AN APPROACH TO FOSTER INTEGRATIVE SKILLS DURING THE ENGINEERING STUDIES

Lennart Elmquist

Department of Mechanical Engineering, School of Engineering, Jönköping University, Sweden

Glenn Johansson

Department of Industrial Engineering and Management, School of Engineering, Jönköping University, Sweden

ABSTRACT

This paper presents an approach to overcome the drawbacks associated with education programs developed on the basis of domain-specific knowledge only. The approach is based on establishment of means for cross-disciplinary meetings and collaboration between students on Master programs in product development and production management. The approach is intended to help reducing the barriers to integration among individuals possessing different competences that have been reported in the literature. The approach originates from discussions regarding two Master programs at the School of Engineering (JTH), Jönköping University, Sweden. The programs are: Master in Product Development, specialisation in Product Development and Materials Engineering and Production Systems, specialisation in Production Development and Management. Both programs are designed according to the principles of the CDIO initiative. The approach was developed jointly by the two Master program coordinators during a workshop at Stanford University on 'Changing mindsets: Improving creativity and innovation' in December 2010. The workshop was organised by the Swedish program 'Product Innovation Engineering program' (PIEp). The approach emerged during the workshop and was modelled as a physical prototype and discussed with other workshop participants. The result was three courses found to be suitable for joint studies.

KEYWORDS

Master programs, Integrative skills, Cross-program collaboration, Teaching, T-shaped people

INTRODUCTION

The need for integration between product development and production to achieve prosperous innovation has been advocated by both researchers (e.g. [1,2]) and practitioners. The underlying rationale is that integration supports individuals that represent different organisational units, and thus competencies, to collectively engage in problem solving during product development [3,4]. However, integration is not easily achieved. Research has revealed various barriers that might inhibit integration. These barriers include personality, cultural, language, organizational and physical differences [2,5].

Despite the convincing arguments in literature and the claims from industry that integration skills are vital, the education system poorly reflects the need of such skills among engineers. Engineering education programs are often constructed on the basis of domain-specific knowledge. Less efforts are devoted to allow cross-domain insights among the students. Consequently, the engineering students do not possess the necessary highly valued integrative skills that seem to be one of the factors leading to competitive advantage in industry.

As an example, engineering students on product development programs and production management programs seldom meet each other during their studies. Even more seldom, or in many cases never, they interact in courses or other program activities. In this paper an approach to overcome this insufficiency of current engineering curriculum is suggested. The idea behind the approach is to ensure that product development students and production management students meet and collaborate during their time at the university. This is believed to increase mutual understanding of each others' competences and therefore it might reduce the barriers to collaboration when they become practising engineers c.f. [2,6,7].

The paper is structured as follows. First, the structure and contents of the two master programs are briefly outlined. This is followed by a short description of the purpose and methodological considerations. Thereafter the approach is introduced, followed by a discussion about T-shaped engineers. The paper ends with some conclusions and discussion.

STRUCTURE AND CONTENTS OF CURRENT MASTER PROGRAMS

This section gives an overview of the master programs in Product Development, specialisation in Product Development and Materials Engineering and Production Systems, specialisation in Production Development and Management, respectively. Both programs are supported by a steering group with representatives from various industrial branches reporting about the industrial needs. In common for both programs is that all teaching is given in English, and the students come from many different nationalities and cultures. In order to overcome some of the potential barriers described above, students from both programs are given a short introduction in multi-cultural competence. The aim is to train the students in the basics of intercultural communication.

Product development, specialisation in Product development and materials engineering

As competition between companies gets tougher and the number of products on the market increases, many come to realise the importance of product development and materials knowledge as competitive means. The program aims to develop the knowledge and skills that are needed to develop and design advanced products with the use of modern information technology regarding knowledge-management and modeling. It also aims to develop knowledge in applied mechanics, modeling, and simulation in order to optimize product function and performance, material selection, and manufacturing processes. This includes a deeper knowledge concerning technical materials and how they are manufactured, their structural design, properties, and how they can be used in products.

