Many of the problems we face in today’s society are getting more and more complicated; they are tend to be ill-structured, and their solution tends to require a creative, solution focussed approach that spans many different disciplines. In other words, many problems we face in today’s society are bearing an ever closer resemblance to design problems. There has already been an extensive study into the possibilities of developing a ‘design methodology of the social sciences’, where fields such as ‘lawmaking’ and ‘the making of a curriculum’, have been described in design-like terms, and supported by design methods (Van Heffen et al. 1999).

We can also see that design thinking is spreading through society in yet another way – we find people with a design background in all walks of life. And they profess they use their designerly way of thinking to solve the problems they face.

But what IS this designerly way of thinking, exactly? There have been descriptions of the particular competencies that characterise what it means to be a designer in terms of ‘design abilities’ (Cross, 2001). But these statements just provide a vague, general idea of what possibly constitutes a designer. In this paper we will set out to explore and validate a model that endeavours to describe different kinds of design thinking, and the development of design thinking in students and designers.

To develop such a model, we base ourselves on the work of Hubert Dreyfus (2003). We will present a preliminary framework, in which we distinguish seven levels of expertise: (1) A novice will consider the objective features of a situation, and will follow strict rules to deal with the problem. For an advanced beginner (2) the situational aspects are important, and maxims are used for guidance. A competent problem solver (3) selects the elements in a situation that are relevant, and chooses a plan to achieve the goals. The proficient designer (4) immediately sees the most important issues and appropriate plan, and then reasons out what to do. The expert (5) responds to specific situation intuitively, and performs the appropriate action, straightaway. The master (6) does not take these ‘expert’ ways of working for granted anymore, but sees them as contingent. The visionary (7) searches for the anomalies, the strange and innovative ideas and developments at the edge of an established fields that could revolutionise its practice.

In this paper the competency-based model of design thinking (concentrating on ‘design abilities’) and this model of the development of design expertise will be described at length. We will use an extensive literature survey and a set of empirical data (consisting of self-evaluations that students at Eindhoven University write to report their learning progress) to explore the validity and descriptive value of the models. Possible repercussions of these findings for the teaching of design will be discussed.

This paper is programmatic in nature: the conclusions that will be drawn concentrate on outlining directions for the further development of these models of design thinking.

Apart from the new, scientifically interesting questions that we might generate, there is also a sense of ‘real world’ urgency connected to this research programme. In this day and age, our world is rapidly changing from an ‘industrial society’ to a ‘knowledge society’. Designers have to find new roles for themselves. To create these roles they will need an acute awareness of what it means to be designer, and what the value of design thinking is. (Product design agencies like IDEO are acutely aware of this, and they spurned their own (practice-based) research in this area). We need a much more detailed and clearer understanding of what ‘design thinking’ really is.
Investigating the nature and development of design expertise

(approx 2750 words (not counting the tables))

Introduction

Many of the problems we face in today’s society are extremely complicated; they tend to span many different disciplines, to be ill-structured, and their solution requires a creative, solution focussed approach. In other words, many problems we face today are bearing an ever closer resemblance to design problems. This realisation has led to an extensive study into the possibilities of developing a ‘design methodology of the social sciences’, where fields such as ‘lawmaking’ and ‘the making of a curriculum ’, have been described in design-like terms, and supported by design methods [Heffen et al. 1999, Visscher-Voerman, 1999]). The solution of these problems requires design expertise. We can also see that ‘design expertise’ is spreading through society in yet another way – we find people with a design background in all walks of life. And they profess to use their design expertise to solve the problems they face. Designers find new roles for themselves. To create these new roles for design we need a much more detailed and clearer understanding of what ‘design expertise’ really is, and how to support its development.

But what IS design expertise? In this paper we will describe this ‘design expertise’ in two, quite different ways: we will start with a brief description of the nature of design expertise (§ 1). Then we will introduce a model that deals with the development of design expertise (§ 2,3), and match that with some empirical data (§ 4). The conclusions (§ 5) concentrate on outlining a research programme for the further development of these models of design expertise.

