study environment was set up in a lab because the lab had a good experimental environment such as stable network support and a comfortable light environment. Because digital design tools are part of the computer, designers in the digital environment design will inevitably formed private working habits. In order to minimize the influence of the test environment on the participants design capability, this study allowed the participants to use their own laptop computers during the experiment. However, the software used for the testing is provided by this study. The participants of this experiment were randomly selected from the College of

Table 2. Basic information of participant X

	Properties
Sex	Male
Age	25
Current Professional	Digital media design
Former Professional	Digital media design
Degree	Master
Engaged in design	8 years
Use of draw-based design tool	8 years
Use of code-based design tool	Less than 1 year
Whether can programming	Yes, Java

Design, using a volunteer approach to ensure that participants have a certain design experience. Basic experiment environment as **Table 1**.

Pilot Case Study

We introduced a pilot study with a volunteer prior to the formal start of the experiment. We expect this pilot study to identify shortcomings in the experiment process and to improve it. The experimental procedure is as follows:

Step 1. Please search the Google search engine for a picture of a snowflake. (15 minutes limitation)

Step 2. Please use a draw-based design tool (such as Illustrator, Photoshop, etc.) to design the snowflake found in Step 1. (60 minutes limitation)

Step 3. Please take 30 minutes of Processing teaching.

Step 4. Please use a code-based design tool (such as Processing) to design the snowflake found in Step 1. (60 minutes limitation)

During the whole period of Step 2 and Step 4, we use the recording software to record the participant's computer screen to analyze their design process.

We use two ways to look for volunteers, social network and verbal notice. The payback for volunteer is the next year free teaching support on Processing. The participant of pilot study was informed by oral notification of the experiment and expressed willingness to participate. The basic information of the volunteer is as shown in the **Table 2**.

When the participant is ready, the experiment begins. First, he search for a satisfactory snowflake picture through Google, and then download it to the computer desktop. The participant then need to follow the specified process to start using the design tool to design. In Step 2, the participant selected to use the public computer Thinkpad T410i provided by the study to finish the task. The computer has been installed Illustrator, Photoshop and Processing, and the participant choose to use Illustrator to complete the test in Step 2. Because of the Processing teaching period is next to Step 2, so the researcher let the participant rest for 5 minutes to relieve fatigue. After 30 minutes teaching, there is also a 5 minutes rest arranged

Table 3. The visual output of participant X at different stages

	Picture Searched On Google	Picture Designed By Illustrator	Picture Designed By Processing
Image			
Time Consume	2′10″	3′30″	40′52″

Note: ′ for minutes, ″ for seconds.

for the participant. When he finished rest, he start to open the Processing for final testing. When he is in the testing, there is an accident occurred. He was unable to complete the test due to lack of programming knowledge. At that moment, the researcher decide to return to Step 3, and give him the exactly same teaching again. After the second session, the participant completed the test within one hour. The selected image, the picture designed by draw-based design tool, and the picture designed by draw-based design tool are shown in the Table 3.

In the pre-test, the exposed problems are mainly three aspects: Processing teaching in Step 3, rest time between each steps and teacher assistant in Step 4. On the teaching part, the main problems found in the realization of the completion of design in Step 4, corresponding functions need to further explain. Participant without experience of code-based design has significant relationship with the understanding of relative functions. On the rest time part, different participant have different degrees of tolerance to different mental workloads. There is an agreement on the rest time of researcher and participant to set 15 minutes for rest time between each stage interval. For the test task in Step 4, different participant may show different results, but do not understand the code-based design tools make it very easy to get experimental continue failure. In order to alleviate this situation, the researcher and participant X decided to revise the experimental process of Step 4. The researchers can provide three times of assistances for participant on function understanding. The adjustments to the experiment flow are shown in the Table 4. Besides, participant X also proposed 2 feedbacks: first, people who study design are generally not good at mathematics; second, something like sin() & cos() is difficult to understand at a time.

