

A study on comparing design behaviors of experts and novices in the design process

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The importance of design is increasing in many industries. The design process could dominate the outcome of the design to some extent. It is obvious that expert and novice designers work in different ways and also have varied behaviors during the design process. In order to have a better understanding of how they behave during the design process, the objective of this paper is to explore the differences in their behaviors. The study adopted a protocol method to examine the sequence of the design phase and design activity, along with the time spent and the occurrences. The results are revealed by protocol analysis with sequence maps, and quantitative data. It should be noted that although the paths of experts and novices were both iterative, they were executed in different ways. Additionally, experts could spend more time than novices on the Design phase because they could evaluate the problems precisely based on their experience and knowledge. The outcomes of this paper provide new insights for not only designers themselves but also educators and team managers of companies.

Keywords: *design process; design behavior; expert and novice*

1 Introduction

Maciver (2016) indicated that design and designers have become more important roles recently. Design is a sequence of processes (Kotler & Rath, 1984) and the design elements are for meeting the needs of the clients and the company benefits (Bruce & Bessant, 2002). During product development in a company, the designers have a great impact on the product, which can significantly influence the performance of the company. Designers develop products by different design processes, and the design process is dynamic and complex. Browning (2018) mentioned that people who thoroughly understand the design process could have advantages in order to get the leading status. Thus, it's valuable for people to focus more on the design process.

Based on the research by Green, Southee, and Boulton (2014), the design process is located between input and output. The design process includes different phases and the ways that designers execute them are varied, resulting in different design behaviors. There have been discussions about the differences between experts and novices. Many studies have addressed the comparison of the problem-solving strategy and problem analysis of experts and novices (Brand-Gruwel, Wopereis, & Vermetten, 2005; Kim & Ryu, 2014), which are related to the earlier phases in the design process. Some researchers mainly focus on comparing expert and novice designers' design behaviors (Chen, 2007; Kavakli & Gero, 2002).

Although we can learn from these articles which are focusing on earlier phases and the actual design phase to understand more about how expert and novice designers work during the design process respectively, it's still hard to have a holistic understanding of how designers work from phase to phase because there is lack of studies into how these two phases work together. There is a need to have a continuous study to understand the process as a whole.

Therefore, the objective of this paper is to explore the differences in behavior between the expert and novice designers during the design process. The study would be conducted with these following research questions: How do they execute the different phases in sequence? What phases do they emphasize on more? What do they do in each phase? The findings in this study can help novice designers learn from expert designers and help expert designers understand how novice designers act during the design process. This should result in better communication in order to improve the design quality and increase efficiency.

2 Literature review

2.1 Understanding of the design process

Design is considered an inevitable element in the creative industry and in new product development. The design process determines the quality of the product. If designers would like to improve the product, they also need to improve their design process, because the better the design process is, the better the creation will be (Chapman, 2006). Dubberly (2004) states that the purpose of having a comprehensive understanding of design process is (1) decreasing the risk of failure and increasing the possibility of success, (2) setting the expected result and decreasing uncertainty, and eventually (3) increasing the repeatability to make improvement easier.

2.2 The development of the design process

The first design process originated around 1920, when it was used for the development of battleships. Research of the design process began in the post-war period, starting with new technologies such as the computer and military technologies, and then the complexity of these inventions required standardization. Afterwards, standardization led to the engineering design process, which formed the basis of the design process in the field of product design. Recently, the engineering design process is gradually comparing and combining with the design process in the field of product design. Cross (2001) defined that the design process has a scientific basis and supports 'designerly ways of knowing'. However, Blessing and Chakrabarti (2002) indicated that there are many uncertainties and confusions in the design process. Dorst (2008) also mentioned that the design process lacks comprehension. During

the evolution of the design process, Green et al. (2014) proposed Interim Design Ontology (Figure 2.1) based on the research about critical points in a design process.

