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Nordic Post-Graduate Sustainable Design and Engineering Research from a Supervisor Perspective

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Abstract

The multi- and interdisciplinary field of sustainable product innovation is rapidly expanding as an arena for scientific research. Universities in Nordic countries can be considered as an exponent of this type of research, with active research groups in, among others, Göteborg, Helsinki, Lund, Lyngby, Linköping and Trondheim. In the context of a Nordforsk funded project, seven second generation PhD supervisors from these universities, who have been active in this field for many years, discuss funding, publication, research traditions, education and supervision practices related to PhD research in this field. A number of recommendations to improve current practices are made, including the mapping currently existing differences in different academic institutions, studying the cross-over learning effects between academia and non-academic partners, and the development of ‘quality indicators’ of research in the SPI domain

Keywords: *Nordic PhD research, research supervision, sustainable product design*

1. Introduction

Sustainable Product Innovation (SPI) is a young but rapidly expanding research field, especially in the areas of environmental product assessment and design for environment. It has evolved from end-of-life focused approaches towards prevention through cleaner production and eco-design. In industry too a number of pro-active companies changed their controlling and complying posture in the direction towards a more preventive and strategic attitudes on environmental issues. The emphasis on environmental issues thereby shifted over the years from a more technical approach towards more organisational aspects of sustainable design.

Whereas in recent years, the balance between ecological and economical considerations have been subject of research, a growing attention for social matters has resulted in this becoming a third component of what is now understood to be design for sustainability. Thus, sustainable product design is product development in which the three aspects of the 'triple bottom line' -- the economical, environmental and societal sides of design (or profit, planet and people) -- are increasingly taken into account.

The first academic scholars that, in the mid 1990s, earned their PhD degrees in this field were often supervised by professors without any academic upbringing in this particular field. Generally, these professors had backgrounds in traditional technical, natural science or social disciplines, in either academia or industry. So, this first generation of PhD students did their research in the context of a variety of disciplines and environments, without the ability to rely on a common research culture, norms, methodologies, a large body of previous research, or even a network. In many ways, research into sustainable product innovation in the period 1992-2002 was of a grounded and explorative nature. Boks and McAloone provide an overview of historical developments in this field [1].

The scholars who earned their PhD degrees in this field five to ten years ago, are today's supervisors of PhD research. These people do have the academic background and network in the field, but are often young and relatively unexperienced in supervising PhD students. Regular courses in scientific research and supervision training may offer tools to develop general PhD research supervision skills, but likely, such skills are to benefit from systematic consideration of experiences from fellow supervisors.

This view is strengthened by the fact that, as Sustainable Product Innovation is still a relatively small field and multidisciplinary by nature as well, academic activities in these fields are often housed in environments that only provide one perspective, such as mechanical engineering, chemical process technology, industrial economics, machine design, product design, industrial ecology, or business management. Therefore PhD candidates as well as their supervisors are often surrounded by only few colleagues (or sometimes none) that face the same academic challenges, like building further on a SPI research tradition, making use of previous departmental research results in SPI, or using similar theoretical frameworks and similar networks.

In the autumn of 2007, the Nordic scientific research funding body Nordforsk provided the necessary funding for an initiative to bring together a number of young, 'second generation' Nordic PhD research supervisors within the SPI field, to share and systematically document their experiences, with the goal of improving PhD supervision quality.

This paper aims to report on their findings, with the main goal of dissemination of experiences and discussion outcomes, to further research within this field, in the Nordic region and beyond. Within the context of education and supervision of PhD candidates in SPI, discussion addresses issues related to multidisciplinary field (e.g. how to define this field), related to scientific publication and research funding, and looking at how Nordic research traditions influence PhD research quality.

It should be noted that most findings are not a result of scientific research, but a result of discussion by a number of professional researchers that each have been active in this field for over ten years, who can as such be regarded as an expert panel. In most cases, there was a high level of agreement about both positive and negative observations, which should contribute to regarding the discussion outcomes as reasonably objective.