1 The Design Ability

In his important paper, ‘The Nature and Nurture of Design Ability’ [Cross, 2001], Nigel Cross describes the particular competencies that characterise design expertise in terms of the ‘design ability’. Based on an extensive study of design methodology literature, he names a set of eight basic ‘elements’ of this design ability:

Designers...
... produce novel, unexpected solutions
... tolerate uncertainty, working with incomplete information
... apply imagination and constructive forethought to practical problems
... modelling media as means of problem solving.
... resolve ill-defined problems
... adopt solution-focussing strategies
... employ abductive/productive/appositional thinking
... use non-verbal, graphic/spatial modelling media.

Other authors have largely supported this view of the design ability. Design methodologists and design schools differ considerably in the terminology they use, in the content-knowledge of the design domain they cover, and in the priorities they attach to the different constituting elements of design. For instance, at the faculty of Industrial Design at Eindhoven University of Technology, the stage for the empirical study that we will describe in paragraph 4, the development of the design student is divided into seven basic competencies: ‘ideas and concepts’, ‘integrating technology’, ‘user focus’, ‘social and cultural awareness’, ‘multidisciplinary teamwork’, ‘market orientation’, ‘visual language’, and two so-called meta-competencies, ‘design and research processes’ and ‘self directed learning’. Some of these nine competencies map directly to Cross’s elements of the design ability, whereas others are more closely linked to the application domain. But all eight elements of the design ability mentioned by Cross are covered in the curriculum. Cross’s model of design ability can be taken as a reflection of a general consensus (see also a recent conference on Expertise in Design [Cross and Edmonds, 2003]).

This general consensus on what constitutes the design ability is valuable in itself. However, this list of the elements of design ability just provides a static and general picture, a basic understanding of what possibly constitutes a designer. The notion of ‘design ability’ is more often than not used in the context of discussions (within design science or education) which deal with the development of design ability, for which the static framework of eight elements does not suffice. In addition to the static model we also need a dynamic model of design ability.

Several questions can be asked within the framework of such discussions:
- **How can we distinguish levels of design expertise?**
  This is an important issue, if only because we need ways to distinguish between the simple, naive design activities that are part of everyday life (i.e. the design steps that are involved in planning a holiday) and the professional design practice, in all its complexity.
- **How are all these ‘elements of design ability’ developed in design education?**
  In order to explain, justify and develop our methods for design teaching, we need more than a general model of what constitutes an able designer: we need to be clear about the development of the design ability from novice to expert levels.

These will also be the lead questions in this paper. In the next section we will introduce a general model for skill acquisition that can help us to describe the development of design expertise.

## 2 A Model of the Development of Design Expertise

To explore the development of design abilities and the levels of design expertise we now turn to the papers and lectures by Hubert Dreyfus [Dreyfus, 2002, 2003]. Dreyfus’s model of expertise development, which is widely used
in professional education, takes the development of skills as the starting point for a model of learning. This closely resembles the 'learning-by-doing' approach that is at the basis of (almost) all design education.

In the model, Dreyfus distinguishes seven distinct levels of expertise, corresponding with seven ways of perceiving, interpreting, structuring and solving problems. See Table 1.

1. **Novice**
   A novice will consider the objective features of a situation, as they are given by the experts, and will follow strict rules to deal with the problem.

2. **Advanced beginner**
   For an advanced beginner the situational aspects are important, there is a sensitivity to exceptions to the 'hard' rules of the novice. Maxims are used for guidance through the problem situation.

3. **Competent**
   A competent problem solver works in a radically different way. He selects the elements in a situation that are relevant, and chooses a plan to achieve the goals. This selection and choice can only be made on the basis of a much higher involvement in the design situation than displayed by a novice or an advanced beginner. Problem solving at this level involves the seeking of opportunities, and of building up expectations. There is an emotional attachment, a feeling of responsibility accompanied by a sense of hope, risk, threat, etc. At this level of involvement the problem solving process takes on a trial-and-error character, and there is a clear need for learning and reflection, that was absent in the novice and the beginner.

4. **Proficient**
   A problem solver that then moves on to be proficient immediately sees the most important issues and appropriate plan, and then reasons out what to do.

5. **Expert**
   The real expert responds to specific situation intuitively, and performs the appropriate action, straightaway. There is no problem solving and reasoning that can be distinguished at this level of working. This is actually a very comfortable level to be functioning on, and a lot of professionals do not progress beyond this point.