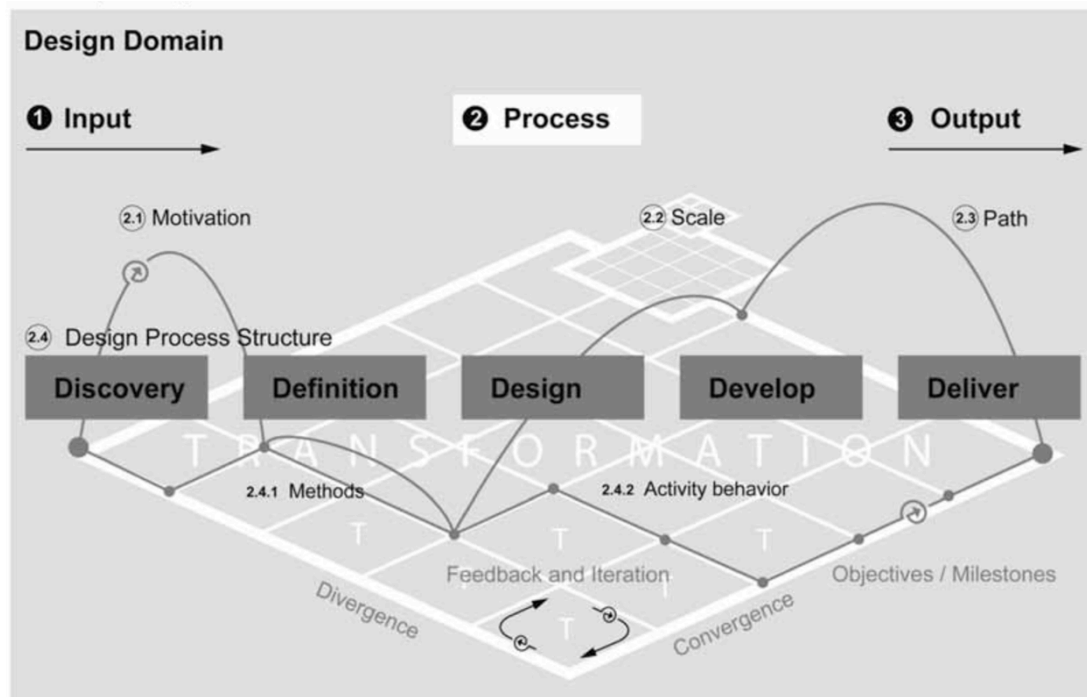


Figure 2.1. Visualization derived from the Interim Design Ontology (Green et al., 2014).

According to the Interim Design Ontology, the design process is divided into five phases: Discovery, Definition, Design, Develop and Deliver, which is called the 5D model. Additionally, 'the Path' is the way that designers execute these five phases. They can be executed in linear, iterative and crossing ways. Furthermore, the Interim Design Ontology defined activity behavior, which is the characteristics of how design process methods are carried out, is under the five phases. The design process model is proposed clearly and comprehensive. It's also useful to help people have a better understanding of how the design process works. However, Green et al. (2014) were still unsure how this design process would be executed in reality and what the behavior of the designers during the process would be.

2.3 Expert and novice designers

An expert is a person who is professionally trained or has the experience to have professional knowledge in a certain field (Chi & Glaser, 1980). Compared with an expert, a novice is a person who lacks experience, knowledge and skills. The novice designers tend to use trial and error to conduct design and their design processes tend to be iterative. The expert designers tend to solve the problem and have the solution at the same time. In addition, the expert designers are good at evaluating the moment when they need to move on to another phase to control their design result. However, the actual executive situation and behavior of the experts and novices in the design process have not been fully discussed and understood (Cross, 2004).

2.4 Summary

Overall, there are few papers discussing how designers conduct the design in a design process and fewer papers comparing expert and novice behaviors in a comprehensive design process. As a result, this study compares 'the Path' and 'the Activity' behavior

between expert and novice designers by adopting the Interim Design Ontology as the design process model. Besides, this study also uses time spent on each phase and behavior to deeply evaluate the difference.

Last but not least, although the Interim Design Ontology has the 5D model of the design process, this study only focuses on the first three phases: Discovery, Define and Design to analyze the result, because the Develop and Delivery phase cannot be observed in a short time. That is long-term research. Additionally, these phases are more about manufacturing and business, which is beyond the scope of the study. Therefore, this study only compares the data within these first three phases.

3 Methodology

The study of the article is to compare the behavior differences of experts and novices in the design process to help novices learn from the experts efficiently and help the experts understand the novices' behaviors. This study focuses on: (1) the sequence of the experts and novices, (2) the time they each spent on different phases, and (3) exploration of the detailed behaviors within each phase.

3.1 Participants

Based on the methodology research review, two experts and two novices are selected for this study. The experts should have more than ten years of working experience in the product design field. As for the novices, in order to make sure that they have enough knowledge in design, the novices should be the third-year college students who are majoring in product design and have done more than 4 projects or have finished their internship.

