

# KNOWLEDGE EXCHANGE BETWEEN MASTER AND PHD STUDENTS WITH REGARD TO EVOLUTIONARY PRODUCT DEVELOPMENT

Arthur O EGER and Robert WENDRICH

Faculty of Engineering Technology, Section of Product Design, University of Twente, The Netherlands

## ABSTRACT

In this paper the exchange of knowledge between PhD- and master-students with regard to the theory of Evolutionary Product Development is presented. At the University of Twente this theory, based on six product phases, is shortly introduced in the bachelor programme. In the master programme students learn to work with the model. At this moment five PhD students work on improving the theory. The paper describes how the master and PhD students work together and exchange information to learn how to use the model and to further improve the model. The theory of product phases, first published in 1987, was formulated in a PhD thesis in 2007. Generally speaking, the emphasis in the first product phase – performance – is on new technologies. In the second phase – optimisation – new knowledge is required. The market no longer accepts imperfections and other disciplines become important. Product development is aimed at improving performance, better reliability, improvement of ergonomics and safety. In the third phase – itemisation – high quality and safety no longer suffice. Extra features, including special editions of the product for different trade channels and target groups, and styling become important success factors. The last three phases – segmentation, individualisation and awareness – co-exist. Product development is either aimed at the extra features and accessories, including special editions, or at mass customisation or co-creation, thus allowing the customer to influence the final result (individualisation). The social behaviour of the company or organisation behind the product is becoming more and more important to the customer (awareness).

*Keywords: Evolutionary product development, design methodology, bachelor/master and PhD education*

## 1 PARAMETERS FOR PRODUCT SUCCESS

In this research on the parameters that influence the success of products, it is tried to develop a model that enhances the chances of success. According to several researchers ‘real’ innovations (defined as new products for new markets) have a chance of success of about 5% (Researchers come to different results that vary between 1-7%) [1,2]. To increase the chances of success some researchers suggest to choose step by step strategies [1,3,4]. However in many courses in design education students are often stimulated to make an innovative ‘leap’ (revolutionary product development) instead of a small evolutionary step. To teach students in practicing to make this evolutionary step, the theory of product phases, that is intended to take small steps, is used.

## 2 INTRODUCTION: ORIGIN OF THE THEORY OF PRODUCT PHASES

The theory of product phases originates in the design practice of the bureau Van Dijk en Eger (later: Van Dijk/Eger/Associates, nowadays: WeLL Design) that was founded in 1979. From the very beginning, it was tried to describe the experience of the bureau in terms of a model. The first publication was realised in 1987 in ‘Dutch Design’ [5] on the occasion of a large exhibition that five museums in the Netherlands had organised regarding design in the Netherlands. In the first publications the product phases were named ‘product levels’; and their descriptions were not very detailed. In a subsequent publication [6] the first five product phases were named as follows: Performance, Optimisation, Itemisation, Segmentation, and Individualisation. The sixth product phase, Awareness, is first described in an article in *NieuwsTribune* [7], and afterwards in the book

‘Succesvolle Productontwikkeling’ [8]. In later studies [9,10](Figure 1), it was shown that each product phase can be described by means of ten product characteristics: Newness; Functionality; Product development; Styling; Number of competitors; Pricing; Production; Promotion; Service; and Ethics. Generally speaking, products will follow the product phases in the same order. The aim of the model is to improve insight into a product’s life cycle.

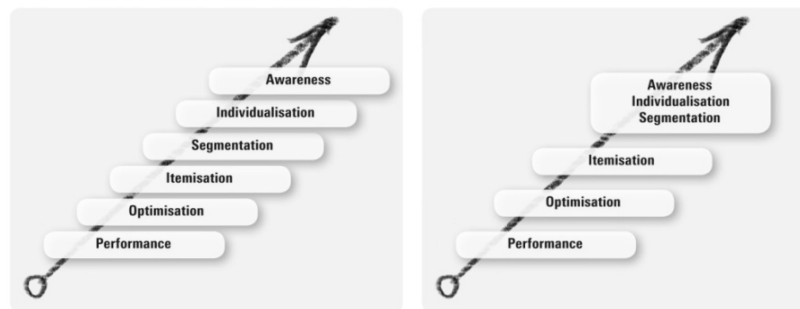


Figure 1. The six product phases; original model (left) and improved model (the last three product phases occur simultaneously)