2. Establishing the Nordic PhD research supervision collection

In May 2007 the Nordic scientific research body Nordforsk decided to fund a project proposal initiated by a group of 'second generation' PhD research supervisors sharing an interest in sustainable product design, development and commercialisation. All of them are based in one of the four Nordic countries (Norway, Denmark, Sweden and Finland). They felt it was very valuable to bring together such experiences related to PhD research in this field, and supervision thereof, as crossfertilization of research supervision experiences across different academic institutions is essential for research inspiration in general as well as establishing a common ground for practice and understanding. So, these supervisors, all of which are (co-)authors of this paper, formed the so-called PhD Supervision Collective for Sustainable Product Innovation. In this paper, these supervisors are referred to as 'the collective'. Thanks to the Nordforsk funding, the collective was able to meet five times for mostly two day meetings within the period of September 2007 to February 2008. At most meetings, fellow staff members and PhD students were invited to participate in part of the discussions. Also, representatives from industry, a sustainable business consultancy and a government environmental research institute participate in one of the meetings.

3. Contents

Under the umbrella of 'exchanging knowledge and experience' related to PhD research supervision within the field of sustainable product innovation (SPI), in the first stages of the project a discussion agenda evolved, and a number of discussion points were formulated. These are addressed here as follows. Section 4 addresses interdisciplinarity as a crucial aspect of (improving) research quality, and in the context of research supervision in particular. Section 5 addresses Nordic research and supervision traditions. Section 6 discusses the role of environmental academic research in (inter)national research and funding policies. Section 7 addresses the role of environmental academic research in scientific publishing. Section 8 then discusses the role of education and supervision of PhD candidates in SPI. Section 9 concludes this paper with a summary of findings and recommendations.

4 Interdisciplinarity of the field

Bringing scientific disciplines together is increasingly seen as strength of scientific research. This has in particular been noted for the field of sustainable product innovation. The authors of this report themselves work in different departments which all represent disciplines that have a connection to sustainable product innovation: these Environmental Systems Analysis, Product Development, Product Design, Economics and Business Administration, Management and Engineering, Mechanical Engineering, and Industrial Environmental Economics. With so many scientific fields forming the backbone of sustainable product innovations, mapping Nordic SPI research has been an important discussion topic throughout the project with the dominant question being how to map and/or visualise past and present Nordic research into sustainable product innovation. This requires focusing not only on *topics*, but also on research *methodologies* used (case study research, explorative research, descriptive or prescriptive research), *case studies* analysed, and *theories* used (such as innovation theory, institutional theory, organisational learning, entrepreneurship, technology management, or design theory). Apart from it being a means to answer the above question, additional motivation for this exercise lies in defining what is to be regarded as part of our joint field, and what is not.

In the mapping exercise each collective member presented reflective overviews of past and present research activities in or supported by their respective departments. This fuelled, among other things, discussion on how departmental research evolves, and how researchers have extended and elaborated on each others theories and scope. For example, at DTU research started from the theory of technical systems and the theory of dispositions, to, among others, product life thinking, superartefactual environmental problems and augmented product thinking, to including actor- and user thinking, to arrive at the current product service systems research focus. Similarly, at Chalmers University researched started in 1991 based on a packaging study for the Swedish Ministry of Environment, branching out to Life Cycle Methodology, Life Cycle Practice, and Environmental Management of Industrial Systems. Research at IIIIE evolved from a mere focus on improving resource efficiency of manufacturing enterprises through cleaner production (1990s) to focus on product policies (late 1990s), lifecycle management, corporate social responsibility, consumption, product servicing and product service systems. Discussing these developments eventually led to realizing the necessity of formulating relevant dimensions of our field; to understand what elements are parts of it, and to understand what distinguishes it from other scientific disciplines. This resulted in *proposing five dimensions* that together should describe any piece of research within the domain of Sustainable Product Innovation. Each dimension was then further and broken down into three or four levels of different aspects. Without going in much detail because of lack of available space, the basic dimension structure proposed is as follows:

1. Research aim. Here, a general distinction is made into prescriptive and descriptive research. *Descriptive* research usually takes a level of either explanatory research, thick descriptions of societal phenomena, with or without the ambition of theory extension, which can in turn be through for example modelling or hypothesis testing. In contrast, *prescriptive* research is considerably more popular and can take many forms. Distinctions can be made in audience (companies of different size, consumers, and policy makers), types of outcome (management tools, policies, creativity tools, evaluation tools, etc.) and ambition level (ranging from incremental improvement, product innovation, function innovation, to system innovation).
2. Research method. It is suggested that research in SPI usually depends on either 1) field or *case study research*, using various techniques such as questionnaires, experiments, interviews and observations, 2) *literature research*, both on theoretical domains such as organizational theory, institutional theory, actor-network theory, as well as engineering-type literature, 3) *action research*, which is popular in studying industrial innovation processes in real time, and 4) various types of *modelling*, including life cycle modelling and types of economic modelling.
3. Level of analysis. Here, four levels can be distinguished, 1) artefactual (components, products), 2) organizational (institutions, industry sectors, companies, departments, individuals such as designers), 3) technological, and 4) societal, focusing on policy, culture and/or public or private actors.
4. Object of analysis. Here, a number of objects can be distinguished, including processes (management, technical, etc.), phenomena (such as trends or controversies), infrastructures, actors, but also environmental data, policies or product categories.
5. Stage of the product life cycle. Different sub-dimensions can be used to distinguish sublevels, mainly using the product life cycle stages, or by using a developmental focus, distinguishing between fuzzy front analysis, idea and concept generation, detailed design, and commercialization).

Clearly, not all dimensions are unique solely to SPI research area or only the Nordic research traditions. However, each dimension does reflect some elements unique to SPI.

The mapping exercise has been supported by an initial survey of existing PhD dissertations written at Nordic universities, addressing topics related to the sustainable product innovation area. This exercise will be continued, as monitoring where former PhD researchers have ended up professionally will help determine

- to what extent knowledge and expertise is transferred from research institutes to, and adopted by, industry, government bodies and NGOs by the researchers themselves. Do LCA researchers end up doing LCAs? Does a company hiring an environmental specialist benefit from this expertise?
- to what extent PhD students are able to capitalise on their 'time and salary investment' becoming doctors of science. Are their expectations to benefit from their research (education) justified? To what extent does this provide insight for PhD supervisors?

5 The role of environmental academic research in (inter)national research (funding) policies

The collective shared the opinion that research in the area of interdisciplinary environmental sciences (and in particular that of an applied nature) is difficult to find funding for from the traditional academic funding bodies. Although, in many of the research project calls of the latter the importance of interdisciplinarity is stressed, when it comes to a more applied nature of projects, the evaluators find it difficult to classify and evaluate the quality of proposals (including finding the right evaluators). Generally speaking, for many involved stakeholders such as university and funding body officials, it is unclear under what academic umbrella this research area fits. A clear signature, such as 'biomedical research' or 'nanotechnology', is lacking. In most (if not all) cases, departments in which sustainable product innovation research is done, are not recognized as institutions where pure environmental research is done. This situation has a number of consequences:

- It is often unclear under what schemes research funding is available, if available at all.
- More time than average needs to be spent on writing funding proposals with low success rate.
- Applied research in the area of SPI often involves industry that is necessary for practical significance. However, it is often difficult to get funding on a large consortium basis if no partial external funding exists. Also, formal requirements of many national and international funding schemes and programmes (e.g. the EU FP7) complicate the involvement of private stakeholders or make their participation subject to too many bureaucratic obstacles (the latter is not typical for just the SPI area).
- Another significant hindrance in some Nordic countries (e.g. Sweden) is the need to secure funding for PhD students for the entire period of PhD education. However, very often the projects funded by the industry (or public body) are significantly shorter. In addition, the involvement of private sector in research funding schemes may hinder the distribution of research results due to the need of confidentiality agreements.

