INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKHOLM, AUGUST 19-21, 2003

NEW REQUIREMENTS FOR ENVIRONMENTAL EDUCATION FOR DESIGNERS AND ENVIRONMENTAL ENGINEERS

Johan Tingström, Anne-Marie Åkermark

Abstract

In order to achieve a sustainable society new demands on product development have to be met by companies. When new products are developed their life cycle has to be taken in account in order to minimize the environmental impact. Today environmental improvements can be an advantage in competing with other companies. To meet this new demand designers have to be educated regarding environmental issues in general, but also specifically about design for environment.

In this paper education for designers is discussed. A survey of former students from the environmental engineering program at the University of Kalmar was carried out to obtain their view of the education. Interviews were also held with designers/mechanical engineers working in Swedish companies regarding their environmental education. The aim of the study was to see what kind of environmental education companies provide for their employees and to what extent former students of environmental engineering have use for their education.

Key words: Environmental education, Engineering education, Sustainable engineering, Design for Environment (DfE), Eco-design.

1 Introduction

From a historical point of view, environmental work within companies can be divided into different phases (see figure 1). In the period 1950-1970 emissions from society increased rapidly which resulted in environmental problems. Awareness of these problems led to environmental legislation. This forced industry to take action and treat their emissions. Industrial environmental work thus consisted mainly of minimizing waste during production. This was connected with a cost since the industries had to invest in treatment equipment.

When the World Commission on Environment and Development (WCED) presented their report 'Our common future', which is well known as the 'Bruntland report', a new concept was launched, the idea of *sustainable development* [1]. The definition of this concept is:

"A development that satisfies the needs of today without compromising the possibility of future generations to fulfill their needs."

A more recent definition of the concept sustainable development is. *"... one that can persist over generations, one that is far-seeking enough, flexible enough, and wise enough not to*

undermine either its physical or its social systems of support." [2]

The 'Bruntland report' has led to a change in the focus of the environmental work connected with product. This is illustrated in figure 1, which shows how the strategies have changed from dump and dispose in the 1960´s to Green Design and Life Cycle Manufacturing, initiated in the 1990´s. This means that the environmental effects of a product have to be integrated into the development process from the very start. This leads to new demands on designers and engineers who have to give the same attention to environmental aspects as to conventional ones such as function, quality, and economics. Designers and engineers must therefore be educated to meet these demands.

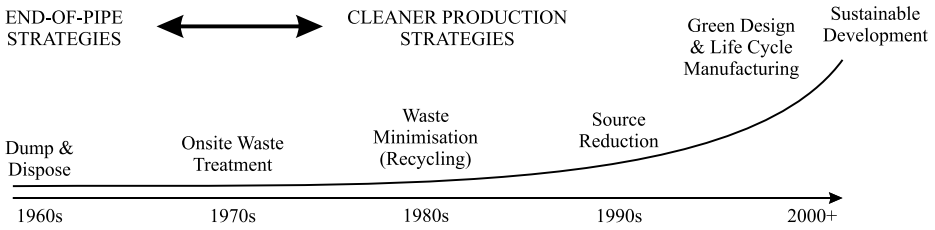

Figure 1. How the environmental focus has changed over the time (modified from Brattebø, [3]).

The change of environmental focus also leads to demands for a change in the education. Traditionally environmental related education/research has been classified as natural science. The focus has been on basic research into cause and effect and learning about the interaction within all environmental systems. In contrast, the environmental work for engineers up to 1990 has been to find technical solutions for treating different processes and outlets (figure 2).

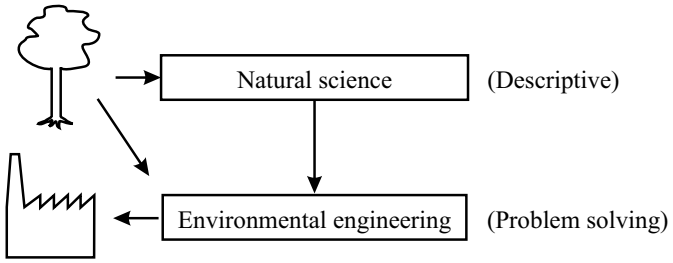

Figure 2. Connection between natural science and environmental technology.