In the previously mentioned studies a number of recommendations for future research were given. In the next section the following of these questions will be addressed:

- Is the model a useful tool in the first phase (Preliminary phase, figure 2) of the design process, when the product and the market are analyzed?
- Does it offer starting points for a redesign?
- Can it give directions regarding functionality or styling of a product?
- Does it leave enough design freedom for the designer or is it too rigid? (On the delicate balance between ‘enough freedom’ and ‘too much rigidity’)

To find an answer to these questions designs that were made with the aid of the theory by master students of Industrial Design Engineering at the University of Twente were analysed.

### 3 THE NEW, IMPROVED MODEL OF PRODUCT PHASES

From the various researches (including the one described in this paper) it can be concluded that introducing product phases opens up the possibility to analyze the relationships between the different fields of industrial design engineering: ergonomics, marketing, construction and styling. The form giving of a product can be analyzed in relation to its (primary and secondary) functionality, its ergonomic qualities, its production technology and its possibilities to offer emotional benefits. In the original study [9,10] ten product characteristics were proposed; in the more recent studies [11] two of them turned out to be statistically insignificant. However, both of them are more or less exogenous to designers. One of them, the number of competitors, is usually a given fact. The second, the way promotion is done, is in most cases not or only partially influenced by designers. The eight product characteristics – of which four apply to the product itself and the others to its market, its production technology, the services that accompany the product and the ethical aspects of the product in question – are: Newness, Functionality, Product development, Styling, Pricing, Production, Service, and Ethics. Each of the six product phases displays a typical pattern of product characteristics. In this section, these product characteristics will be made explicit for each product phase.

#### 3.1 Performance

New products – that is: products based on new technologies – normally suffer from teething troubles for some time when they have been put on the market. By implication, improvement of primary functionality (i.e., the technical performance of the product) is the most important aspect of product development in this phase. The product characteristics of the product phase ‘performance’ can be summarized as follows. The product is technically speaking new and results from a ‘technology push’. The performance of the product is often poor. Product development is primarily aimed at improving the performance. Design in the limited sense of ‘overall form giving’ is often unimportant, and therefore, product aesthetics are of minor concern. Price competition is usually low. As a consequence, the price per unit can be relatively high. The product is frequently produced by standard machinery

equipment; it often has more parts than the number that would be technically feasible, and assembly is mostly done by hand.

### **3.2 Optimisation**

In the second phase, product development is broadened to include ergonomic aspects and issues of reliability in use and safety. The product phase 'optimisation' is characterized as follows. Although the product is technically speaking still new, consumer awareness of the product starts to develop. The performance of the product is reasonable, but product development is still aimed at improving performance. Other aspects, like increased reliability, improvement of aspects of ergonomics and safety are becoming serious considerations. The price per unit is still relatively high, but increasing competition creates a tendency towards lower prices.

### **3.3 Itemisation**

When producers have improved their product to the point that they satisfy generally accepted standards of functionality and reliability, the edge of competition shifts to convenience. The growth of the market becomes less and the number of competitors increases. As the product range grows, prices fall and promotion costs increase. An endeavour sets in to develop extra features and accessories, including special editions of the product that are developed for different trade channels and target groups. Design becomes more important, and product aesthetics become a major concern. The number of product parts of the basic (cheapest) products decreases, but accessories or extra features can cause an opposite effect: an increase of the number of parts. Mechanic and/or automatic assembly becomes more important. If needed, well-organized service organizations are set up to support the product.