Table 4. Revises of the study environment

	Original	Revised
Teaching materials	Basic: Setup() & Draw() Point: point() Line: line() Shape: rect(), ellipse() Color: stroke(), fill() Logic: if(){} Random: random() Recurrence: for(){}	Basic: Setup() & Draw() Point: point() Line: line() Shape: rect(), ellipse() Color: stroke(), fill() Logic: if(){} Random: random() Recurrence: for(){} Rotate: rotate(), sin(), cos() rotation formula
The rest time between each Step	5 minutes	15 minutes
Assistant in Step 4	0 times	3 times (not for solution, only for function understanding)

Experiment between draw-based design tool and code-based design tool

The experiment was carried out in a research room of the School of Design. Because the design is a strong practical discipline, has a specific demand on working environment, we assumed that the familiar working environment will have a better affinity. The experimenters were recruited voluntarily. Three people were recruited and five were actually recruited. Since the other two people did not have any programming experience or had a strong interest in programming, they volunteered to quit after communicating with the researcher. Eventually, three people participated in the experiment. The interaction between the researcher and the subject is mainly composed of 3 parts: experiment introduction, Processing teaching and assistant, involving three stages in the experiment. The experimental description and experimental environment setting are before Step 1. The teaching of Processing is completed in Step 3. The assistant is performed in Step 4. Complete the mid-period instructions and teaching part is essential, that can make the participants have a clear understanding on the purpose of the experiment and the experimental process. Teaching period can calibrate the subject, to warming up their brains before Step 4. On the part of the assistance is optional, the experiment does not require the subject must request for assistant, set the purpose of this interactive link is to prevent the failure to complete Step4 led to the failure of the experiment occurred. Instructions and the teaching part is essential, which can make the participants to have a clear understanding on the experimental purpose and experimental procedure. Teaching can calibrate all participants, to make their brain to have a knowledge wake-up before testing. The part of the assistance is optional, experiment does not require participant must request for assistant. The purpose of setting this interactive part is to prevent the participant led experiment to a failure when they cannot complete the experiment. In addition to Step 2 participants can be free to complete the remaining three stages require the participation of researchers, there is not yet in Step 4 shown not need of researcher assistance. With the technology civilization, tools popularity and education promotion, we believe that will appear similar situations in code-based design (in Step 4) like in Step 2 which does not

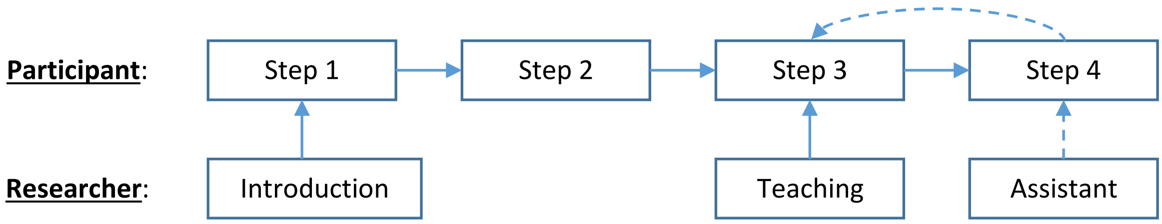
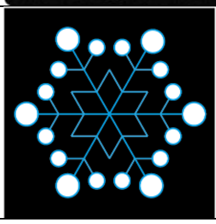
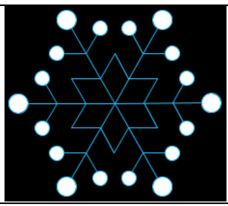
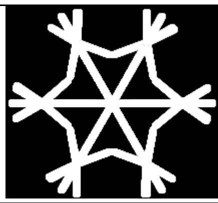
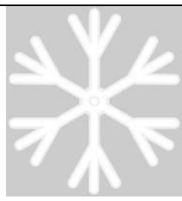


Figure 5. The interaction model between researcher and participant

Table 5. Comparing the Basic Information and the Design Output of Three Participants

	Participant A	Participant B	Participant C
Gender	Female	Female	Male
Age	27	23	23
Current Professional	Industrial Design	Interactive Design	Digital media design
Former Professional	Industrial Design	Digital media design	Information Science
Degree	Doctor	Master	Master
Engaged in design	8 years	2 years	2 years
Use of draw-based design tool	2 years	6 years	6 years
Use of code-based design tool	0 years	2 years	1 year
Whether can programming	N/A	Yes	Yes
Design Tool	Adobe Illustrator	Adobe Illustrator	Adobe Illustrator
Reference Picture			
Draw-based Design Output			
Time Consume	14’06”	5’21”	14’56”
Code-based Design Output			
Time Consume	18’18	42’31”	34’09”

require the involvement of researcher. The interaction model between the researcher and the subject is shown in Figure 5.