3.2 Tools

The experiment is conducted with two cameras and one voice recorder to record the videos, images and verbal data. This set of tools is the same as the use of previous research (Kim & Ryu, 2014). A computer, white papers and drawing utensils are provided for participants during the experiment.

3.3 Experimental design

Before the formal experiment, the participants will practice the Think-aloud protocol for ten minutes by designing a USB for an office worker. At the same time, the researcher will remind the participants to speak their thoughts out loud simultaneously. After the practice, the topic of the formal experiment is to design an alarm for hearing-impaired people. This product is obviously aiming at a specific target group, so that will need some additional research to have a better understanding. The participants will not skip the phases of discovery and definition. In addition, because the product is a common item that most people are familiar with, it will avoid extreme design due to misunderstanding. The experiment will last around sixty minutes, but not more than one hundred minutes or less than forty minutes.

During the experiment, the researcher will stay with the participants in the same room. The researcher will remind the participants with a question like "Could you tell me what you are thinking about?", which is commonly used in Think-aloud protocol when the participants stop talking over thirty seconds (Laing, Apperley, & Masoodian, 2017). When the Think-aloud protocol is done, the retrospective protocol will be conducted with a semi-structured interview to make up the missing data (Coley, Houseman, & Roy, 2007). According to the advice by Lindlof and Taylor (2002), the researcher can ask questions based on their record

or participants' design by open-ended interview. All the interviews will be one-on-one in order to prevent interference.

3.4 Procedure

The experiment is divided into three steps. The first step is the warm-up to make participants feel familiar with the Think-aloud protocol, to make the data more precise. The second step is the Think-aloud protocol during the formal experiment. The participants will conduct the provided design topic in a laboratory with the researcher. The last step is the retrospective interview in both semi-structured and open-ended way.

3.5 Data analysis

This study will conduct the protocol analysis with the coding scheme. The 5D model in Interim Design Ontology (Green et al., 2014) will be used for this study to determine the first three phases of the design process: Discovery, Definition, and Design. For evaluating the details among each phase, the study combines the coding scheme from Gero and Neill (1998), Salman, Laing, and Conniff (2014), Kim and Ryu (2014), and Schön and Wiggins (1992) to make the observation of the behavior more precise, as shown in Table 3.1.

Table 3.1 Codes of phase and design activity

Code	Phase of design process	Code	Design activity
Dc	Discovery	Ap	Analyzing the Problem
		Cp	Consulting Information About the Problem
		Ep	Evaluating the Problem
		Pb	Postponing Analysis of the Problem
Df	Definition	Ru	Retrieval of Functional Description
		Ro	Retrieval of Form Description
		Rs	Retrieval of Semantic Description
		Al	Analogy
Ds	Design	Cr	Creating and Revising Figure
		Cs	Creating Symbol Word
		Ms	Moving Same Object

Source: Gero and Neill (1998), Salman, Laing, and Conniff (2014), Kim and Ryu (2014), and Schön and Wiggins (1992).

4 Results

Based on the research questions and objectives, the study addressed the experiments by using the Think-aloud protocol method with experts and novices individually. Table 4.1 shows the general description of participants. The durations of the whole the design processes were varied, and the two experts had the longest and the shortest duration among these four. The longest duration (59:30) had the most proposals. Novices acted differently from the experts. Novice 1 spent less time but had more ideas than Novice 2.

Table 4.1 General description of participants

	Age	sex	Years of design expertise	Area of expertise	Design process duration (min:sec)	Number of design proposals
Expert 1	37	male	13	Industrial design	59:30	3
Expert 2	37	male	15	Industrial design	39:10	1
Novice 1	22	female	3	Industrial design	42:26	2
Novice 2	23	female	3	Industrial design	51:02	1

4.1 Sequence of design phases

The first research question concerned the sequences during the design process, and data is clearly shown in Figure 4.1. The data shows some similarities between the experts and novices. The experts and novices all began with the Discovery phase (Dc) and the Define phase (Df) occurred several times during their Dc. They all did the Design Phase (Ds) at the end of the process.

