THE ABILITY TO DEVELOP INNOVATIVE PRODUCTS AS A RELEVANT COMPETENCE FOR ENGINEERING STUDENTS.

R.M. Bakker, H.G.M. Geraedts, P.A.M. van Kollenburg


(HGM.Geraedts@Fontys.nl; R.Bakker@Fontys.nl; P.vanKollenburg@Fontys.nl)

Abstract

Innovation seems to be the most important element of activities of companies to stay vital in a very competitive international market. Innovation is the process of developing products or services in an organisation for a market. Especially small and medium-sized companies, for which it is difficult to invest in innovation research and development, need to be provided with young professionals to help them make the right decisions on innovation development. At the moment higher professional education in the Netherlands is not preparing students enough as future professionals in SMEs, for the task of initiating and to developing innovations in these SME’s. Therefore it is needed that higher professional education comprehensively implement these innovation competences in its curriculum. At the Fontys University of Applied Sciences in Eindhoven, the Netherlands, innovation has become an important element in teaching students innovation competences. In 2007/8 a pilot has been introduced the department of Engineering with first year students in a multidisciplinary and action-based setting. First year students of Mechanical and Electrical Engineering in a 5-credit programme try to find new patentable products. The outcome of this first try-out was that students realized the importance of innovation for the profession and they were eager to work in this innovative setting. Some adjustments in the education will be made as there are: timetable and project settings to timetables and schedules will have to be made.

Keywords: Product innovation, action-based education, patents, competences, SME’s.

1. INTRODUCTION

It is important for each company to know: “Will I sell my products to customers in the future?” All the present activities have effects on the profit and loss account of the company in the future. The development of a new product that matches the needs of customers in the future is essential for companies to stay alive. This process to achieve a healthy future business can be called innovation. In SMEs this innovative process is not regularly carried out. Innovation is not something that spontaneously will emerge from the ongoing activities of a company and therefore companies need to invest in their capabilities for innovation. The employees of a company are a most relevant factor for developing innovation. As innovation is a multidisciplinary and complex process it is reasonable to state that higher educated employees in a company will play an important role in it. As causal consequences of this, curricula in higher

---

1 SME: Small and Medium sized enterprises are companies up to 250 employees. Above 250 employees is called a big company
education have to pay attention to competences relevant to becoming professionals intrapreneurs (entrepreneurs within the company) within SMEs. These employees are Key Persons for a company in developing innovations. They are able to foresee possible innovative projects for developing products or processes for the market. Furthermore they can accurately point out to which extent the company is able to carry out innovation projects. The topic of this research paper is to find out how to educate innovative engineers. How to implement product innovation courses already for first year students of Engineering to prepare them for the innovative role as professional practitioners in their future job.

In our curricula, students will be educated to develop relevant theoretical and practical skills through courses and practical projects. Every discipline has specific elements to be learned by students in the process of becoming professional. Some specific elements need to be constructed during several years to develop certain higher qualities. These chains of courses directed to certain discipline-oriented issues can be called ‘learning-trajectories’ along which students learn during their studies to become professional practitioners concerning important discipline-relevant issues. Innovation development should also be seen as one of the important and relevant learning-trajectory for technical students. In the first year of this innovation learning-trajectories students are provided with basic knowledge to understand the complexity and diversity of the topic and actions to be taken to develop a product innovation. It is also important for technical students to realize that in addition to product innovation other elements of innovation need to be taken into account, for example how to realize the production process, how to organize the process in the company, and how to investigate the market for that new product. For Fontys University of Applied Sciences, Engineering students (both Mechanical and Electrical Engineering) are working together multidisciplinarily in a first year project called ‘The Invention’. In this project students need to come up with an invention on a specific topic. They first need to search for good ideas. They start with the customers’ point of view, go further in developing good concepts, compare them with patents already available in a patent data, and develop their idea further towards a prototype.

Graduates in the Netherlands very often find their jobs in SMEs. SMEs are an important key player in the economy of the Netherlands and innovation is an important key activity in SMEs in order to stay attractive for customers in the future. In: The need for higher educated employees in SMEs (Boorsma & de Vries, 2004) research in five branches was done in the Netherlands: retail trade, process installation, brokers, metalwork and technology. Concerning the relevance of teaching higher education students, they gave three important conclusions. 1. In SMEs the need for higher educated employees will grow, 2. These higher educated employees are needed because strategic goals, amongst which innovation and product development, are important to be developed and 3. SMEs do need these higher educated employees as necessary conditions for future existence and industrial growth.