In order to reduce the complexity of the study object, this study uses a basic hexagonal snowflake as the design object, the basic hexagon is also the official example dedicated to teaching polygons in Processing. In addition, hexagons have a similar presence in the real world, such as snowflakes, so they are capable to use as design objects. In the participants, three volunteers voluntarily participated in the test of two female and one male. Their learning background from an industrial design to two digital media design. Their ages are about 25 years old. Two of them had a programming background, and both used the code-based design tool, while the other had no access to a similar tool before. Interestingly, although Subject A has eight years of design experience, it appears that her use of digital design tools is not a long time, even if the experience of traditional draw-based design tools are only 2 years. The other two participants were different from their learning experience, they seemed to be interdisciplinary, not original design profession people, which also explains why they are in the reference pattern selection is not the same as the participant A choose which is more Complex, and more with beauty. In Step 2, three participants showed a surprisingly consistent choice of tools, all choosing to use Illustrator for the design task rather than Photoshop, which is in line with the market positioning of Illustrator. Illustrator was originally designed to solve the problem of vector graphics design, it is more suitable to solve design issues similar to snowflake.

Experiments were carried out on three participants separately, each lasting less than three hours (plus break time). The experimental results show that the reference pattern selected by participant A is the most complicated, the reference pattern selected by participant B is relatively average, and the reference pattern selected by participant C is the simplest. When designing with the draw-based design tool, participant B showed good efficiency, he completed the test in the shortest time. While the remaining two participants took almost 14 minutes to complete the design task, spent nearly 3 times more than him. From the completion of the design, we found all participants were completed request tasks within time, but there are differences between the use of draw-based design tool and the use of code-based design tool. It is closer to the reference picture of the output done with Illustrator than the one done with Processing, which may be due to the mastery of the tool. Comparing participant A and the other two participants, it was found that the same effect was achieved with Illustrator, indicating that the draw-based design tool such as Illustrator significantly correlated with the success rate of pattern design expression.

DATA ANALYSIS

The data were analyzed within 1 week after the end of the experiment. The experiment results and the experimental procedure were divided into two parts and analyzed separately. For experiment design output, analysis focus on the differences between the different stages design output and the reference picture, as well as the contribution of the participant's behavior to the degree of difference. Analytical tool is self-made by researcher for the test. It is image differential degree identification software based on Processing, have the ability of contrast analysis for two different images, and output the result to the TXT document. The analysis method used by the analysis tool is based on the pixel space distance algorithm. First, pixelate two images and then compared every pixels on each position one by one. If the pixel difference is larger than the threshold, then add it to the difference various. When finish the detection of the entire picture, total number of differences will be summary and output. The analysis objects are reference picture vs. draw-based design output, reference picture vs. code-based design output and draw-based design output vs. code-based design output.

The results show that the similarity between the draw-based design output and code-based design output of participant A is higher than to the reference picture. For participant B, there are significant difference between his design outputs, regardless of the design tool used, and there are also significant difference between his design outputs and the reference picture. But the participant C is quite different. There is no significant difference between the output and the reference picture when using the draw-based design tool, but there is a significant difference between the design output between the code-based design output and the draw-based design output. Analysis results as shown in Fig 6.

For the design process in the experiment, this study regards it as a composite behavior with a 3-level architecture. Using the self-developed analysis tool, we can detect the design activities of the tested personnel by pixel changing in the recorded video. We divided activities into the macro-scale activities, mesoscale activities, and micro-scale activities. We set up threshold for these 3 level activities such as micro-225 (15 x 15), meso-10000 (100 x 100) and macro-250000 (500 x 500). The design activity analysis process is divided into three steps: first, we need to adjust the video to meet the requirements of analytical tool; second, we use artificial methods to check the original video, comparing it with analyzing record and excluding participant design activities but identified as the design activities by the analysis tool; third, use the analysis tool to analyze the experimental data one by one and record the analysis results.