The program plan and its progression is shown in Figure 1. This structure is based on the three research areas Materials and manufacturing, Computer supported engineering design, and Simulation and optimization. Courses related to each of these areas respectively are given parallel through the program, with increasing degree of difficulty.

The use of computer based methods and simulation tools are extensive in most of the courses, and the program gives an understanding of the theory behind and the practical use of these computer based tools. In most of the courses the students have the opportunity to work in projects.

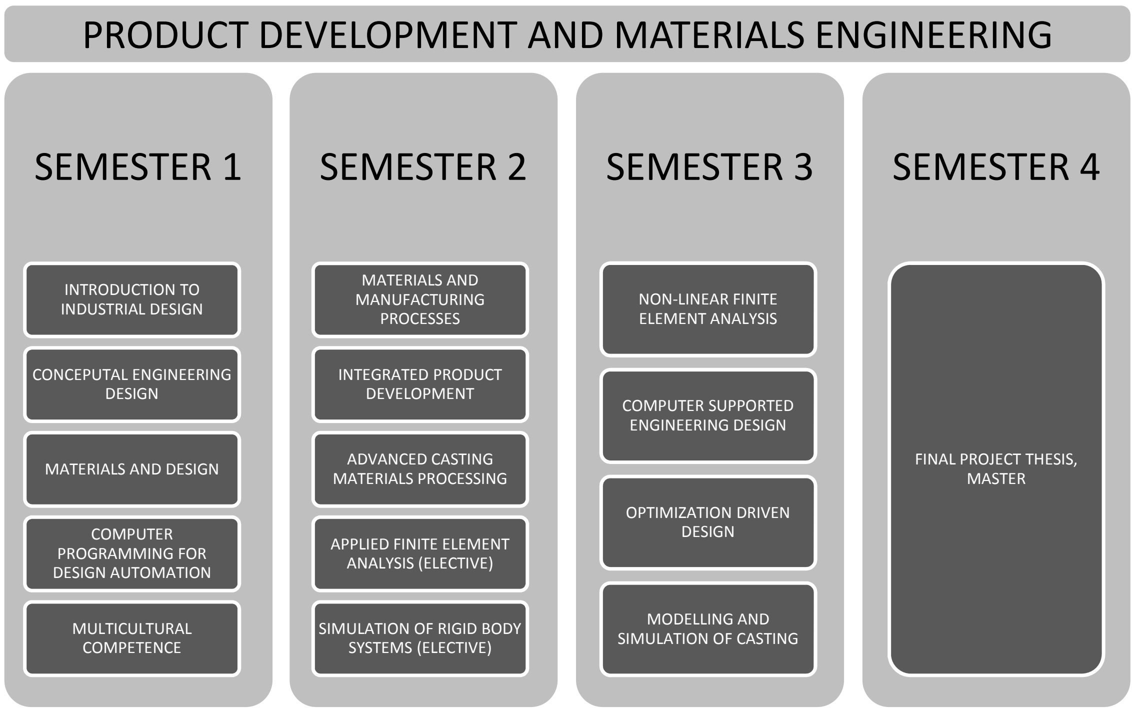

Figure 1. Current program plan for Product development and materials engineering.

Production systems, specialisation in Production development and management

The Master program in Production Systems, specialisation in Production Development and Management aims at contributing knowledge and overall understanding about industrial production systems and competitive production. The program develops the knowledge and skills that are needed to organize and manage the design, implementation, start-up, operation, further development and maintenance of industrial production systems.

The program structure is illustrated in Figure 2. The program starts with a few courses that provide the students with a common starting point for the following profile courses which address industrial production from two perspectives: development and operation of production systems. The development perspective focuses on the design and development of the production system as well as the possibilities and limitations that are related to the design of products and the supply network. The operation perspective focuses on how materials and information should be planed, monitored and transferred within as well as to and from the production system. The operation perspective also focuses on how the production is organized to achieve efficient and effective production. Moreover, the interaction between technology and humans in the system is addressed.