In the research report for EIM (De Jong, 2006) gave an overview of the importance of product innovation in relation to technological SMEs. Whereas it is important all the SMEs develop innovation projects, particularly for technological SMEs it is important to develop product innovation. SMEs translate new developments of knowledge into realisation of this new knowledge in their new products and processes. It seems according to (De Jong, 2006) these technological companies are more organised in their strategic thinking about the future. In figure 1 the most important items in

---

Figure 1 Important strategical statements of SMEs in the Netherlands in 2005.
strategical goals are documented. This shows that nowadays-technological companies, in formulating their company goals, are more focussing on the (strategic) future than on the daily job.

The branch organisation of SMEs of the Netherlands pointed out in their annual report in 2007 (MKB, 2007) the need for investments in innovation. They further pointed out that it is of importance that developed knowledge will better find its way to the companies. In this report you may find a summary of the importance of the total of the SMEs against the importance of the total of the big companies. Figure 2 shows this comparison. From this matrix it is very clear that in the economic participation of the Netherlands SMEs represent an important part of the total turnover in the Netherlands.

The information given in the 3 reports is consistent regarding the proposition that it is important for SMEs to develop innovation processes. In addition to government, SME branch organisations and also research institutes see the importance of stimulating SMEs to invest in innovations. Furthermore it is clear that all the above mentioned parties also see the importance in participation of higher education in these companies and a form of participation of the companies in higher education. This will, on the one hand, create a form of valorisation of developed knowledge of universities regarding the companies, and the other way around, brings real time conditions to education with which students can be taught better how to act professionally in companies. This two-way advantage is the basis of the knowledge trajectories for innovation in the Fontys University of Applied Sciences, department of Engineering, to be designed and analysed in this research for the first year students. In the first year we provide students with a concept of innovation building so they learn to understand that innovation is more than having a good idea. In the second year students can choose an
optional 30 credit-course to develop capacities on initiating innovations in a company. In this later programme technical students work more interdisciplinarily with students coming from economic departments, for example.

2 IMPORTANT ELEMENTS OF EDUCATION OF INNOVATION FOR ENGINEERS

In most educational systems curricula are organized in a way that knowledge is split into rather rigid compartments without links and interdependences. The result is that young engineers are not able to integrate their experiences, a capability that is fundamental for innovation (Cascini et al, 2008). In order to accomplish innovative assignments engineers have to fulfill different types of roles:

*The engineer as problem-solver*

In general students work on authentic problems with social relevance. Working on these projects needs integration of different technical courses. In this way the (first year) student understands and practice the applicability of the “abstract” theories. Using a clear timeline with intermediate deadlines, utilizing specific “content” roles makes the project more transparent. According to the objectives of the project “The Invention” (innovative design assignments) the problem is formulated as open a manner as possible in order to stimulate the entrepreneurship of the future engineers.

*The engineer as entrepreneur (or intrapreneur)*

A good entrepreneur takes initiative, can be a leader, can work in teams, communicates and is flexible, plans and organizes the tasks and takes the economic aspects into account (Heylen et all, 2007). These skills are trained through project-based learning. To practice these skills even more, student from different disciplines work together on the same project.

*The engineer as creator*

On the other hand innovators in companies need, in the first place, to be creative. This is a mental process involving the generation of new ideas or concepts, or new associations between existing ideas or concepts. But innovation is more: it is the process of both generating and applying such creative ideas in some specific context. In industry creative ideas that are worthwhile to invest in need to be protected against competitors. A patent protects these ideas. A patent search is done to determine if an invention is truly a new idea or if it has already been patented.

In such a context the education of the engineers is crucial for enhancing technical creativity and innovation capabilities, since they can constitute the cheapest way to introduce new products in the market. An engineer of this kind will be able to perform activities to support innovation, problem solving and technological forecasting in different industrial contexts.

*Designer/innovators attitude*

To look at the design/innovation process in a more abstract way (Horváth, 2006) synthesizes five different generic design capacities: capability, knowledge, skill, experience and attitude (Horváth, 2006). When we focus on attitude we can state that “good attitude” is of importance for all professions. Attitudes influence the way of thinking, acting and seeing concerning the design/innovation tasks. For creative and intuitive professions, like the designer/innovator, a good attitude is of extra importance. (Bakarman, 2005) gives the following summary of designers’ attitudes that have to be addressed:

- Professional behavior in dealing with and handling the design problem.
- Dedication and motivation to be a professional designer.
• Constant acquisition and management of knowledge.
• Teamwork and the ability to run the task smoothly.
• Applying good time management.
• Feeling responsible for the outcomes.