Macro-Scale Activities Analysis

In this study, macro-scale activities are defined as large-scale image differentiation activities in screen (500x500pixels), usually these activities have connection to the interaction of the window and the operation of the overall picture, e.g. check the design result, open / close window. For draw-based design tools, macro-scale activities are more likely to occur, because they supply the convenient drag and drop feature which allows the designer to easily carry out regional image operations, such as: copy and paste. In addition, the function of the design software is being strengthened constantly. In many cases, the floating auxiliary windows will appear. When the floating window scale does not reach the detection threshold, it will not be judged as macro activity, but the risk of misjudgment is still exist. In addition, the draw-based design tool provides drag-and-drop functionality, which can directly drag

Table 6. Macro-Scale Activity Analysis Results

	Participant A	Participant B	Participant C
Illustrator	0	7	0
Processing	0	75	0

image resources from the outside into the workspace. Once the user performs this operation, it is easily detected by the analysis system as a macro-scale activity. Also, draw-based design tool usually has a variety of functions, some of which are require actions in the pop-up window, such as adjusting parameters, when the pop-up window is too large, it may trigger detection, then recorded as one macro-scale activity.

For the code-based design tool, many macro-scale activity situation in the draw-based design tool will not occur. First of all, the main function code-based design tool provides designers is to construct a design project from the bottom. That is to say designers can get rid of the design functional limitations which lying in draw-based design tool, designers can develop new design tools to meet their design needs or project requirements. Most of the code-based design tool running in IDE (Integrated Development Environment) mode, the main design behavior shown as coding. So even designers need to including external resources, they only need to add two lines in the code call function and do not need to use drag-and-drop operations like they do it before in the draw-based design tool. However, since the code-based design activity is a coding-based activity type, it is necessary to be able to modify the design at any time. Take Processing for an example, every time when the designer check his design he is open the entire canvas, this behavior will be basically detected by the analysis system as a macro-activities. We can use these effects of macro activities as an activity node in the analysis of code-based design activities, and divide the designer's design activities through these nodes.

From the analysis results, participant A and C did not detect macro-scale activities, only participant B detected macro-scale activities. In the experimental stage of Step 2, the activity time of participant B mainly concentrated within the first minute. We found that it is because the participant drag the entire tool frequently. In the experimental stage of Step 4, the activity time of participant B mainly concentrates in the period of 5-8 minutes. Through manual contrast with screen recording, we found that it is caused by participant B frequently switching between the reference picture and design result.

Meso-Scale Activities Analysis

In this study, the meso-scale is defined as a block of 100x100pixels in the canvas, and the meso-scale activity is defined as a design activity between the macro-scale activity and the micro-scale activity. The design activity of the designer within the scale mainly in the induction and finishing. For the draw-based design tool, the emergence of meso-scale activities are mostly concentrated in the designer call the system functions, such as: in Illustrator adjust the corresponding properties of the line. For the code-based design tool, the mesoscale

Table 7. Meso-Scale Activity Analysis Results

	Participant A	Participant B	Participant C
Illustrator	99	83	40
Processing	49	165	230

activities will appear in the code browsing, and sketch folder opening. Participants suggested that the code-based design tool does not perform the cut-and-paste operation directly in the software as with the draw-based design tool. However, the reason for this is seen by researchers as a result of participants' unfamiliar with design tool. This means that participants need a longer learning experience and operational experience in order to better use the code-based design tool to design.

From the analysis results, we found that in the Step2 test showed an interesting phenomenon. In the test, the behavior of participant A and participant C has the opposite trend. Participant A's large design activity occurs in the first half of the whole activity time, while the main activity of participant C is after the intermediate time. Participant B exhibited a large number of high frequency activities in a short period of time during this pilot phase. In Step 4, participant A exhibits a large amount of activity at the beginning of design. After a certain period of time, the activity frequency of participant A is fixed in a tank range. While the large number activities of participant B and participant C are below the boundaries of 50000 pixels into a uniform distribution of the situation. But participant C has a lot of high frequency activity at the final stage.