The collective also expresses criticism on national research funding strategies in relation to what could be a unique selling point in Nordic countries. It may be worthwhile to reconsider research funding strategies. For instance, millions being spent on clean rooms in the Nordic region could be questioned. Some of these funds may be better spent on creative research; i.e. research where creativity towards solving of societal (sustainability) problems is required, and where

interdisciplinary research plays an important role. The authors feel that the incentive to write such funding proposals will significantly increase with a strengthened perception of an increased likelihood of such proposals actually getting funded – a perception that is now weak.

As such, it is suggested that Nordic research funding bodies put out more explicit calls for interdisciplinary, creative research, in all science fields. The current development of research assessment exercises in the Scandinavian countries is already resulting in the creation of research indexes and classifications, intended to be used for research reporting – and in the future for prioritising funding. Highly interdisciplinary in nature, ecodesign is an example of a research field that is very difficult to treat by the use of stringent, discipline-oriented research classifications. Therefore the need is pointed out to consider, support and encourage highly interdisciplinary research fields, rather than categorising them out of range for research funding.

6 The role of environmental academic research in scientific publishing

The previously described situation of a lacking Nordic research “signature”, is found relevant related to scientific publication as well. The conclusions in Baumann’s article on publishing environmental research still maintain validity [2]. Based on two investigations, identifying existing environmental academic journals, and investigating publishing patterns of interdisciplinary research groups and the characteristics of the journals in which they publish, Baumann concludes that potential publication outlets for environmental researchers are not represented in the Science Citation Index (SCI) and the Social Science Citation Index (SSCI) -- both often used as an indicator of academic quality. While there is a certain convergence towards publication of multidisciplinary environmental research in a select number of journals (e.g. Journal of Industrial Ecology, Journal of Cleaner Production and to some extent Environmental Economics, Journal of Life Cycle Assessment), it is insufficient. This situation has negative implications for the evaluation of research careers, research departments, and funding for research projects.

7 The role of Nordic research traditions

The Nordic region is internationally known for having a high potential for innovation. Not only the legislative frameworks, strong technical-material base and the tradition of close cooperation between industry and academia are reasons for this. Nordic research traditions are an important element of it as well. Therefore, it was discussed whether there are any characteristics that can be used to distinguish Nordic research from ‘other’ international research in this field. With several members originating from outside the Nordic countries, it became clear that this is in fact so. In various discussions, the Nordic research was characterised as follows.

- It benefits from ample opportunities to do field research to collect empirical data as a result of the positive attitude in industry towards academic research in this field.
- Nordic research in general displays modesty, both in writing and promoting research, which might lead to less than deserved dissemination of good research results, and less than deserved recognition by potential collaboration partners and potential funding bodies.
- It was noted that the remarks above might also negatively influence exploiting presence at international conferences, which are generally good places for discussion – something that Nordic PhD students might tend to avoid.

The Nordic research tradition also displays a considerable trust in society, and may consequently suffer, to some extent, from a degree of naivety, a lack of ‘scientific’ scepticism and academic

debate. Taking position against the establishment may be contra-cultural in the Nordic context but is often characteristic of what is internationally seen as good scientific research. There is fear of criticising others as this is socially undesirable; it might however be essential for achieving good quality scientific research. Lack of academic debate, avoiding conflicts and too much of a consensus culture might lead to substandard dissertations. The German context, where it is more common to separate between criticism on an individual and on his/her research, was discussed as a good example of the opposite, possibly more productive situation. Then again, it was noted that often there is a correlation between a researcher's personality and work ethics and performance.

Further discussion focused on how this possible situation may have special repercussions in our scientific field. This led to considering that sustainable product innovation research being a relatively new area, may lead to a lesser critical attitude by lack of being able to compare progress with past accomplishments. Secondly, there is an unwanted negative effect for international researchers in Nordic academic environments: they might unjustly perceive lack of criticism as a sign of good quality. Nordic research supervisors may not have the international repertoire of being able to adapt to different cultures when supervising: towards for example African or Asian researchers one *may* need to maintain a more authoritarian attitude than towards fellow Nordic researchers. On a side note, it was also noted that Danish culture might be less sugary and more critical than Swedish and Norwegian culture.