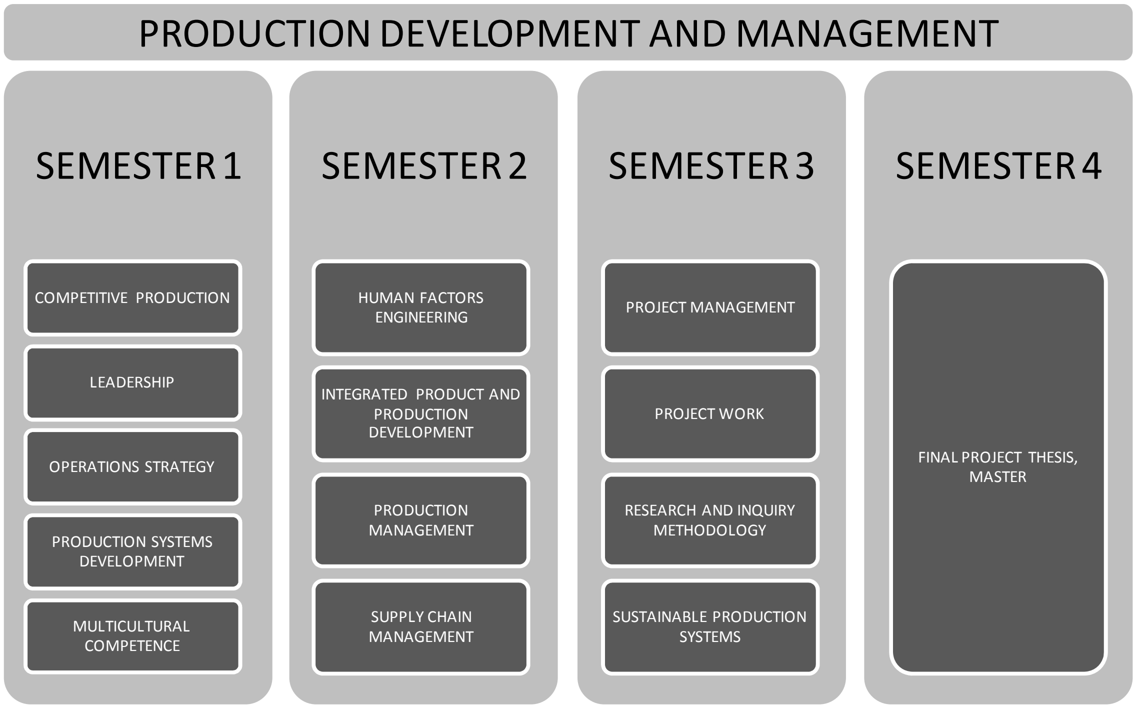

Figure 2. Current program plan for Production development and management.

PURPOSE

The purpose of this paper is to present possible cross-disciplinary activities between the Master programs in product development and production systems, in order to foster integrative skills among the engineering students during the studies. Today, there is no interaction at all between students at the programs, and identification of any possible joint courses or other activities will lead to increased co-operation. Ultimately, this will result in students that are more attractive to industry because they are better prepared to meet the industrial needs.

METODOLOGICAL CONSIDERATIONS

The approach presented in this paper was developed during a workshop on ‘Changing mindsets: Improving creativity and innovation’ in December 2010. The underlying idea of the workshop was the need of continuous upgrades and revisions to existing curricula’s and faculties’ pedagogical methods and processes. The workshop was organised by the Swedish program Product Innovation Engineering program (PIEp, that is financially supported by VINNOVA – the Swedish Governmental Agency for Innovation Systems). The workshop was hosted by Stanford University, which was chosen because it is a place where creativity and innovation is indigenous to the campus culture. As the workshop focused upon various issues related to creativity and innovativeness, the idea was to inspire changes to the engineering curricula that the participants were responsible for.

The participants at the workshop had various teaching and education responsibilities within their organisations and represented different Swedish universities, including the Royal Institute of Technology, Lund University, and Jönköping University. A majority of the participants were responsible for different bachelor/master programs or specific courses.

Two of the participants were the program coordinators of the master programmes outlined above.