6. **Master**
   With the next level, the master, a new uneasiness creeps in. The master sees the standard ways of working that experienced professionals use not as natural but as contingent. A master displays a deeper involvement into the professional field as a whole, dwelling on success and failures. This attitude requires an acute sense of context, and openness to subtle cues. In his/her own work the master will perform more nuanced appropriate actions than the expert.

7. **Visionary**
   The world discloser or 'visionary', consciously strives to extend the domain in which he/she works. The world discloser develops new ways things could be, defines the issues, opens new worlds and creates new domains. To do this a world discloser operates more on the margins of a domain, paying attention to other domains as well, and to anomalies and marginal practices that hold promises for a new vision of the domain.

**Table 1. The model of expertise development**

This admittedly is a general model of the development of expertise, developed to cover many fields. In the next section we will discuss some characteristics and limitations of this model that might be relevant for its application to the field of design.

3 **Discussion**
Three general remarks need to be made that further describe the nature, scope and limitations of this model
- As a first qualification of the model, it is important to realise that the levels of expertise should not be taken as characterisations of a complete person. The levels can co-exist within a single design project: designers can simultaneously display the rule-following behaviour of the novice in some parts of their work, while displaying the interpretation and reflection that characterise higher levels of expertise in other parts of the design project.
- We should be careful in taking these levels of skill acquisition as a blanket model for the complete development of a designer. Learning design doesn’t just involve skill acquisition, it also involves the learning of declarative knowledge, and the building up of a set of experiences that can be directly used in new projects. These experiences become a repertoire of earlier solution that can be applied by the designer. They could be seen as a store of ‘frames’ [Schön, 1983], as ‘design prototypes’ [Gero 1990], or as ‘design gambits’ [Lawson, 2003].
- It is important to realise that this model of the development of expertise has been built up by Hubert Dreyfus over a number of years, as a reaction to different influences. There might be discontinuities in the model because of that. The first three steps in the model have been developed in connection with Dreyfus’s early investigations into the claims and limits of Artificial Intelligence [Dreyfus, 1992]. This work has later been extended into a fundamental treatise on mental representation [Dreyfus, 2002]. The last two steps in the model, from ‘expert’ to ‘master’ and ‘world discloser’, have been inspired on the existential ‘anxieties’ as they have been posited by Heidegger.

Having said this, the general set-up and the descriptions of levels of expertise that are defined in the model DO spark intuitive recognition by designers and those involved in design teaching. Apparently this description of the development of a designer in terms of skill-acquisition potentially describes an important aspect of the advent of a designer. It could thus be a useful tool for design teachers to describe the development process we want to stimulate and foster in our students.

However, to be really useful this model of the development of design expertise needs to be developed much further, and should eventually be validated by empirical research. In the next section we will take a small step in the development of the theory by trying to match the levels of expertise to a set of empirical data. This is as yet an informal check, not an ‘official’ empirical study to validate the model of design expertise. This informal check should be seen in the context of an exploration to find out whether the model as it is seems to reflect design reality, and to get inspiration for the further development of a design expertise model.

4 Levels of expertise in design education

A set of empirical data is used to explore the descriptive value of the model of design expertise development in design education. The data consists of self-evaluations of a student at the faculty of Industrial Design Engineering at
Eindhoven University of Technology (see section 1). In this design curriculum, that is solely project-based, students have to describe their own learning progress in ‘self evaluations’. These ‘self evaluations’ are a critical part of the design curriculum in this faculty: no marks are given, but the students are assessed on the basis of the learning progress they report in these self-evaluations.

We will try to see if the statements in the self-evaluations support the kinds of levels and transitions that are being described in the expertise development model. For this very first exploration, we will take the self-evaluations that one student produced in the first three years of his study (encompassing 10 big design projects and about 25 ‘assignments’), this is approximately 90 pages of text. In Table 2 we present some examples of quotes from these self-evaluations, categorized as expressions of the student being at a ‘novice’, ‘advanced beginner’ and ‘competent’ level, or signifying a transition between these levels. The data has been processed by a researcher who is not involved in education at the Industrial Design faculty at the TU Eindhoven.

novice-level:
... I think (it is) an excellent tool in the idea generation process, definitely when you’re evolving from a concept to a product...
... What I still miss is some more theoretical background on form (theory of forms). I know there are certain rules in graphical design...
... It strikes me that I never put any effort in learning how to handle requirements while they are a fundamental part of the design process...