This change of environmental focus has lead to new demands on product development. These new demands are referred to as industrial ecology, design for environment (DFE), and eco-design. There are a variety of different definitions, all fairly similar, and here are some examples:

Industrial ecology *"The multidisciplinary study of industrial and economic systems and their linkages with fundamental natural systems. It is a system perspective that includes the entire scope of economic activity, including consumer and producer behavior, and consequent impacts on natural systems at all temporal and spatial scales"*, [4].

Design for Environment (DFE) *"… systematic consideration, during new product and process development, of design issues associated with environmental and human health and safety over the full product life cycle"*, [5].

Eco-design is defined by Poyner and Simon [6] *as "Design which addresses all environmental impacts of a product throughout the complete life-cycle without unduly compromising other criteria like function, quality, cost and appearance"* . There are several

other slightly different definitons af Eco-design for example Brezet and van Hemel, [7].

This new approach in contrast to previous environmental work in industry, can lead to direct cost reduction examples are recycling and reduced costs for material, and transports [8].

2 Objectives

In our opinion, the goal of a modern environmental education for engineers should be not only capability to understand basic science and to be treating outlets and processes but also to adapt the products to environmental demands. This means to produce products that give less environmental effects, e.g. less consumption of energy and materials. This introduces new demands on engineering education. There is probably also a need for two different types of environmental education:

- General environmental education for all engineers.
- Special competence for environmental experts within industrial ecology, Eco-design, and design for environment (DFE).

In order to get a background for such an approach, we have made two surveys, one with former students of the environmental engineering program at University of Kalmar and one with industrial designers, regarding their views on environmental education.

Three different aspects of environmental education for people working with product developing are discussed:

- Existing environmental education
- Requested environmental education
- Advantages gained from environmental education

These issues are highlighted from the perspective of the different survey groups. Former students from Kalmar evaluate their education and designers in Swedish industry describe their situation.

3 Research Methodology

One of our two surveys consists of a questionnaire that was sent to former students of the environmental engineering education program, at the University of Kalmar. The other was an interview study with designers working in five Swedish companies.

3.1 Case study 1

A questionnaire was sent to all students that have been examined the first two years with a bachelor degree (210 ECTS credits, 3,5 years) in environmental technology. The questionnaire was sent one respectively two years after they left the University, this to give them some time to find an employer and to grow in to the position, and feel the advantage and/or disadvantage of their education.

The questionnaire was a structured form with 20 questions divided into three different categories. The different categories were questions related to the present work position; general questions about how they use their knowledge in their work, and the last part had course specific questions within the education program.

The questionnaire was sent to all 14 students that were examined at that time, and 11 forms were returned. Two did not respond because it was not possible to locate them, and one person did not respond.

3.2 Case study 2

Designers were interviewed with semi-structured interviews based on the quality research interview method [9]. All interviews were made in large Swedish companies which are world leading within their areas. Each designer has been interviewed individually with no former knowledge of the questions asked, according to a semi-structured interview guide. Each interview was recorded, transcribed and analyzed. The interviewed designers work ordinary in PD teams and are not involved in environmental projects. For the numbers of interviews and companies see table 1.

Table 1. Interviews in different companies.

Company, type of products	Number of interviewees
A, household supplies	6
B, heavy vehicles	10
C, electrical motors	8
D, automobiles	6
E, busses	11

4 Environmental technology education

The education program at the University of Kalmar aims to graduate engineers with deeper knowledge in environmental management and eco-design. The environmental programme results in a bachelor degree in environmental technology. This education started in 1996 and today 35 students have graduated. This was originally a mechanical engineering programme that was transformed into an environmental engineering program. Due to this background, the students also get traditional engineering education. During their first year, students take courses in natural science e.g. ecology and chemistry to get a basic knowledge of environmental aspects.