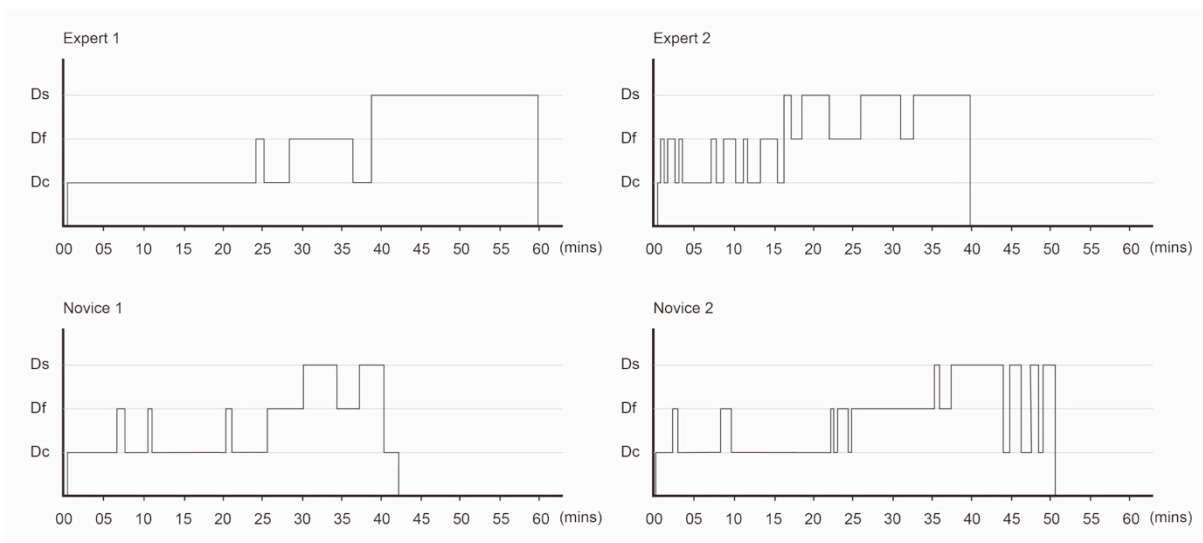


Figure 4.1. Sequence of phase.

Expert 1 started from Dc and then moved to Ds, and there were only two Df occurrences during Dc. Within Ds, there was no interruption in this phase for him. Expert 1 tended to stick to each phase for a long time. As for Expert 2, he went to Df at very beginning right after the short Dc, and he was going back and forth between Dc and Df. When he started to Ds, he also sometimes went back to Df and then continued the design again. It is obvious that the Df ran through his whole design process.

On the other hand, novice designers were more iterative than experts. Novice 1 started from Dc with a short Df and shortly went back to Df during Ds. Novice 2 also began with Dc, and she went into Df within the first few minutes. Before moving on to Ds, she kept spending time on Df. Furthermore, she not only went back to Df but also back to Dc several times during Ds. It was noticed that the novices tended to turn back to Dc in the last moment after they almost finished the design proposals.

4.2 Occurrences and time spent during the design process

In order to address the question about how much emphasis that participants put on each phase, time spent is a factor to observe. Table 4.2 presents that both experts spent about 40% of the time on Ds during the whole design process, which is two times more than the novice designers. Focusing on the experts, Expert 1, compared to Expert 2, spent more time on Dc, which was approximately half of the time of the design process. However, Expert 2 spent his time more even on Dc and Df. Focusing on the novices, they both spent more than half of the process on Dc, especially Novice 1, who spent almost 60% on this phase. Additionally, the novices spent the least time on Ds, which was less than 20% of the total time.

Table 4.2 Occurrences and time spent (min:sec) of each phase

	Dc	Df	Ds	Total
Expert 1	3	2	1	6
	28:59	09:05	21:26	59:30
	48.71%	15.27%	36.02%	100%
Expert 2	8	11	4	23
	11:16	12:19	15:35	39:10
	28.43%	31.59%	39.97%	100%
Novice 1	5	5	2	12
	25:24	10:22	06:40	42:26
	59.86%	24.43%	15.71%	100%
Novice 2	8	6	5	19
	25:04	14:39	06:40	51:02
	51.33%	30%	18.67%	100%

For more details, the occurrences could also help to illuminate the emphasis that participants put on each phase. Once there is a transition between each phase or activity, it is defined as an occurrence. According to the same table, the results show that the total occurrence numbers of the experts were significantly varied. Expert 1 had six occurrences during the design process and Expert 2 had twenty-three. For Expert 1, most occurrences happened in Dc, while for Expert 2 most occurrences were in Df. As for the novices, the numbers of occurrences (12 and 19) were in between the ones of Expert 1 and Expert 2(6 and 23).