Design/innovation problems are often complex problems and there is no single answer to them. The first solution found might not be the best solution possible. Developing more than one solution gives insight into the design problem. A designer in a multidisciplinary team must be open to other perspectives, visions, ideas, knowledge and skills of the other team members: an open mindset attitude is needed to fully use all capacities within a multidisciplinary team.

So summarizing this project-based educational program should provide to young engineers following orientating-level competences:

• Capacity to create new innovative products or services
• Knowledge of the disciplines necessary to solve a problem in a multidisciplinary approach;
• Capacity to abstract the problem, to identify analogies and different application fields;
• Basic knowledge of project and team management;
• Basic knowledge of Intellectual Property
• Knowledge of marketing as an element of planning strategies for innovation.

3. RESULTS OF INQUIRY INTO STUDENTS OPINION OF RELEVANCY OF INNOVATION INCORPORATED IN EDUCATION

First one has to focus on initial conditions within education of this ‘learning trajectory. The elements of the competence ‘innovation’ are organizing innovation processes and initiating product creation. It is important to create action-based learning conditions where students can experience developing innovation elements in a project. Next to the knowledge building elements in the curriculum an innovation project: ‘Invent your invention.’ has been set up. Here companies are involved to advise students in their attempt to invent a new product. A patent bureau is involved to help students to find new products. Winning a prize is implemented in the project as a motivator and as an element of competition for the student groups.

This new education was built upon the experiences of a likewise, but monodisciplinary, innovation education in earlier years. The basic condition of this older education was typically monodisciplinary and it turned out to have a too tight schedule for students to manage the project goals.

In autumn 2007 Fontys University of Applied Sciences restructured the curriculum of the Engineering Department. Main goal was to streamline the courses and create the possibility for Mechanical and Electrical engineering students to work together. The first year consists of roughly one-third of the time available for theoretical courses based on the chosen course (Mechanical or Electrical Engineering). One-third of the time students work together in generic fields (mathematics, modelling, integrative design tools, languages, etc) and one third is used for project work. In total we have 180 first year Engineering students and from these 70 students have chosen the
Electrical engineering course and 110 have chosen the mechanical engineering courses.

As part of the curriculum in the first year an integrative design tools modules is implemented. In the curriculum a mix of technical items and more managerial items are implemented so students are more prepared for a job as higher educated engineer in SMEs. Unfortunately technologically oriented students are not so motivated to work on managerial competences. The SMEs however indicate this as an omission: when working in a company everybody and all activities are focussed on turnover and profit and especially survival of the company. For engineers it should be quite obvious to work with these business-related strategies as a natural part of their job. This is important for SMEs, but also for entrepreneurs and even for large companies, where engineers often are the key persons to successful operations. So that is why the engineering department wants students to work already in their first year to learn to focus on the business side of a technical company. Topics related to this are amongst others: target groups, customer needs, requirements, target cost pricing, chain value, turnover and profit, product lifecycle.

In the second semester of the first year we focus on innovation. In the first semester we focussed on how business successes may be reached, and in the second semester we focus on how to run the rat race of being first on the market, in other words, how to be innovative. First year students come from middle technical schools or from secondary education. In this primary technical education students are very directed what to do. This is contrary to the type of education in undergraduate studies, where students need to take actions of their own to end up with good results. In respect to this matter first year students in bachelor education are more guided during their education. So in the course ‘The invention’ students will be provided with relevant knowledge and accompanying project to help them to use the right order of sequence of activities to end up with a good invention. The following steps are used:

1. Identify customer needs
2. Establish target specifications
3. Generate and select product concepts
4. Design the product according to the standards
5. Prepare a product prototype
6. Make the prototype
7. Present the prototype at a innovation exhibition

The theory, the students will be taught in order to do the project well, is:

1. Scope of product creation and processes in the context of a company
2. Important elements during concept generation
3. Doing patent research
4. Getting an overview of costs of development and return on investment for a company.

With the theory building and the corresponding project students get more acquainted with the important elements of product innovation in real companies and therefore learn as a first step what the subsequent steps are in the process of product innovation.
In a questionnaire we have asked the opinion of engineering students on experiencing the innovation course and their view on the importance of innovation in the industrial society. In spring of 2008 147 students were working in the innovative project. 70 students responded to the questionnaire/survey.