During the workshop we jointly and critically reviewed the two master programs to identify potentials for increasing the integrative skills among the engineering students in both programs. Essentially, the goal was to find courses within which students from each program could be engaged in collective activities or to develop one or a few courses that would be included in both programs. As one of the issues addressed during the workshop concerned prototyping and all participants were given the task to model a change in their program or course as a physical prototype, we aimed at developing a physical prototype illustrating how the programs could be modified to enhance the student's cross-disciplinary knowledge. The approach presented next in this paper thus emerged as a result of this joint program review and physical prototyping of suggested changes.

AN APPROACH TO FOSTER INTEGRATIVE SKILLS AMONG ENGINEERING STUDENTS

The result from the workshop, and the resulting prototype, is shown in Figure 3. This picture illustrates the physical prototype which was the outcome from the prototyping activity during the workshop. The prototype illustrates the key challenges and core aspects of the approach to foster integrative skills among the students of the master programs.

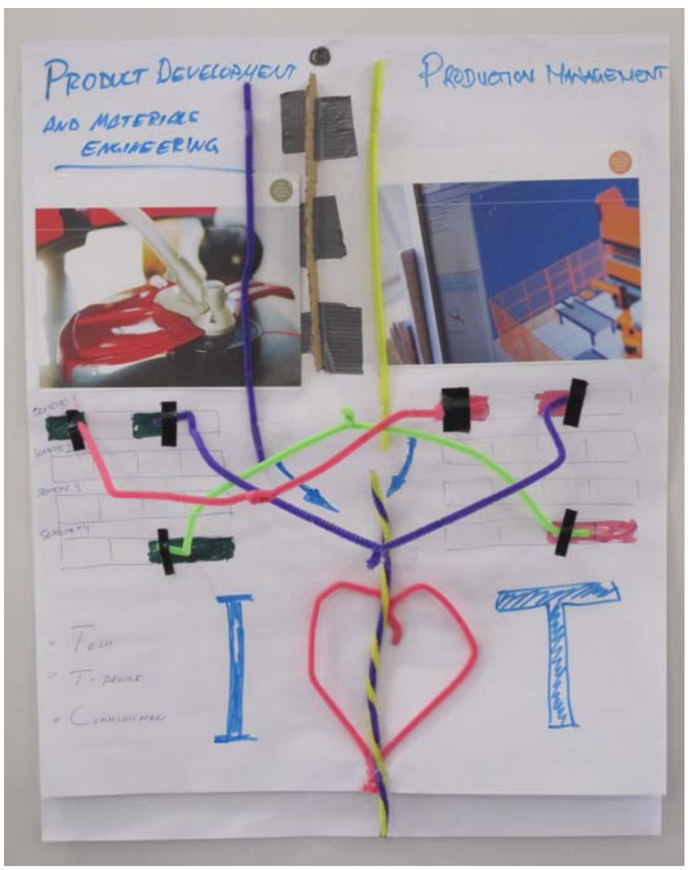

Figure 3. Prototype made during the workshop.

On top of the prototype, the programs are separated by a “wall”. This “wall” illustrates that there is no interaction at all between the programs and their students today. Students that belong to each program respectively are symbolized with different colours, purple sticks represent students from product development and yellow sticks represent students from production systems.

On the next level, the program plans are shown, and courses found suitable for joint studies are connected with wires. This level describes what can be done to increase the integrative skills, it is also illustrated without the “wall”, showing that now there is an interaction between the programs. Figure 4 is a simplification of the most important results from the workshop and prototype and shows the courses identified for joint studies.