4.3 Design behaviors in each phase

On top of the data about how designers worked during the three design phases, the study also had a deeper investigation into the detailed activities of each phase that experts and novices had, in order to understand more about their actual design behaviors.

4.3.1 Sequence of design activity

Figure 4.2 shows that both experts and novices started with Analyzing the Problem (Ap) in the phase of Dc, but worked differently afterwards. Within the phase of Dc, the experts tended to Consult Information to the Problem (Cp) and Evaluate the Problem (Ep) earlier than novices. Expert 2 started to Ep in the very beginning, however, Novice 1 did not Ep during the whole process. Furthermore, these two experts ended the Dc phase with Ep before the phase of Ds, whereas novices ended the Dc phase after Ds phase with Ap and Cp, respectively.

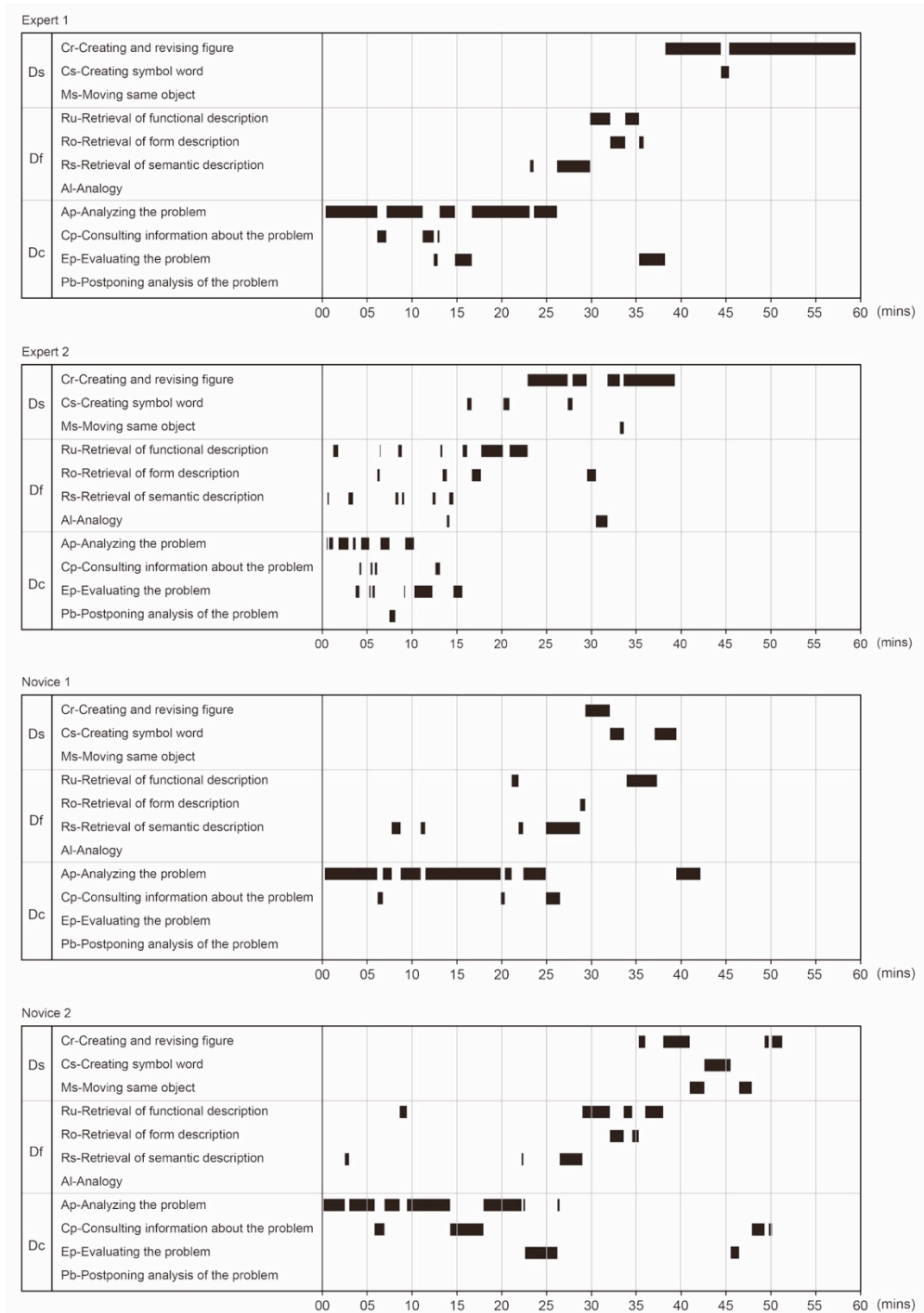


Figure 4.2. Sequence of design activity.