In the Fontys Engineering department students indicated already in the first year their ambitions. Which field of engineering attracts them as their ‘dream’ profession. Figure 3 shows that 54% of the students want to be a product developer. Add to that the students who do want to work in the research area (12% of the first year engineering students) and it turned out that two-third of all engineering students want to work in R&D. The other one-third of the students want to work in more generic engineering fields, as there are Human Engineering (Commercial engineering) 7%, Industrial Engineering 10%, and Service and Maintenance engineers 4%, or students who haven’t made up their mind yet 13%.

![Figure 3, expected field of working of first year engineering students 2008](image)

It is clear that two-thirds of the engineering students do want to work in a product development environment or in a research area where they can work on integration of new technologies into new products. There is no significant distinction in the figures for Mechanical Engineers or the Electrical Engineers. Their view of the future is more or less the same. So the creative part of engineering will be an important part of the job of these engineers who really are eager to work on new product development.

Innovation in the curriculum is very important for them. That is what the students also indicate in the questionnaire on the opinion of students of the importance of innovation for the industry:

<table>
<thead>
<tr>
<th>Innovation is of huge importance for an engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondents</td>
</tr>
<tr>
<td>Average</td>
</tr>
</tbody>
</table>

Page: 7
On the statement “Innovation is of huge importance for an engineer” we found a very high score of 3.9 on a scale of zero to five. Students indicate the importance they see for innovation and their later work. In the questionnaire they also could indicate their personal thoughts about the statement. For above statement the following additional particular comments were made: “Being the best is an excellent motivator.” and “Innovation is fun and important for my future.” The latter individual statement is also a common view as indicated by the next inquiry statements. Engineering students have been asked on their view of the relation between innovation and the competition for companies’ competitive strengths needed to survive.

**The Dutch economy will only survive when SMEs are strong in innovation and they can compete with foreign companies.**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>67</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StdDev</td>
<td>0.86</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**In future innovation will turn out as the most valuable criteria for companies as a guarantee to survive.**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>66</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StdDev</td>
<td>0.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A high average score has been found on the importance of innovation for companies as a view of the first year students. They are really aware of the engineering work and the change in Europe from cost effective, lean production towards innovative first on the market designs and developments.

**I don’t have to be educated in innovation because I think it is not important for my profession in future.**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>66</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StdDev</td>
<td>1.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Most of the students indicate and see the importance of being educated in innovation. With a low average of 2.5 there is a high standard deviation found of 1.09 showing that there are also students disliking innovation as a course. This could be as a result of little things that went wrong in this course which was being given for the first time or students don’t see the importance of innovation for industry.

Looking back on our first inquiry results according to the opinion of students about the quality of the course:
The set up of the project is fine.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>70</th>
<th>Average</th>
<th>3,2</th>
<th>StdDev</th>
<th>1,06</th>
</tr>
</thead>
</table>

The team was really pleased with this general outcome. Students like the way of working in an innovative project. Although the students had one comment: “project activities should be planned more carefully: plan the same hours for all students participating in the project.” It is not easy to plan this throughout the different departments but it is the key element for having success.

The theme of the project is fine.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>66</th>
<th>Average</th>
<th>3,5</th>
<th>StdDev</th>
<th>0,96</th>
</tr>
</thead>
</table>

I think the project is challenging.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>66</th>
<th>Average</th>
<th>3,5</th>
<th>StdDev</th>
<th>1,00</th>
</tr>
</thead>
</table>

I learned a lot in this project

<table>
<thead>
<tr>
<th>Respondents</th>
<th>66</th>
<th>Average</th>
<th>3,3</th>
<th>StdDev</th>
<th>1,01</th>
</tr>
</thead>
</table>

In the above table the student expressed that the set up of the project (an open assignment just within a general context (invent a new toy with electronic and mechanical parts) was a nice set up. Just to try to be unique gives the student groups extra motivation. They phrase it as “the challenge to be original” is driving them to explore new technologies and creative minds. To work on these kind of projects a student said “I learn to think of possibilities of innovation e.g.” and another student was encouraged by using the database research on patents: “you face lots of knowledge and knowledge is power!”

The used educational methods are okay (lectures, working class, project).