### **3.4 Segmentation, individualisation and awareness**

In the original study, based on five retrospective case studies and a classification by experts, it was proposed that the product phases follow one another, although in the conclusions and recommendations some questions were put with this result. Based on the work of master students in the course Evolutionary Product Development (See section 4.2) [11] it can be concluded that the last three phases often exist simultaneously, and that sometimes one or two of these phases are not suited for the product or product group.

### **3.5 Segmentation**

In the first three product phases the focus was on improved functionality, reliability, ergonomics and safety. An endeavour to add extra features and accessories in order to differentiate the product from its competitors, sets in somewhere in the third stage. However, possibilities of differentiation are limited, due to technical restraints, price considerations and usability. Actually, it occurs more often than not that during the overall improvement pattern of a product, a stage is reached where performance offered is apparently more than performance required. For relatively uncomplicated products, such as furniture and trinkets, the possibilities to add features or accessories are limited. Moreover, for innovators and early adopters, products become less attractive during the latter product phases. The market share is such, that the product can be considered to be 'accepted'. Owning the product is no longer distinctive, as it does not offer any form of status. Adding emotional benefits to a product is now a possibility.

### **3.6 Individualisation**

Extrapolation of segmentation (continuous fine tuning of products on ever smaller target groups) ultimately leads to a product well tuned upon one individual. Recent developments in information and production technology make this kind of individualisation even more possible. Product development is geared to mass customisation and co-creation, allowing the customer to influence the final result. The market starts to shift from a homogeneous polypoly into a heterogeneous polypoly. Although prices approach average technical production costs of the dominant design, co-creation and mass customisation offer possibilities to realize higher prices. Interactive media are used to customise the product to the needs of the individual customer.

### **3.7 Awareness**

A substantial part of the consumers is willing to contribute to a better environment and to help solving societal problems by changing their consumption patterns, but only if this can be done without much

effort, and only if it does not lead to decrease of consumer satisfaction and to an increase in financial burden. A company can successfully tempt consumers – especially those who are committed to purchasing luxury products – by offering them the possibility to show their ethical involvement by acquiring products that claim in some way to be more environmentally or socially beneficial than their competitors. The addition of extra features and accessories, including special editions of the product for different trade channels and target groups, has not stopped, but becomes of secondary concern. Design is focused upon the enhancement of expressive features, aimed at increasing emotional benefits, but when these benefits start to include ethical concerns, this can lead to a sudden leap into ascetic and sober forms. This tendency is reinforced even more by product claims on societal and environmental issues. The producing company explicitly communicates company ethics in its promotion campaigns. The ethical behaviour of the producing company does influence – to some extent – consumers’ choices.

## 4 COURSES REGARDING THE THEORY OF PRODUCT PHASES

Since 2003 the theory is shortly introduced in the bachelor curriculum of the programme of Industrial Design Engineering of the University of Twente; and since 2004 a course in the two years master programme is dedicated to the theory.

### 4.1 The bachelor course ‘Introduction to Industrial Design Engineering’

In the bachelor course ‘Introduction to Industrial Design Engineering’ the so-called ‘Stappenplan’ (Road Map) is introduced. The Road Map consists of four steps: Preliminary phase, Design phase, Embodiment and detailing phase and Implementation phase. In the Preliminary phase students are encouraged to use the model to analyse the product and its market. Figure 2 shows the four phases of the Road Map.

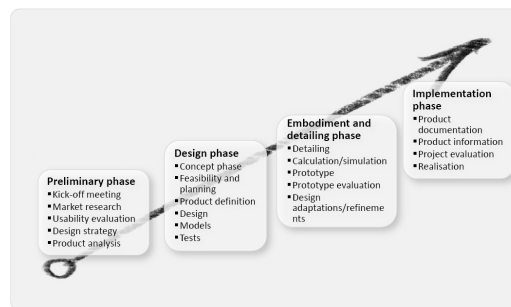


Figure 2. The Road Map used in the bachelor course

### 4.2 The master course ‘Evolutionary Product Development’

As stated before, in many bachelor and master courses students are encouraged to make an innovative ‘leap’. However in the design practice a considerable number of the projects regard small improvements of existing products. In the master course Evolutionary Product Development students learn how to take a small step in their design process. In the first part of the course the history of a chosen product (the students can choose from a list of products or come with their own suggestion) is studied with the theory of product phases in mind. The literature to be reviewed consists of websites, trade papers and scientific publications and since the course of 2010-11 of consumer guides (See section 4.5). An existing product has to be obtained and dismantled during a practical. Special attention has to be paid to the used production methods (forming, separating and joining processes), use of materials and surface textures (coatings) and product arrangement or assemblies.