Micro-Scale Activities Analysis

In this study, any design activity will default to a microscopic scale. The threshold should be set higher than the cursor size to avoid false detection caused by the system's own cursor flicker. In the situation without scaling of screen, the normal cursor size on the screen is 15pixel, so 15x15pixel is used as the threshold for microscale activity. Microscale activity is very different from the activities of the first two scales, because it has very small detection threshold, so it is very sensitive. By observing micro-scale activities, we can draw the frequency of activities of a designer in the digital design environment and find out his design habits. Combined with meso-scale activities and macro-scale activities, designers can understand the actual design problem in the design process. In the process of analyzing the microscopic activity scale, we also found that it and the activities of the first two scales will appear at the same time, so we need a manually control method on the corresponding time of the video to carry out specific activities to determine. From the analysis results can be found, three participants in the use of the same design tool activities are also different. Participant A showed a large number of high-frequency activities in the middle period, the activities of participant B showed a uniform distribution of the state, a large number of participant C activities below a threshold and occasional shows small amount of high-frequency activity.

CONCLUSION

On the basis of a lot predecessors, we explored new design education path for code-based design tool. This study may be the first code-based design education exploratory study. After the study we found that at this stage for the education of code-based design is still in its infancy, which can be seen in two things, first, it's hard to find volunteers and second, participants performance in the experimental process. In addition, the performance of code-based design in graphic design activities is still unable to match the traditional draw-based design tool, its own customization potential has not been able to be played out. Moreover, when designers using draw-based design tools, their design activities are affected by the state of the design tools, which is indicating that the traditional digital design tools still have their limitations, they may not as convenient as code- Based design tool in a specific design requirements environment. Although this study used a pilot study approach, in a certain range to reduce the bias generation, and by adjusting the experimental process to improve the fluency of the experiment and the success rate. However, due to lack of any reference same experimental experience, this study tends out to be a step by step in the experimental process of improvement. In particular, we still found a certain internal validity of the experimental environment will reduce the possibility of post-experimental research difficult. For other researchers engaged in digital media design education, this study can be used as a useful reference sample.

In the data analysis section, we obtained a few things through research. First, we learned how to compare different types of design tools in a digital environment. Through the use of design tools for designers, and then use the recording mode to record all of his operations, we can get the complete observing data on the participant. Second, we find ways to analyze the digitized design activity records. Also, we understand that it is necessary to calibrate the design activity records, and inconsistent activity records will affect later data analysis. Besides, we also found the difficulty of data analysis of digital design activities. In addition to the experiment it will produce a lot of observation data, participant's personal habits will also produce large amounts of data. The processing of these data will directly affect the final data analysis.

Two tools were developed for this study, one was used to analyze the difference between the two images and used to analyze the final outputs designed by the participant in Step 2 and Step 4. The other is used to analyze the difference between the current frame and the previous frame in the video. It is used to analyze the design activities of different scales in the experiment. The second tool is based on the first tool, the core technology is the image contrast differential algorithm. The advantage of this analysis method is that it can greatly improve the speed of data analysis in the later period of experiment, and can analyze the patterns of the design activities and the design habit of the participant in the shortest time. But its disadvantages are obvious, it is very demanding on the experimental environment, the requirements of the researchers is not low, and the stratification threshold of this tool also need to be accurately set in order to achieve the desired experimental objectives. We hope that