<table>
<thead>
<tr>
<th>Respondents</th>
<th>76</th>
<th>Average</th>
<th>3,0</th>
<th>StdDev</th>
<th>1,02</th>
</tr>
</thead>
</table>
The assessment of the project and evaluation by lecturers are clear and justified.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>76</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>2.4</td>
</tr>
<tr>
<td>StdDev</td>
<td>1.04</td>
</tr>
</tbody>
</table>

As lecturers we know we have to lecture about the right topics in the right way. Apparently we have done that. But we forgot to tell the students in a clear way how we would assess them and how to pass or fail. This is what we have to improve. What is needed to pass: is it the elevator pitch, the product, the way of working or the mini-assessments or should all be assessed with a ‘pass’ and how is the weighing factor then? It was during the semester that we decided to use the following scheme:

- 20% of mark: final management report and presentations
- 20% of mark: Prototype
- 20% of mark: individual process role report (process wise)
- 40% of mark: individual professional role report (content wise)

The prizes available for the best designs stimulate me to build a better prototype.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.2</td>
</tr>
<tr>
<td>StdDev</td>
<td>1.19</td>
</tr>
</tbody>
</table>

The workload for the project is high.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.6</td>
</tr>
<tr>
<td>StdDev</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Students have spent all the time available to work on the project and they felt a high pressure in workload (3.6 on scale 0-5 with only a standard deviation of 0.88). That was because of the high motivation we encountered in the groups. This was not forced by the relatively high prize available (3000 Euro in total), although some student said “prizes stimulate to go somewhat further in work and time investment to get a nice product”. More groups expressed that the drive was given by the battle of being the best, having the best idea and they really enjoyed working for the first time in the study on a real prototype. Furthermore they expressed that they would like to have more feedback on practical issues from the technical coaches while working on the prototype or designs. “More time for actual manufacturing of the prototype is too short, extend this to 14 weeks e.g.” was also responded in the inquiry.

4 CONCLUSION:
Students during a period of 14 weeks have worked on creating an invention, a new and not already patented idea, within the field of toys and games. Students had the opinion that this part of the curriculum was a challenge. Some typical outcome of the inquiry can be made:

- Students see innovation as an important element for their career and see innovation as a strong element for SME to survive in the future. Therefore we can state that the courses on innovation are relevant for engineering education and the course ‘the invention’ in the first year is relevant to starting to build this competence.
- Students are satisfied about the course ‘The invention’, however some organisational flaws need to be reconsidered and students have the opinion the workload of the course is high.
- A patent expert from a patent advice company also advised student groups. The opinion of this expert was that students came up with good, patentable ideas.
- Technical students are very focused on designing and constructing and making products. Less attention is given to important knowledge about forecasting the profitability in order to decide to produce these new ideas. The theory students been taught, about concept generation, patents, and financial information was enough for them to understand. They were not eager to use this information.
- Students of Electrical and Mechanical Engineering need to learn to work together. This was a problem in the projects.
- We had some prizes to give to the 10 best groups out of 30 in total. We thought this would motivate them. In the inquiry students said this relatively did not increase their motivation.

So in overall conclusion we managed to set up a course on innovation for students in the second semester of the first year that is relevant for learning for engineers. Students were relatively positive about the content and the project in the course. For the next year we will bring following changes:

- We need to set up a plan of approach for students with a tight schedule so students use the whole period to build on results.
- Give a better start in collaboration between Mechanical – and Electrical engineering students. Students need to be prepared better to collaborate with different disciplines.
- Give students more opportunities to contact companies to ask advice.
- The major attempt is to provide students with competences to develop on a professional basis innovation in companies. This we have to measure in the future when these students are working in companies.
- We have to instruct teachers more on the real context of innovation development in companies, so they will coach the student groups more from a point of view of the conditions in companies.

The course ‘The Invention’ will be implemented in the curriculum in 2008/2009 after been revised on the points mentioned above.

5 Literature
• Bakarman, A. A., 2005 “Attitude, Skill and Knowledge: (ASK) a New Model for Design Education”, King Saud University, RiYadh, Saudi Arabia.

• Boorsma en de Vries 2004; De vraag naar HBO-ers bij MKB-bedrijven.; een onderzoek in vijf mkb-branches; Dijk 12 beleidsonderzoek.

• Cascini, G., Russo, D., Reazzoni,D., Rizzi, C., Proceedings of TMCE 2008 Symposium, April 21-25, pp. 733-742, Izmir, Turkey.


• Jong, de, 2006, EIM ‘onderzoeksrapport’ M200604; Technologiebedrijven in het MKB.

• MKB, jaarbericht 2006/7; Nieuwe kansen voor het MKB.