transition from novice to advanced beginner:
... The things I’m learning are changing; at first you really learn project related things. Every project you found out a number of specific things and you wonder how to ever learn all things. But the last periods I’m beginning to see the bigger lines, how all those things relate to each other. You draw connections between things you’ve seen earlier and new things you see in projects...

advanced beginner:
...I can hardly believe that for all these different design problems (there is) one process (that) is the most effective...
... Another thing I would like to experiment with is how this method will work on different sort of project...

transition from advanced beginner to competent:
... For me as designer it’s important that are different ways to look at the interface problem so that I can select & follow the appropriate principle for each individual project...

competent:
... Most of the times when you apply a certain method you will have to adapt it so that it will fit your project...

Table 2: Some examples of quotes from the self-evaluations

As a very preliminary conclusion from this first check with empirical reality, we can say that we can actually find an empirical basis for these levels of design expertise, and that there is also evidence that the transitions from level-to-level really take place. The deeper questions that arise from the development of this model of expertise, like: ‘Are these all levels that can be distinguished? (or are there intermediate steps that should be distinguished in the model?)’, ‘How do the transitions between de levels actually take place?’, require a
much more mature and rigorous model, and much more extensive empirical study that will be outlined in the next section.

5 Towards a research programme on design expertise

The classic remark, at the end of almost every scientific paper, is that ‘more research is needed’. That is putting it very mildly, in this case: we have hardly begun. This model of design expertise opens up a whole field of design studies, concentrating on describing and defining the properties of the designers and their development in design training and practice. There are several directions for the further development of this design expertise model. We can distinguish four main questions/directions for research:

(1) One could start by mapping the development of design expertise on all different design abilities. The research field that is then opened up can be visualised as a matrix, with the rows containing the different levels of expertise and the columns the different design abilities. With Nigel Cross’s eight basic abilities and the seven levels of expertise from the model by Dreyfus, this potentially adds up to 56 (!) fields of detailed design research, not counting the study of the transitions.

(2) We should explore the different kinds of reflection and problem solving that take place on every level of expertise. For instance, the kind of problem that is perceived by the designer at the first level of expertise (how can I use my methods?) is quite different from that on the second level (when should I use this particular method/rule of thumb?). The reflection that takes place on the novice-level deals with the rules themselves, the reflection for the advanced beginner centres on the applicability of a rule in a specific design situation.

(3) This can then help us define and study the transitions that link the different levels of expertise. What does a designer need to learn to get from one level to the next? How can he/she do that? What problems stand in the way of learning the next set of skills? It has been observed before [Dorst, 2003] that the acquisition of design skills is not a gradual process, but that it goes in leaps and bounds. But what are the conditions for such which leaps to occur?

(4) A fourth stream of research should be focussed on the aspects of design learning that might not be captured so easily in this skill-based learning model: the development of the declarative and process-knowledge of the designer, and the acquiring and use of ‘design prototypes’. These aspects of design learning should then, if possible, be used to extend and enrich the general, skill-based learning model of design expertise that we have described in this paper.

There are several means we can use to attack these issues. An extensive literature survey is in order, spanning several disciplines. There is much more theoretical work on expertise development to be found in educational research (e.g. [Visscher-Voerman, 1999]) and in the field of educational psychology (where [Ericsson, 1993] is an influential work).

On the empirical front, a detailed longitudinal study needs to be set up. We need to actively follow students in their education, tracing their development from the actual work that they are doing. In this way we would not have to
depend on the students being able to verbalise these points in their self-evaluation, and wait until they do so. Designers in practice could be interviewed and other research techniques could be used to trace their development in the ‘higher’ steps of the expertise development model. In addition to this longitudinal study, cross sectional research could support more in-depth analysis of a specific level of expertise or a specific transition within the model.

If we can get a grip on the development of design expertise, this could lead to a number of new developments in design education. A model like this could lead to the development of testing methods that would enable us to more precisely target the position and learning possibilities for every student, at every point in their studies. Design exercises could be made much more specific, opening up the possibility for a much more efficient learning process. Design methods and design tools could be provided to the design student at exactly the right time to foster the next step in their development. The model of design expertise could lead to the development of new, more specific methods and tools for design practice and design education.

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