As for the phase of Df, Retrieval of Semantic Description (Rs) was the activity that both experts and novices did first, followed by Retrieval of Functional Description (Ru) and Retrieval of Form Description (Ro). It is obvious that the path of the activities of Expert 2 was the most diverse; he made a lot of transitions among Df. Experts tended to finish Df with Ro, and the last step of Expert 2 was Analogy (AI). Novices finished Df with Ru, instead. In the phase of Ds, Expert 2 started with Creating Symbol Word (Cs), and others started with Creating and Revising Figure (Cr). For the expert side, they tended to stick to Cr for a period of time, however, novices were doing the activities more evenly during Ds phase.

4.3.2 Occurrences and time spent of design activity

The occurrences and time investments were used to evaluate their design behaviors. In terms of the Discovery phase, novices spent most of their time Analyzing the Problem (Ap), especially Novice 1 who spent 91% of the time to Ap. Novices also had the highest number of the occurrences in Ap. As for experts, although they also spent more time on Ap, they also put efforts into Evaluating the Problem (Ep). However, Expert 2 spent two times more than Expert 1 in Ep. Novices spent more time on Consulting information about the Problem (Cp) than experts. Novice 2 spent almost 30% of her time on it. Additionally, both experts and novices nearly Postpone the Problem (Pb). This is shown in Table 4.3.

Table 4.3 Occurrences and time spent in Discovery phase

	Ap	Cp	Ep	Pb	Total
Expert 1	6	4	3	0	13
	22:05	02:45	04:09	00:00	28:59
	76.19%	9.49%	14.32%	0%	100%
Expert 2	7	4	6	1	18
	05:23	01:22	04:03	00:38	11:16
	46.30%	12.13%	35.95%	5.62%	100%
Novice 1	7	3	0	0	10
	23:07	02:07	00:00	00:00	25:24
	91.01%	9.88%	0%	0%	100%
Novice 2	7	4	2	0	13
	17:14	06:55	00:55	00:00	25:04
	68.75%	27.59%	3.66%	0%	100%

In the Define phase, on the expert side, both experts spent more than 40% of the time on Retrieval of Function (Ru). Although Expert 1 had two occurrences and Expert 2 had seven. Expert 1 spent more time on Retrieval of Semantic Description (Rs) than Expert 2, whereas Expert 2 had more occurrences than expert1. Only Expert 2 was spending time on Analog (AI). As for the novices, Novice 1 emphasized more on Rs, while Novice 2 put more efforts into Ru. None of them carried out AI. Besides, it is obvious that there is not always a positive correlation between the occurrences and the time spent. For example, Expert 1 had the same number of occurrences during each Ru, Retrieval of Form Description (Ro) and Rs while the time spent was respectively 40.37%, 23.85% and 35.98%. Another evidence is that Expert 2 had three occurrences during Ro with 20.03% of time spent, whereas he spent less time on Rs with two times more occurrences. This is shown in Table 4.4.

Table 4.4 Occurrences and time spent in Define phase

	Ru	Ro	Rs	Al	Total
Expert 1	2	2	2	0	6
	03:40	02:10	03:15	00:00	21:26
	40.37%	23.85%	35.98%	0%	100%
Expert 2	7	3	6	3	19
	05:59	02:28	02:11	01:41	12:19
	48.58%	20.03%	17.73%	13.67%	100%
Novice 1	2	1	4	0	7
	04:00	00:35	05:47	00:00	06:40
	38.59%	5.63%	55.79%	0%	100%
Novice 2	4	2	4	0	10
	07:06	02:18	05:15	00:00	14:39
	48.46%	20.03%	17.73%	0%	100%

Table 4.5 is about the behaviors in the Design phase. Both of the experts focused most of the time on Creating and Revising Figure (Cr), especially for Expert 1 (95.72%). Expert 2 also spent around 20% of his time on Creating Symbol Word (Cs) and he was the person who had the highest number of occurrences in total. Novice 1 also emphasized more on Cr, which is similar to Expert 2. Novice 2 spent half of her time on Cr and the rest of her time more evenly on Cs and Moving Same Object (Ms).