In the second part of the course a redesign has to be made for the product. The combination of the study of the history of the product and the analysis of the obtained product makes it possible to position the product in the model of product phases. Based on the gathered information a strategy has to be developed for a possible next step for the second part of the course. This means that the design can never be a ‘revolutionary concept’, although it could contain new production methods, materials or other state-of-art features. The students also have to give their opinion on to what extend the chosen product follows the theory. They are challenged to find gaps in the theory and to make proposals for improvements. They know that their results will be used to further develop the model.

### 4.3 Working method

The results presented in section 3 are partly based on the work of over 150 students of the master course Evolutionary Product Development. These students created redesigns for over 125 products, guided by the model of the product phases. (Several products were handled twice.) The designs were created between 2005 and 2010, in which period the course was given five times. The results of the first 81 students are described in Eger and Drukker [11].

### 4.4 Conclusions

Students that participated in the master course were very well able to develop a new, evolutionary version of an existing product. When using the model, most of them found good starting points, both in the theory and in what their research into the history of the product produced. Remarkable is that the students nearly all chose consumer products (BtoC) and that – according to their research – the products were all in the segmentation phase or in one of the two next phases. The only BtoB product that was chosen, was the TIG welding torch which was, according to the researcher, in the itemization phase. In only a few cases the students decided not to follow the theory. Examples are the facial tanner and the pocket calculator. From the research of the history of the product it proved that the facial tanner was at the end of its economic life cycle. The student therefore decided to develop a new product (in the performance phase) aimed as much as possible at the same target group. In the second example it proved that a calculator function nowadays can be found in a lot of products, such as mobile phones, PDA's, and laptops. The pocket calculator is only used as a present given to business acquaintances. Based on this finding, the student decided to make use of a completely new technique for his calculator: micro liquid technique. With that he also chose for the performance phase.

In general it can be concluded that the theory offers a useful tool in the first steps of a new product development project: the Preliminary phase (Figure 2), where existing, competing products are studied with regard to their functionality, ergonomics, safety and marketing; and in the phase where ideas are generated for the preliminary design (Design phase, figure 2). On the other hand the theory does always offer several options, never only one; and these options are not very detailed, leaving a lot of room for the designer to choose and detail the chosen concept. It is the question if it is desirable to offer more detail or is the remaining design freedom an advantage of the model? It is very well possible that this differs per individual.

### 4.5 Improvements in the course

To facilitate the research of the PhD students several improvements were made in the master course. After the first year the students were instructed to present their research results in a table (an example of such a table can be found in figure 3). In the first year the researchers had to read the reports and determine themselves what the students had meant. Also the students received the instruction to not only use internet references. An absolute minimum of two scientific references was requested. At this moment we are working on an algorithm for price inflation correction to be used by the students when studying the consumer guides. For a meaningful interpretation of the development of price (of a product) over time one needs to correct it for inflation. It is apparent this requires a lot of background. Doing this from scratch is to complex a task for students design engineering. Therefore we will provide an algorithm that will give a good approximation of the inflation correction. This will improve the learning from further products analyzed.

Product characteristics	Performance	Optimisation	Itemisation	Segmentation	Individualisation	Awareness
Newness	+	+	+	+	+	+
Functionality	+	+	+	+	+	+
Product development	+	+	+	+	+	+
Styling	+	+	+	+	+	+
Number of competitors	+	+	+	+/-	+/-	+/-
Pricing	+	+	+	+	+	+
Production	+	-	+	+	+	+
Promotion	+	+	+	+	+	+
Service	+	+	+	+	+	+
Ethics	+	+	+	+	+	+

Figure 3. Example of a table for students to present their conclusions;

+ = applies; - = does not apply; +/- = applies only partially; ? = unknown, uncertain.