During the final year of the programme, the students have their focus courses in eco-design and environmental management, and related courses e.g. environmental legislation. The aim with these courses is to provide industry with engineers who can work as environmental experts with environmental management systems and eco-design.

5 Product development

Product development (PD) is an interdisciplinary activity with several different actors such as market, design, and production. The product development process can be divided into different steps see figure 3.

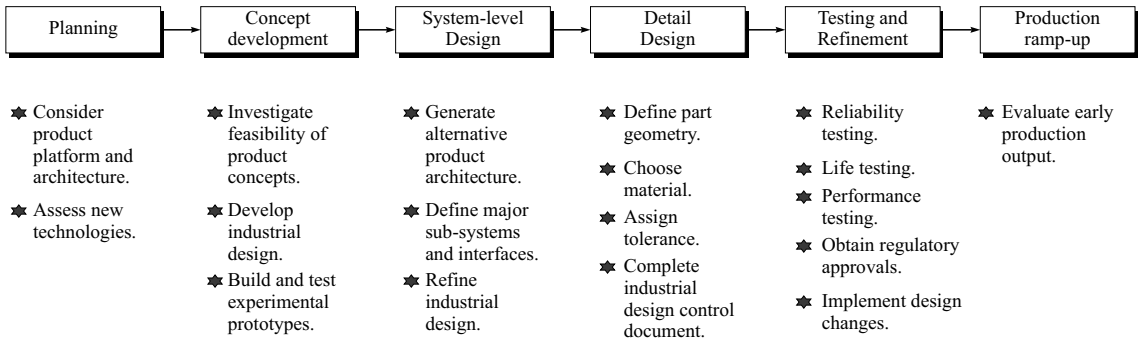

Figure 3. Product developing process by Ulrich, Eppinger [10].

It is important to remember that: "*Most design problems have a multitude of satisfactory solutions and no clear best solution*" [11]. This means that the designer has an opportunity to choose both central concepts and less important issues throughout the product development, see figure 4. The degree to which the environmental aspect is considered throughout the product development process therefore depends on the individual engineer/designer.

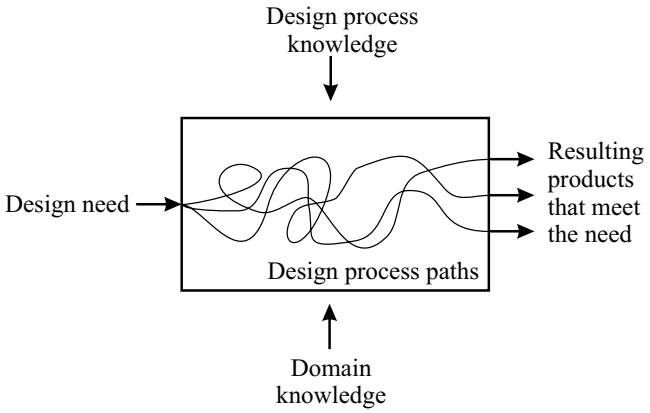

Figure 4. The many results of the design process, [11].

Designing is a combination of many different factors, for example creativity, technical knowledge, mathematical knowledge, and team dynamics. According to Paul and Beitz, [12], there are three different elements in designing:

1. The psychological aspect; designing is a creative activity that also calls for a sound base in mathematics, physics, chemistry, mechanics, thermodynamics, hydrodynamics, electrical engineering, production engineering, materials technology and design theory, together with practical knowledge and experience in specialist fields.
2. The systematic aspect; optimization of given objectives within constraints. Because both objectives and constrains will change with time, also the result of the optimization will change with time.
3. The organizational aspect; a close collaboration with specialists from many different fields is required. Information from purchasers, production, manufacturing and customers must be coordinated.

