1. INTRODUCTION

It is said that inference, which we regularly employ in daily life, can be divided into deduction, induction and abduction [1]. In the product-design thinking process, we identify issues based on numerous facts using inference, conceive a solution, and create a concrete shape. In reference [2], the authors presented a framework for deduction, induction and abduction by applying a design process that is actually used by product designers; and, taking the example of a specific product-development process, showed that a certain pattern, combining abduction and induction, exists when a shape is created. This pattern illustrates what we call an “analogy-based approach.” We evaluated the usefulness of the method by actually carrying out the molding process adopting this inference pattern.

2. FRAMEWORK FOR INFERENTIAL THINKING PROCESSES

In [2], the authors proposed inference process diagrams (Figures 1 to 3) to visualize three types of inference process: deduction, induction, and abduction. We proposed that each inference process could be conceptualized in terms of production systems, which were developed in the field of cognitive science; and created diagrams to describe the respective processes in these terms. Each thinking process is explained and illustrated below.

[Deductive thinking process] Deduction is a form of inference in which a conclusion is derived as a subaltern from a general and universal statement (laws, conventional practices, etc.), based on logical form [3,4]. The knowledge base in the deduction process diagram
(Figure 1) is experiential memory; specifically, a long-term memory in the form of a rule called a production rule: “If-then-execution (conclusion)”. If the universal statement “If A, then B” exists in the knowledge base, the information “A,” which is input as a premise, is temporarily held in the working memory and checked, and the conclusion “B” is output.

**Inductive thinking process** Induction is a form of inference in which a general statement or law is derived from concrete experiences [3, 4]. As shown in the inductive process diagram (Figure 2), similar facts in the long-term memory are sought (among various input facts), confirmed and ‘generalized,’ and a conclusion is output. In this form of inference, the conclusion is not guaranteed to be true, even if the premise is true, because there is the possibility that a fact different from the premise may exist.

**Abductive thinking process** In this form of inference, a hypothesis is developed as a plausible explanation based on examples [3, 4]. As shown in the abduction process diagram (Figure 3), given a certain premise statement, various hypotheses are developed to explain the (possibly startling) fact, and the one considered most true is selected.

**Combination of abduction and induction using the analogy approach** Generally, the analogy approach offers a means to infer information on the Target, the area of interest, which shares similarities with the Base, or known area. In the analogy approach, it is important to conceive ideas by homologizing only relationships and structures at an abstract level. We must not imitate shapes by homologizing those that are observable at a concrete level. Figure 4 shows the process of abduction using the
analogy approach. First, we try to develop hypotheses to explain the surprising fact when we have a premise statement. At this stage, inductive thinking is used in the known area, which is similar to the area of interest where the ideas are conceived. Many facts and specifically known facts in the long-term memory are generalized, and the relationships and rules shared by their shapes and functions are extracted. The shapes are conceived in a hypothetical manner, based on these thinking processes. Then, the result is obtained by selecting the most plausible hypothesis.

3. EXPERIMENTAL METHOD

An experiment was performed on 25 second-year students in the School of Design, Kyushu University, aimed at the sketching of design conceptions of chairs that provide a sense of “loveliness” to the user. First, the framework for deduction, induction and abduction was explained to the subjects using Figures 1 to 3, and combined patterns of thought suited to the analogy approach were explained using Figure 4. The approach itself was also explained. Then, in order to design chairs that provided a sense of loveliness, they collected images of objects that provided them with this sense; determined the reason(s) why they received this sense from the respective objects; and shared the shape elements that provided this sense, as well as the reason(s) why. The subjects employed concrete examples as well, when the examples were similar to their own.

Each then sketched a chair that would provide this sense to users, incorporating these shape elements in the chair’s design. Finally, they subjectively evaluated the approach.

4. EXPERIMENTAL RESULTS

4.1 Results of the Shaping Process Based on the Combination of Abduction and Induction

Figure 5 shows an example of the analogy-based inference process used by the subjects. They began the abductive thinking process with the question, “What shape of a chair provides a sense of loveliness?”, and conceived a shape. Inductive thinking was used in this approach. They discovered a sense of loveliness in shapes such as a USB terminal and pencil sharpener, and inferred that this sense was clearly attributable to the objects’ resemblance to the faces of animals. They then conceived certain shapes as hypotheses, using the shapes and concepts as shape elements of the chair. Finally, they completed a sketch of the chair that provided a sense of loveliness, by selecting a plausible shape from among the hypotheses. Other subjects performed the experiment in the same way, and sketched a chair. As a result, their thinking process can be visualized as shown in Figure 5. In this paper, however, the figure is simplified. Here, 10 subjects were selected, and their processes of conceiving ideas are shown as examples. In concrete terms, Images of Concrete Examples collected by inductive thinking, Relationships between Shape and Concept (Schema) generalized by inductive thinking, and Hypotheses of Shapes developed and selected by abductive thinking are extracted and summarized in Figure 6.