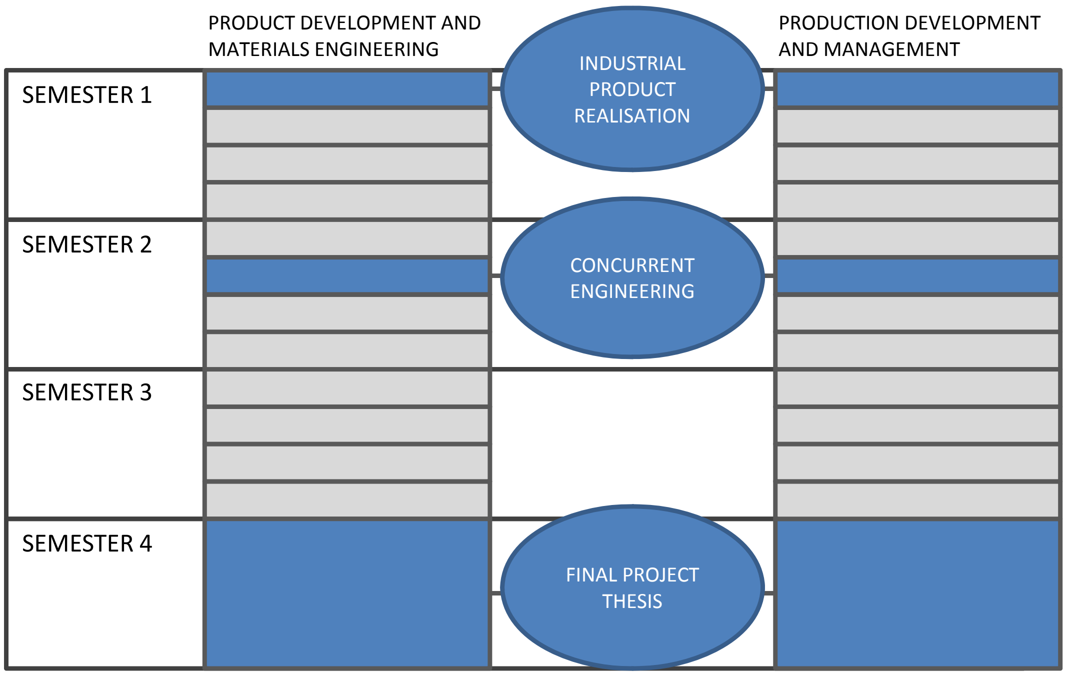

Figure 4. Three possible joint classes were found.

The first suitable cross-disciplinary activity was identified already in the first segment, the introductory courses. In both cases, the program starts with an introductory course. In the master program in Product Development, specialisation in Product Development and Materials Engineering, the first course is Introduction to industrial design. The program in Production Systems, specialisation in Production Development and Management, starts with a course in Competitive production. During the workshop it was realized that these two courses could be replaced by a common introductory course, where students from both programs jointly study the course. This new course was suggested to be entitled Industrial product realisation, and cover both product development and production-related issues from an industrial perspective. There are at least two reasons for this joint course. First, it provides an opportunity for the students to get to know each other and thus develop personal relationships supporting future collaboration, and this is encouraged already from the beginning when the programs start. Second, it gives the students a common platform of background knowledge for their continuing studies. This common platform makes it easier for collaboration in later courses, and also when the students become practising engineers. It is suggested that this introductory course contains projects where students from respective program work together.

As this is an introductory course, the projects will be of a more general kind, covering aspects related to Industrial product realisation in general. The projects will be individual putting higher demands on the supervision. However, as this course is intended to be given by several lecturers coming from different disciplines, supervision will be shared among the teachers. The number of students in each project team depends on the number of students following the course, but approximately four students, ideally two from each program. The projects will, as far as possible, be performed together with the industry and based on a relevant industrial problem.

The next opportunity found suitable for joint studies was in segment three, year one. Today, students on the master program in Product development have a course about Integrated product development. The aim of this course is "...*to give the students knowledge and an understanding of how a product's design is affected by, and has effects on, important aspects related to different interested parties and life-cycle phases. The course will present different approaches to support integrated product development. The integration of design and production is specially emphasized.*" At the same time, students on the master program in Production systems study the course Integrated product and production development. This course "...*aims at providing the students with knowledge regarding how activities carried out and decisions taken during product development affects the possibilities to achieve efficient and effective production.*"

As the goals and contents of the two courses to some degree overlap, it was realised that the courses could be combined into one course only, with the suggested name Concurrent engineering. The course will specifically focus on aspects related to concurrent development of products and production systems as well as the need for co-ordination and collaboration between product development engineers and production management engineers. Also in this course the engineering students from both programs work in a collaborative setting on a project task which illustrates the complexity and interdependencies that exist between product development and production. In these projects there will be an increased focus on teams and problems based on the different competencies, and also the degree of industrial participation will be higher.