There is not one true solution but a multitude of different solutions to every design task, and

designers have to consider the environmental issue throughout the entire process in order to make environmentally sound products.

6 Results

The results from the two surveys are presented in chapter 6.1-6.4.

6.1 Student opinion on the environmental engineering education – case 1

According to the former students it is important to have a general environmental education for engineers. Furthermore they were satisfied with their education in environmental science and had use for it in their work. When asked if the programme should contain more thorough education about tools and methods e.g. Life Cycle Assessment (LCA) and Environmental Effect Analysis (EEA), the student was not unanimous but had a variety of opinions. They were not interested in more general information and guidelines, but requested a higher level of knowledge.

For those who studied to become environmental engineers, further education need to be added as well. More than 50% had participated in continuous education. Subjects that were added are for example internal auditor for ISO 14 001 and ISO 9 000, environmental code, leadership, and FR2000, but not all courses have been in the subject of the environment e.g. technical English, leadership, and word processing software. Some of the courses that they have taken aimed at becoming more specialised and some to get a broader knowledge in areas other than the environment. Different positions lead to different demands on courses.

The students had been employed in many different positions mostly in some way connected to the environmental issues. There were a variety of different positions such as, quality and environmental manager, environmental inspector, environmental engineer, environmental technician, quality engineer, quality coordinator, and development engineer. Most of them were employed within the area of their education. Companies show that they have environmental issues on the agenda since they employ staff in these positions. All these positions can be seen as resources in PD.

On the question of whether they judge they had enough skill for the position most of them answered that they had except for skills in quality management systems. The connection between environment and quality is obvious in the answers; some persons were employed with mixed tasks within environment and quality. The education they have undertaken makes them able to carry out the work they are employed for.

6.2 Education for designers – case 2

Few interviewees had received any environmental education prior to their employment. They had received environmental education within their companies consisting of an overview of the ecological restraints, life cycle perspectives, guidelines, and Eco-design. This education had often been given when ISO 14001 was implemented. Such education would last for 1-2 days and was not especially adapted for engineers or designers, all employees in the company participated in the courses. According to the interviewees the education did not provide direct support for PD, but it highlighted the question of environmental issues.

6.3 Requested education – case 2

Complex products that are developed are divided into sub-systems in which designers work. Therefore they request not only environmental education adapted to their projects but also information regarding environmental work within similar projects. In table 2, more specific education in the different product developing phases is described.

Table 2. Different steps in PD according to Ullman,[11], and requsted education.

PDP step	Education
Planning phase	In the planning phase the expected product is studied to investigate the effect on the environment and to find out where the largest impact is and thereby try to avoid or minimize it. In this phase knowledge of the ecological issues is needed. The outline of the new product will be made here. In this phase education regarding new technologies (more environmentally friendly) is needed, such as alternative energy sources, new materials, and new production methods. A sound base of domain knowledge in order to find a more environmental design path (see figure 3).
Concept development	Education regarding different evaluation methods and possibilities. How to evaluate and grade concepts from an environmental view.
System-level Design	How to take the environmental issue in account when generating a product architecture. Importance to be able to communication a message on personal level.
Detail Design	More information/education regarding material choices, structural optimization to minimize the environmental impact and recycling
Testing and Refinement	
Production ramp-up	No specific education requested

All interviewees requested an environmental expert with whom they could discuss different options and possibilities but also as information source. This expert has to have environmental expertise as well as knowledge of PD. The interviewees pointed out that it is not possible to be expert within all areas and a designer's main task is to develop and design products.

The time pressure during PD is quite large. This means that very little time could be spent on education and since the environment is not a main issue for designers, they would not by themselves choose to participate in such education. The main problem for the interviewees was to find time to participate in the courses they wanted to. Due to this time pressure, no education should last more than one or two days at a time.