Another aspect of PhD research particularly relevant in our field is the fact that, because of the multi- and interdisciplinarity of the field, the PhD candidates after 1-2 years often have more specialist knowledge than their supervisors. This stimulates the already existent 'equal' relationship between the supervisors and the students, characteristic of Nordic working relations.

The Nordic tradition on how to put a dissertation together was discussed; in particular the issue of chapeau plus appended papers versus writing a monograph. It was noted that in engineering environments, the collection of papers is traditionally most common, but that there are several issues in favour of writing monographs: they may be more suitable for getting across ideas and holistic thinking and will as such better contribute to the development of our academic field. Also, the lack of good, high impact, and appropriate journals (and often-lengthy peer-review processes) often prevents finishing a dissertation binding high quality journal papers together. It was noted that the best strategy is probably to write monographs while at the same time maintaining publishing activities (writing conference and journal contributions) throughout the research – as such publications are more likely to be read, will contribute to the researcher's CV, and often are a source of income for departments.

Apart from many similarities within the Nordic region, also differences were noted that sometimes create obstacles for cooperation and straightforward mutual understanding of academic procedures. First, *differences in academic functions* exist. All countries use different nomenclature for similar academic positions. In Norway, a "*førsteamanuensis*" is generally considered equivalent to the internationally better known position of associate professor. In Sweden, such a person is often referred to as "*docent*", who generally holds a position as "*universitetslektor*", i.e. a university (senior) lecturer who holds a PhD degree. Also in Denmark and Finland, different nomenclature is used. The responsibilities associated with the different functions also differ, which has an impact on PhD research supervision. In Norway, for example, PhD supervision is often done through associate professors although they might not have PhD degrees themselves, which is evidently an unpreferred situation. The collective proposes therefore that research be done to map this situation and to make a research assessment on how

these differences hamper the interaction of staff members across Nordic research institutes. Second, *differences in formal regulations and procedures* exist. Procedures to initiate (PhD) research differ from country to country. The main differences apply to procedural documents and other bureaucratic requirements, also there is a difference who applies (candidate or department), shall the applications be open and advertised or individually targeting, etc.). Also, big differences exist when it comes to funding requirements, which can be on a PhD project level or a department level. Differences also exist in legislation covering the regulations for tuition fees, e.g. in the current Swedish legislative framework the departments are not allowed to earn money from potentially good candidates that could fund themselves (except the status of “*industridoktorand*” in Sweden) while there is a requirement to employ them full time. Some departments are very strict on securing full time coverage and refuse accepting prospective candidates with partial funding. This leads departments to employ “shadow doctoral students”, a person employed on a project basis (not taking the formal PhD position), earning relatively little (e.g. working as an assistant), meanwhile doing PhD research - hoping to get involved in a longer project and being accepted as formal PhD candidate. Another important question is whether a department receives payment for tutoring upfront, or after a successful completion of the dissertation. Payment afterwards may play a positive role, as it provides more incentive to bring a PhD candidate successful to the finish.

Other formal differences exist with respect to examination and defense procedures, requirements for PhD education and courses (as in the amount of compulsory ECTS credits), salaries for PhD students (also relative to those of supervisors), average “clock speeds” for finalising PhD thesis, presence and role of research schools and available ‘standard’ PhD courses, and with respect to procedures for research assessments and visitations.

The collective recommends that existing formalities be reviewed by an independent committee, to assess any potential improvements that could be made to align research efforts among the various Nordic countries. Needless to say, the benefits of such activity would benefit a wider scope of research than just sustainable product innovation.

8 The role of education and supervision of PhD candidates in SPI

The collective extensively discussed the quality of PhD research, both from an education and supervision perspective.