#### 4.6 Bottlenecks for the students

Some of the students used the theory too rigid. If the theory predicts that the next step is individualisation, they decide that the new product has to be positioned in this phase, without critically considering if the product offers enough possibilities to do so and if there is a target group that is interested in the proposed concept. The assignment in the course stated that the students were supposed to take a small, evolutionary step in their design process. A small part of the students had problems with this part of the assignment and tried to make a revolutionary leap, for instance by choosing a completely new technique or completely new materials. Some students, that had chosen a product in the segmentation phase, had doubts if the product would ever reach one of the next phases. The considerations of the students, written down in their reports, contributed to the conclusion that the last three phases often co-exist (Figure 1).

### 5 RECOMMENDATIONS AND FURTHER RESEARCH

The question arose if the theory can offer more detailed starting points for product development (Section 4.4). This question will hopefully come to the front in the PhD research by Ehlhardt [12]. Drawing from an archive with over five decades product test reviews published by the Dutch consumer organization 'Consumentenbond' the history of products and their selling arguments will be analysed based on developments in and differences between products tested by this organization over the years. Special attention will be given to the changes in the aspects of the products that were tested over the years. Another aspect of the research questions was if designers are able to do 'correct predictions about future products'. Because the designers were students and their products will therefore not be brought to the market, it is not possible to draw conclusions with regard to this part of the question. However, at this moment Vermeulen [13] is carrying out a PhD-research at the University of Twente called 'An Innovation Tool for the SME (Small and Medium Sized Enterprises)', where it is the intention to develop products with the aid of the model, that will actually be brought to the market. We hope and expect that with the results of this research some answers to this question can be given. Another important aspect of this research is that there will be more BtoB products considered.

### REFERENCES

- [1] Ansoff H.I. *Corporate Strategy: An Analytic Approach to Business Policy for Growth and Expansion*, 1965 (McGraw-Hill, New York).
- [2] Cooper R.G. *Winning at New Products: Accelerating the Process from Idea to Launch*, 2001 (HarperCollins, New York).
- [3] Popper K. *The Poverty of Historicism*, 1957 (Routledge, London).
- [4] Schumpeter J. *The Theory of Economic Development*, 1934 (Harvard University Press, Cambridge, Mass).
- [5] Eger A.O. Who actually designs? *Holland in Vorm, Dutch design 1945-1987*, 1987, pp.69-75 (Stichting Holland in Vorm, 's-Gravenhage).
- [6] Eger A.O. How the 'product level' can map the status quo and future of a product. *Proceedings of the world conference on packaging*, 1991 (IAPRI).
- [7] Eger A.O. Productniveaus bepalend voor vormgeving, promotie en presentatie (deel 1 en 2), *NieuwsTribune*, 1993, (47), pp.32-35, (48), pp.27-32.
- [8] Eger A.O. *Succesvolle Productontwikkeling*, 1996 (Kluwer Bedrijfswetenschappen, Deventer).
- [9] Eger A.O. and Drukker J.W. Phases of product development: A qualitative complement to the product life cycle. *Design Issues*, 2010, 26 (2) pp.47-58.
- [10] Eger A.O. *Evolutionary product development: How 'product phases' can map the status quo and future of a product*, 2007 (Lemma Publishers, 's-Gravenhage).
- [11] Eger A.O. and Drukker J.W. Product Development: An Evolutionary Model. 2011 (in press).
- [12] Ehlhardt H. Child Restraint Systems, an Analysis of their Development from an Evolutionary Perspective. 2011 (in press).
- [13] Vermeulen F.G.A. Innoveren of Sterven. *BNO Vormberichten*, 2009, (6) pp.11.