6.4 Designing and Environment – case 2

As Pahl and Beitz point out, designing consists of three different elements, the psychological, the systematic, and the organisational aspect [12]. From psychological point of view, designers need basic knowledge in many different areas, one such area is the environmental issue. Such environmental knowledge includes general natural science such as cause-effect chains, environmental problems, information regarding Eco-design, and guidelines. This

general knowledge will not solve design problems or support the product development process. This knowledge will be a sound base and help in finding an environmental solution in the processes.

The systematic aspect optimises the given objectives within constrains from an environmental aspect. The demands and constraints change over time and so will the need for education to be able to deal with these changes.

From an organizational aspect with collaboration from many different fields, all aspects have to be considered and a best solution has to be found. Depending on which issues are in focus, different solutions will be found. From this perspective all designers do need an environmental education. It is also important for designers to be familiar with environmental vocabulary to be able to communicate with environmental specialists.

Eco-design means optimising according to environmental aspects not only to fulfil the requirements in the product specification. Many different solutions exist to every design problem (figure 4). Whether this solution will be environmentally sound depends on the degree of priority of given between all the issues.

7 Discussion

Charter describes eco-design as four different levels where the major environmental benefits could be obtained in the fourth level (see figure 5). Depending on the eco-design approach taken, there are different demands on the environmental education for product developers.

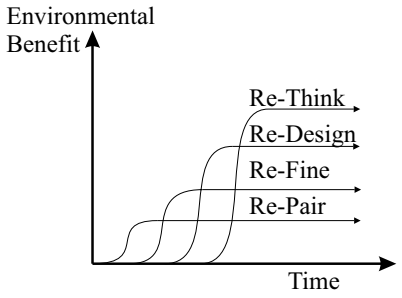

Figure 5. Four step approach to eco-design, [13].

For any significant environmental improvement, levels 3 and 4 have to be reached. For the third level, re-designing, product specific knowledge is needed and if the environmental issue is considered, product developers can make significant improvements to their products. To be able to do this, there is a need for knowledge about the product's environmental impact in order to understand where the greatest improvements can be made. The fourth-level re-think actually calls for new product innovation. In order to obtain such radical product improvements, environmental issues have to be integrated throughout the entire product development. This covers activities from pre-studies to the final design review; it also covers activities in research and development departments where it is important to have environmental experts in the teams and a great understanding of the issue among all team members.

If environmental constraints are set in the product specification, such as, reduce weight X %, reduce number of materials, do not use certain substances, or increase energy efficiency by X %, there will be specified environmental goals and these will be fulfilled (if possible) in the

same way as all other requirements. Such goals do not have to be set from environmental perspectives and do not have to be understood by designers. Single demands can be solved without specific knowledge but to place several demands in a context education is needed. Engineers are problem-solving individuals and given information and instructions from the management they can solve the problem in many different ways (figure 4). According to Handfield [15] it is essential that management indicate that the environmental issue is an important aspect in product development. With environmental education and/or employment of environmental experts it will be clear that this is an important issue.

In reality, designers make all decisions by themselves or in co-operation with the product development team and they can choose which issues to optimise. As Jakobsen and Ernzer [14] point out, with specific guidelines it is possible (for students) to deal with the target conflict due to ecological, technical, and economic aspects. It is in this conflict that the best solutions have to be picked out.

One positive side effect even with a short education is that questions are raised and this should not be underestimated. When people become interested or when they feel that they can influence the design then they are eager to learn more often by themselves. Running some sort of environmental education every year will remind, inform, and highlight the issue for designers. The education requested is almost the same as information and this can of course be provided in a number of different ways for instance by having an environmental expert to turn to.

The designers in the case study ask for a resource person who can offer support when decisions need to be taken. Designers develop all manner of products, and they are consulted in all decisions within the PD. Major decisions are taken at design meetings whereas the designers themselves make minor decisions. When a product is developed many different aspects need to be considered, and an optimisation needs to be found between all aspects.