Table 4.5 Occurrences and time spent in Design phase

	Cr	Cs	Ms	Total
Expert 1	2	1	0	3
	20:31	00:55	00:00	21:26
	95.72%	4.28%	0%	100%
Expert 2	5	2	1	8
	11:34	03:36	00:55	15:35
	74.22%	23.10%	2.67%	100%
Novice 1	2	1	0	3
	05:05	01:35	00:00	06:40
	76.25%	23.75%	0%	100%
Novice 2	4	1	2	7
	05:35	02:24	03:20	11:19
	49.34%	21.21%	29.46%	100%

4.4 Summary

The results present both similarities and differences between expert and novice designers. Looking at the sequence of the design phases, all of them started with the Dc phase, and ended the design process by the Ds phase. However, novices tended to turn back to the Dc phase before they finished their design proposals. Expert designers spent more time on Ds than novices and novice designers spent more time on Dc, as shown in Figure 4.2. Furthermore, the occurrences can show us how iterative that designers work, but does not always have a positive correlation with the time spent. In terms of design activity during the

different phases, both experts and novices started the design process with Analyzing the Problem (Ap) of the Dc phase. Nevertheless, experts tended to get to Consulting information about the Problem (Cp) and Evaluating the Problem (Ep) earlier than novices. Novices did Ep late or did not do it at all. Before moving to the phase of Ds, experts finished the Dc phase by Ep, but novices were still in Ap and Cp of the Dc phase in the very end. In phase of Dc, experts and novices spent most of their time on Ap, but experts focused more on Ep than novices. The time spent on Ep by the experts was two times more than that of the novices. Most of the experts and novices spent the most time on Retrieval of Function (Ru) during the Df phase; only one of the novices focused more on Semantic Description (Rs). In the Ds phase, both experts and novices emphasized the most on Creating and Revising Figure (Cr), especially the experts. The total number of occurrences during Ds were the least among the three phases; the participants tended to have fewer transitions between each activity.

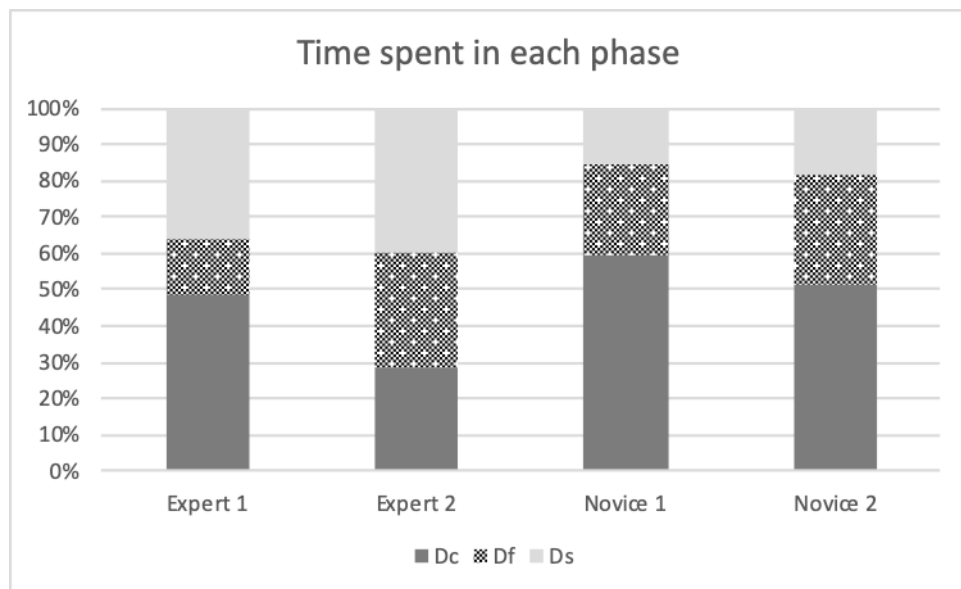


Figure 4.3. Time spent in each phase.

5 Discussion

This study empirically demonstrates how expert and novice designers behave during the Discovery, Define and Design phases of the design process. In order to see how experts and novice designers differentiate from each other by dealing with the tasks in their own ways, the study examines the sequence of the phases and activities. This can provide an understanding of what their priorities are and how they deal with the relationship between each phase and the activities in this phase. Furthermore, the occurrences could help to show how iterative their processes are. The study also would like to examine which phases and activities they spent the most time on. Additionally, by measuring the occurrences and time spent during these occurrences, the total duration of time spent on a specific phase or activity could be revealed.