8.1 Supervision

With the overarching goal of discussing improvement of PhD supervision, the collective evaluated the need for the development of systematic field-dedicated courses for PhD supervisors (as opposed to courses for PhD students). A number of positions are worthwhile to mention here. First, courses focusing on general strengthening of general (field-independent) supervision skills already widely available. Second, regarding discipline-oriented supervision skills, the collective feels that there are very few people that could ‘teach’ such skills – after all, that was in fact the rationale for this collective to exist: as second generation supervisors the collective got very little science- or discipline-oriented supervision and education from their 1st generation supervisors. It is considered more meaningful to organise further meetings to discuss our supervision practices, reflecting amongst each other’s experiences. Within such meetings, systematically recurring discussion topics would need to be:

- Interdisciplinarity – how to make PhD students clear how to connect to relevant academic circles, as this may be a challenge in our field, how to select appropriate conferences to

reduce the risk that students become difficult to impress and difficult to challenge by those in their network, and how to give them a sense of belonging to a community.

- A more fundamental discussion about the need for community – the need for formal cohesive networks versus informal ones
- Embedding a PhD candidate's research into a supervisor's own research strategy; if close, over-guiding may become an issue; if not close, lack of interest or expertise may become one.
- Issues of justification changes between generations of PhD students: to what extent needs each generation its own way of justification; building on an increasingly large backlog of research; increasing the need for niche finding, etc.
- The need for new theory versus adding to existing theory (for example, is there a need for new environmental management theory, or do existing theories sufficiently allow for inclusion of environmental issues).

A further idea for cooperation between our institutes to strengthen supervision of PhD students is to develop so-called PhD examiner pools. In these pools, PhD students would – two or three times during their research project -- be requested to report to and discuss with two or three external opponents from a select number of senior researchers that are within the area of SPI, but with expertise in a different area. For example, a researcher in LCA would benefit from occasional semi-formal discussions with a senior researcher in environmental policy or environmental management, whereas a mechanical engineer could benefit from a discussion with an LCA specialist and/or an environmental designer. Establishing and (semi-)formalising an examiner pool with a select number of specialists and systematically applying this concept would contribute to interdisciplinarity, industrial and societal relevance, and overall quality/credibility of a dissertation.

8.2 Education

The collective experiences that demand for multidisciplinary environmental courses on the postgraduate level is higher than the supply. As a result, the possibility of developing appropriate PhD courses was discussed, as considerable interest for these courses is to be expected. On a frequent basis, most collective members receive questions, mostly from PhD students external to their own department or even from abroad, about the possibility to earn postgraduate level ECTS. The success of past European PhD course modules including elements of sustainable product innovation (like the Oikos Summer Academy in Lausanne) provides a clear signal that active interest for such courses exists.

A number of issues have been addressed through discussion to arrive at a list of demands and wishes regarding PhD courses to be developed, which eventually resulted in a new Nordforsk proposal for funding a number of PhD course modules to be organised in 2009. In this proposal, course modules will be taught by multiple teachers to ensure multi-disciplinarity.

9. Conclusion

All participants have experienced this project as a unique opportunity to explore and discuss an important aspect of their daily work, and are very happy with the outcomes, and the initiatives taken for further collaboration between our institutes. It is repeated and stressed here that to advance PhD research in sustainable product innovation, an interdisciplinary research approach is essential. As such there is a need to consider, support and encourage this highly interdisciplinary research field, through more explicit calls, rather than categorising it out of range for research funding.

The collective intends to continue its activities. Envisaged further research will address:

- Mapping currently existing differences in nomenclature and procedures across different academic institutions in the Nordic area (see section 7);
- Mapping where past PhD researchers have ended up, to learn about cross-over learning between academia and industry, government, and NGOs through the expertise of individuals (see section 4);
- A position paper addressing potential ‘quality indicators’ of research in the SPI domain;
- A further look into establishing examiner pools (see section 8.1).

References

- [1] Boks, C., McAloone, T. Successive Transitions in Ecodesign: From the Stopwatch Era to Technology Transfer and Commercialization. Proceedings of the 15th CIRP International Conference on Life Cycle Engineering: Applying Life Cycle Knowledge to Engineering Solutions, 17-19 March 2008, Sydney, Australia, pp. 118-123, ISBN 1 877040 67 3.
- [2] Baumann, H., "Publish and perish? The impact of citation indexing on the development of new fields of environmental research". Journal of Industrial Ecology, vol 6, no 1, pp 13-25