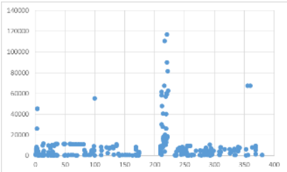
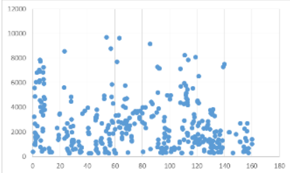
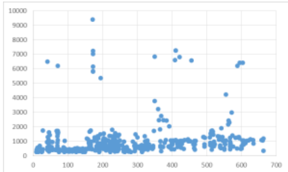
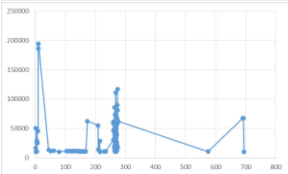
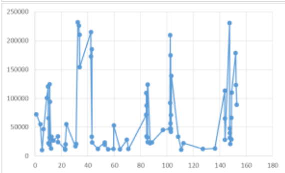
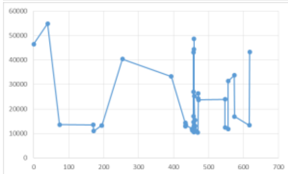
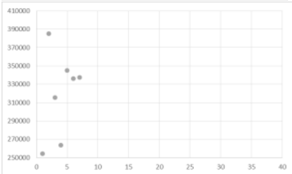
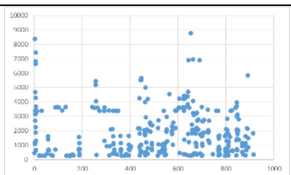
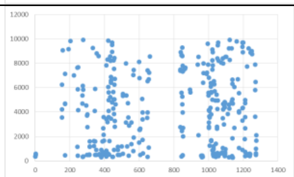
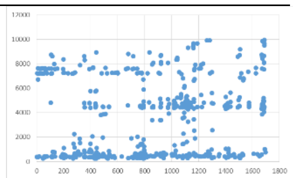
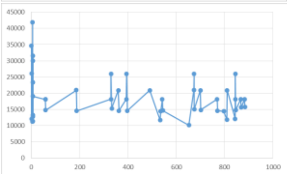
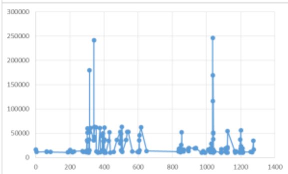
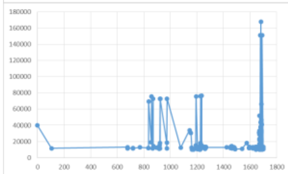
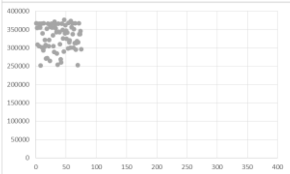
Figure 6. Contrast of Output Differences among Different Participants

by providing this type of analysis tools, to help the researcher needs of similar research types, and to accelerate their research progress.

It is the first time we tried a completely different approach from the traditional experimental methods. The traditional experimental process is usually set up physical video equipment, and then put the participant in the scope of video equipment to complete the experiment, the participant's activity range was constrained by the video equipment. In this study, we introduced a fully digital observation method. Through uninterrupted recording of the computer screen, we were able to obtain the participant's entire experimental process of design activities. While the same time, we can also record the ambient sound of the experimental site through the built-in microphone, which provides a convenient way for the study of thinking aloud. Another benefit of the purely digital experimental approach is the analysis of experimental data. As the data itself is digital, so we can use corresponding digital technology to analyze it. Thereby it can reducing two bias generation, one of the input data bias, the second is the artificial interpretation bias. The digital research process used in this study is still in the initial stage, but also need to continued study of follow-up strengthen to get a better experimental results.

The results show that code-based design and draw-based design have significant differences in the functions above, designer may need to adjust design functions in advance of such design activities. However, in the evaluation process, there is no significant difference between code-based design and draw-based design, this result may be because the commonality of activities bring by *Design*. When people understand the difference between

Table 8. Activities of all participants using draw-based design tool and code-based design tool

		Participant A	Participant B	Participant C
Draw-Based Design Tool	Micro-Scale Activites			
	Meso-Scale Activites			
	Macro-Scale Activites	N/A		N/A
Code-Based Design Tool	Micro-Scale Activites			
	Meso-Scale Activites			
	Macro-Scale Activites	N/A		N/A

the two design behaviors, they can made adjustment in the integrated phase of the *Functions* and *Behavior*. In this paper, we have studied the documentation process of the documentation. Results show the whole documentation process can be carried out automatically, only in certain circumstances need to be artificially intervened. The difference of graphic design results, the digital monitoring of the whole process, the digitization of the experimental environment, and the digital analysis of the experimental results. We show the possibility of a purely digital analysis of the design activity, laying the groundwork for subsequent research.

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