According to the results of the sequence of the design phases, both experts and novices started with Analyzing the problem (Ap) during Dc phase. It shows that the first step of beginning a design process is usually Ap, no matter what experience the designer has. The phase of Dc often has a back-and-forth relationship with the Df phase. Expert and novice designers are used to discovering things during creating definitions. For example, when Expert 2 was browsing the existing alarm products for hearing-impaired people, he often stopped browsing to take notes for the different kinds of definitions, and then continued to look up other products. Discovery was like an inspiration for him to make a definition and keep revising his design direction and prove his idea was on the right track. Although novice designers also moved back and forth between Dc and Df, they often searched without clear purpose and the definitions were repeatedly deleted and replaced with new ones. Experts tended to know what they should look for and what helped their definitions. The results also show the different behaviors between the two experts in the Dc and Df phases. There were many transitions between Dc and Df for Expert 2, however, Expert 1 had only two transitions. Expert 1 was focusing on one phase at a time. Once he felt satisfied with what he did and had a holistic understanding, he would make some summaries or decisions and then move to another phase. As for Expert 2, his behaviors were more iterative, and he spent less time on each activity.

It is interesting that these different behaviors also influenced the numbers of ideas for them. Expert 1 gathered more ideas during the Dc phase without interruption by considering the definitions. Afterwards, he started to sort his different ideas during the phase of Df and he finally had three proposals. Expert 2 was using more discoveries to optimize his one idea. For him, Dc was not only for exploration, it was also for supportive information. He used Dc to revise the definition; the process was more convergent.

After the Dc and Df phases, both expert and novice designers went to the phase of Ds. Expert 2 and novices had transitions between Ds and Df, except for Expert 1, who was focusing more on one phase at a time. When they were designing their ideas, they needed to check their definitions or they would refine the definitions when something was incorrect. Both experts ended the design process with the Ds phase. However, it should be noted that the Dc phase occurred at the very end of the novices' processes. These two novices found some issues, so they wanted to change their concepts and redo their designs. This behavior can be explained by Trial and Error because novice designers often have less confidence in their decisions, hence the two novices tended to redo things during the process (Ahmed, Wallace &, Blessing, 2003).

The results show that the experts spent most of the time on Ds phase, which is two times more than the novices. However, the result is different from a previous research by Brand-Gruwel, Wopereis, and Vermetten (2005). They found that experts would spend more time on definition than novices. The reason why experts spend more time on definition is, according to the research, because the experts have more knowledge and experience to make a quicker and more precise decision about the definition. Therefore, they had more time to develop their Ds. As for the design activity, the experts performed sooner and better at Evaluating the Problem (Ep) than novices. The novices often reached an impasse when they evaluated things because it was harder for the novices to evaluate and come up with design proposals (Kim & Ryu, 2014).

6 Conclusion

For novices, learning from how experts work is one of the most efficient ways to become more professional. When a novice designer is trying hard to improve their expertise to become an expert, to some extent, this study provides a holistic perspective to build the bridge for the leap. Although every expert has their own preference for work, we still found some similarities between experts and their design behavior patterns. The knowledge and experience behind the expert subtly influenced their behaviors during the design process. During the experiments, sometimes experts did not even know that they were in a certain phase or activity, but this research revealed their actual behavior explicitly by protocol analysis.

However, this research might not completely interpret design behaviours. The research was conducted in the laboratory and was a short-term experiment. Also, the amount of data and the limited time period were limitations of the study by protocol methodology. Behavior could be different in the real workplace since the factors of Develop and Deliver phase could also influence how designers work in the first three phases in the 5D model.

On top of the research outcomes, there is something we can explore more to have a deeper understanding of the participants, and it might be critical and influential for in-depth research. Therefore, here are recommendations for future research:

- To understand why experts or novices make the decision to move on or go back between phases and activities at a specific moment.
- To have a study on how experts and novices work in five phases in the 5D model.
- To find out in what way phases and activities influence each other and the reasons why.

Nevertheless, this study still contributes to the data and discussion that can help expert and novice designers examine how they might work differently. By means of comparisons, this research could provide new insights for not only experts or novices themselves but also the educators or team managers of companies.

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Acknowledgement: We would like to express our thanks towards instructors, friends, families and those who supported us.