In both programs, the studies end with a final thesis project. This was identified as a third possibility for joint activities. The goal is to set up thesis projects with one student from each of the programs. Each student is supposed to work with questions related to their specialisation and field of knowledge, but they should do so together in the same project. This also means that each student is examined separately, and on the same basis as if the whole thesis project was strictly limited to the individual disciplines. The supervision will also be shared between the competences. All of these projects will be based on a relevant industrial problem, and therefore in all cases involve companies. Among the advantages is the possibility to gain experience about cross-disciplinary work, but also the possibility to arrange more extensive projects, which might be more attractive for industry because the projects can address highly relevant problems that companies face.

All these three activities, or joint studies identified, have one common advantage, nothing else need to be changed in any of the two schedules. This will make it much easier to implement the changes. These activities also serve as a means of encouraging the students to work together interdisciplinary.

The bottom part of the prototype shown in Figure 3, or bottom level, mainly describes the expected outcome from the cross-disciplinary studies and joint activities. On this level, the coloured sticks, representing the students, are twisted together, symbolising the interaction and collaboration between them. These students, with cross-disciplinary skills, are now better prepared for work in teams with people from different disciplines. They will also be better in communication between the different disciplines.

Finally, as the prototype shows, the result will lead to more T-shaped people (described in the next section of this paper), symbolised by **I** love T.

T-SHAPED PEOPLE

T-shaped people, or people with T-shaped skills, are professionals with interdisciplinary capability e.g. [8,9]. These people will still have the same depth of knowledge as **I**-shaped people, but in combination with the broader communicating capability and understanding for other disciplines, they can collaborate and solve problems across the disciplines. They are actually more willing to collaborate, innovative, and more adaptable to any situation. These qualities are important in many situations, e.g. in problem solving, brain-storming, and needed to build a creative environment. They have the ability to shape their knowledge to fit the different situations. The T is described in Figure 5, where the vertical stroke illustrates the deep knowledge and the horizontal stroke describes the interdisciplinary skill.

The cross-disciplinary activities outlined in the approach presented in this paper will lead to an education where the students are fostered to become T-shaped people. The students from the programs described above will become more like T-shaped professionals, and be better prepared for the newer demands from the industry. Collaboration across the programs during the education provides a means of getting used to discuss and work across disciplines. These students are more likely to establish a good understanding for each other making it easier for them to solve problems together. However, it is important that the disciplinary depth and skill still are there, without the deep knowledge, the broader part of the T does not mean anything. It is the combination of the depth and breadth that is the success.

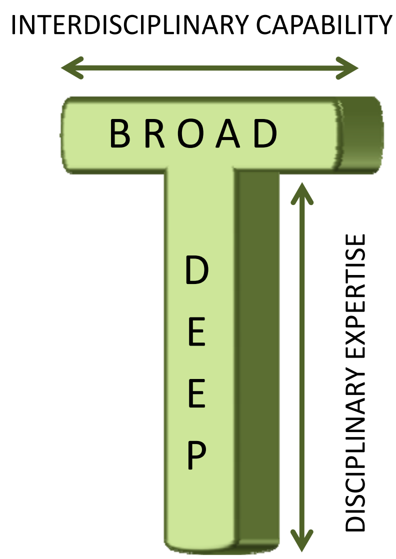

Figure 5. T-shaped people, disciplinary expertise in combination with interdisciplinary capability.

There is a need to develop a more T-shaped education. The higher education of today provides a good quality with regard to the vertical stroke in the T. However, there is deficiency when looking on the horizontal, interdisciplinary, stroke [9]. One way to bridge this gap and develop a more T-shaped education is the cross-disciplinary activities described in this paper.