4.2 Subjective Evaluation Results

A questionnaire survey concerning the design process based on this approach was conducted among the 25 subjects. They answered questions using a 1 to 5 scale: 1 = Disagree; 2 = Somewhat disagree; 3 = Neither agree nor disagree; 4 = Somewhat agree; 5 = Agree.

1) Evaluation items

The following four questions were asked. Evaluation items (1) and (2) were part of the direct evaluation of the experiment conducted in this study, while items (3) and (4) evaluate the possibility of applications of this approach in the future.

(1) By collecting images of things that gave you a sense of loveliness, were you able to determine which shape provided you with this sense? (Did you derive shape elements using inductive thinking?)
Figure 6: Experimental Results (summary of the thinking processes and sketches of ideas)
(2) Did your initial collection of images of objects that gave you this sense of loveliness, make it easier for you to then design a lovely chair? (Did the analogy-based approach promote abductive thinking?)

(3) In this experiment, sketches were made based on the subjects’ own thinking, but if the elements of loveliness are shared by other subjects and you can understand the thinking of others, does it help you extend the range of your conceptions?

(4) Do you think that designers will improve their way of thinking and develop new ideas, by reflecting on their structure of thought?

2) Evaluation results and discussion

Table 1 shows the evaluation results, and Table 2 the score percentages.

(1) Those who answered “somewhat agree” (15 subjects) or “agree” (4 subjects) accounted for 76% of all subjects, showing that more than 70% of the subjects were able to determine what shape provided them with a sense of loveliness.

(2) Those who answered “somewhat agree” (10 subjects) or “agree” (4 subjects) accounted for 56% of all subjects, with more than half, then, finding the approach useful.

(3) Roughly half (13) of the subjects answered “agree,” and these, combined with those who answered “somewhat agree” (6 subjects) accounted for 76% of all subjects, suggesting that many subjects felt they could extend the range of their conceptions by sharing their perceptions of lovely elements with others.

(4) Those who answered “somewhat agree” (10 subjects) or “agree” (8 subjects) accounted for 72% of all subjects, showing that more than 70% of the subjects understood the importance of metacognition in design.

Figure 7 is a boxplot of the evaluation data. Comparison of the evaluation items reveals that item (3) was highly rated, suggesting that the subjects understood the importance of individuals expressing their implicit knowledge (in this case, know-how about shaping) as explicit knowledge, using images and words, and sharing this knowledge with others.

5. CONCLUSIONS AND ISSUES

This paper investigated a process whereby subjects first designed chairs meant to provide a sense of loveliness, using a pattern of analogy-based thinking that combined abduction and induction; and then evaluated the process and assessed its usefulness.

Analogy-based thinking is an approach commonly employed by designers. The significance of the specific approach described here lies in the fact that the visual image conceived by the designer is displayed as a concrete image, and the conception is transformed into explicit knowledge in the form of words. This study
demonstrated that visualizing the pattern of thinking using a framework for abduction and induction offers designers a chance to reflect on their way of thinking, and helps them understand the thought processes of others.

Since designers’ subjective experience will vary, it is important for them to appreciate how others feel, and thereby expand their conceptual horizon, instead of merely consulting their own impressions. The authors believe that, in this way, designers can develop a variety of hypotheses based on one (sometimes startling) fact, and derive an optimal solution based on these hypotheses.

In order to extend their range of conception, it is important for designers to appreciate the thoughts and thought processes of other designers. The relationship between the shape of a thing and its conceptual force is stored as a schema (a structure of information) in the memory of individual designers; and using the approach here discussed, they can discover the reason(s) why they conceived a given shape.

In the future, we will pursue applied research to investigate the effects of sharing one’s thinking process with others. We will also conduct an experiment, using this approach, with young as well as experienced designers, to further evaluate the usefulness of the approach. In addition, we will develop a method for applying a variety of combinations of abduction, induction and deduction to design activity.

REFERENCES