8 Conclusion

There is a need for different levels of the environmental education, a more general education for all engineers, and a deeper education for environmental engineering experts.

Designers in Swedish industry have been given environmental education provided by their companies. The designers pointed out the advantages not only of education but also of environmental resource persons (environmental experts).

The former students from University of Kalmar are satisfied with their education and work with environmental issues in industry today. This education, environmental engineering provides the experts that were requested by the designers.

The side effects of continuing environmental education should not be underestimated. The two main advantages are that the issue is put in focus and that it is considered as an important issue at the management level.

9 Acknowledgement

We would like to thank all participating designers, companies, and ex-students that has spent time with interviews and questions.

References

[1] WCED (1987) Our Common Future, Oxford University Press, London, pp 43.

[2] Meadows, D. H., Meadows, D. H., and Randers, J. (1992) Beyond the Limits, Earthscan Publications Ltd, London, ISBN 1-85383-130-1.

[3] Brattebø, H. (1997) Emerging strategies and concepts – A framework for the future, In: Strahl, J. (Ed): Sustainable Industrial Production, Baltic university, Uppsala, ISBN 91-7005-128-3.

[4] IEEE, Institute of Electrical and Electronics Engineers, Inc Environment, Health and Safety Committee, 1994, White Paper on Sustainable Development and Industrial Ecology, Washington, DC: IEEE

[5] Fiksel, J. (1993) Design for Environment: An Integrated Systems Approach, Proceedings of the IEEE International Symposium on Electrics and the Environment, Arlington, pp.126-131.

[6] Poyner, J. and Simon, M. (1995) Integration of DFE Tools with product development, proceedings of the International Conference on Clean Electronics and Technology (CONCETP), Edinburgh, pp.54-59.

[7] Brezet, H. and van Hemel, C. (1997) Ecodesign - A promising approach to sustainable production and consumption, Delft University of Technology, Delft, Netherlands.

[8] Stevels A., (1999), Integration of EcoDesign into Business, A New Challenge, pp.27-32, EcoDesign '99, first International Symposium on Environmentally Conscious Design and Inverse Manufacturing, February 1-3, 1999, Tokyo, Japan

[9] Kvale S. (1997), Den kvalitativa forskningsintervjun, ISBN 91-44-00185-1

[10] Ulrich, K.T. and Eppinger S.D. (2000) Product Design and Development, McGrawl-Hill, New York, ISBN 0-07-229647-X.

[11] Ullman, D., G. (2002). The Mechanical Design Process. New York, USA, McGraw-Hill Higher Education, 0-07-112281-8.

[12] Pahl G., Beitz W., (1996), Engineering Design - a systematic approach, second edition, ISBN 3-540-19917-9, Springer, Berlin

[13] Charter, M and Chick, A. (1997) Welcome to the issue of The journal of Sustainable Product Design, Journal of Sustainable Product Design, vol. 1, pp 5-6

[14] Jakobsen, M. M., Ernzer, M., (2001) How to get sustainable thinking into student's head, ICED, 2001.

[15] Handfield, R., Melnyk, S., Calantone, R., and Curkovic, S. (2001) Integrating Environmental Concerns into the Design Process: The gap between Theory and Practice, IEEE transactions on Engineering Management, vol 48, pp 189-208.

For more information please contact:
Johan Tingström, University of Kalmar, Dept. of Technology
SE – 391 82 Kalmar, Sweden
Tel: Int +46 480 446322 Fax: Int +46 480 446330 E-mail: johan.tingstrom@hik.se
URL: http://www.te.hik.se/

Anne-Marie Åkermark, Royal Institute of Technology, Machine Design
Brinellvägen 83, SE – 100 44 Stockholm, Sweden
Tel: Int +46 8 7909109 Fax: Int +46 8 202287 E-mail: anne@md.kth.se
URL: http://www.md.kth.se/people/mpk/