CONCLUSIONS AND DISCUSSION

This paper has presented an approach to foster integrative skills among engineering students. More specifically, the approach aims at overcoming potential barriers to collaboration between product development engineers and production management engineers, c.f. [2]. The core of the approach is that the engineering students should meet and collaborate in a number of activities during their studies. Implementing such activities, in terms of joint courses, in the master programs will result in T-shaped people that are more open-minded for others' competences and better prepared to engage in collaboration. This prepares the students for the needs of industry and thus for a prosperous career as engineers.
Within the product development field prototyping is defined as *"an approximation of the product along one of more dimensions of interest"* [10]. Physical prototypes are tangible artefacts used for learning, communication, integration, or as milestones (ibid.). As was mentioned above, the workshop participants were given the assignment to model changes to their programs or courses as physical prototypes. The underlying reason was to stimulate creativity and to communicate the changes made in an unusual way. Normally, changes to curricula are presented in written texts or perhaps as illustrations. Rarely are physical prototypes used. The development of physical prototypes clearly helped to induce creativity among the participants. Our experience is that the prototyping activity assisted to generate a clear focus of the discussion on which changes should be introduced to the programs and how these changes should be communicated in an unambiguous way.

Referring to Ulrich and Eppinger's [10] argument as why prototypes are used, the prototyping activity became a learning tool for when the approach was developed. As we are responsible for one Master program each, we needed to get good insights into the other's program. This was a necessary first step to be able to discuss potential changes that could be made to the programs to increase the cross-disciplinary contents. So when we started to develop the prototype it facilitated the learning from each other about the two Master programs, respectively. The prototype also became a tool for integration, which was at the core of our ambition during the workshop. That is, we strived to find ways to increase the cross-disciplinary knowledge among our master students and by using the prototyping activity it helped us in the search for such ways. The development of physical prototypes induced a number of iterations where different solutions were modelled and compared. This leads ultimately to the approach presented in this paper. Perhaps the most valuable use of the prototype was its ability to support communication. One of the strengths of physical prototypes is that they contribute to enriched communication. Tangible and visual representations are fairly easy to understand compared to verbal descriptions or sketches. This turned out to be true when we presented our ideas for program changes to the other workshop participants.

A key criterion that contributes to the quality of a Master program is how it is embedded in or supported by a dynamic research environment. That is, a program that has close links to extant research and active researchers provides the students with up-to-date knowledge. At the JTH the overall research focus is 'Industrial product realisation, especially applications for small- and medium sized enterprises'. The research focus of JTH includes four research areas: Product development, Industrial production, Materials and manufacturing, and Information engineering. Each of the four research areas provide the students with domain-specific knowledge. However, industrial product realisation is cross-disciplinary *per se* as it involves all activities from idea to finished product. As has been argued earlier in this paper, well-functioning engineers need also to have cross-disciplinary knowledge. The inclusion of a course in each of the two Master programs on Industrial product realisation thus provides the students within both programs with such knowledge. Moreover, it may also facilitate recruitment of students who want to continue their carrier within academia.

The course gives the student a possibility to understand what Industrial product realisation is and how their domain-specific knowledge relates to other types of knowledge fields. By giving the students chances to collaborate with others that have complementary knowledge during their education open up possibilities for cross-disciplinary research. Those students that continue with postgraduate studies might then be able to pose research questions that do not only remain within their specific field of knowledge. It is believed that they will be more motivated and capable of working together with other researchers outside their own domain.

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Biographical Information

Lennart Elmquist is Assistant professor in Materials and Manufacturing at the School of Engineering, Jönköping University, Sweden. He is program coordinator of the Master program in Product Development, specialisation in Product Development and Materials Engineering. He is teaching in courses about Materials and manufacturing, and is coordinator for courses on both bachelor and master level, but also for a course to the industry. His research is about casting, especially cast iron. The focus is on solidification and defect formation and how the solidification affects the properties of a component.

Glenn Johansson is Associate professor in Technology Management and Economics at the School of Engineering, Jönköping University, Sweden. He is research leader of the research area Industrial Production and program coordinator of the Master program in Production Systems, specialisation in Production Development and Management. He is also node leader of PIEp at Jönköping University. His research interests include areas such as innovation management, design-manufacturing integration, and sustainable product development and manufacturing. Recent publications have appeared in *Management Research Review*, *International Journal of Production Research*, and *Journal of Cleaner Production*.

Corresponding author

Lennart Elmquist
Dept. of Mechanical Engineering
School of Engineering, Jönköping University
P.O. Box 1026
SE-551 11 Sweden

lennart.elmquist@jth.hj.se