Situation in Engineering Universities of Applied Science in Oulu and Eindhoven to Teach Methods to Achieve Innovations in Businesses

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INTRODUCTION

In developed economies there is a flow of money abroad for the import of food, fuel, raw materials, cars, etc. Successful enterprises which develop, produce and export products are therefore of crucial importance because they generate assets to balance this flow. Companies have to generate new products and production methods to survive and prosper. Ideas to enhance the actions of people and production systems are common but not all move far from the inventor. To benefit from new ideas they have to be brought into wider use. In business there is a need to find and implement ideas for products which are accepted and used. It is not enough to make an invention based on an idea; the resulting product has to be designed so that it can be produced and brought to market at a price that generates adequate profit.

1. INNOVATION

In the literature there are numerous definitions of an 'innovation'. A common view is that an innovation is present when new ideas are inventive, truly makeable (patentable), and bring profitable success when launched in the market [1]. There is a clear difference between an 'invention' and an 'innovation'. An invention is something new, surprising and possible to realize in an industrial way, but there is no established demand for it except novelty. An innovation is also a new invention, but one that will be brought into wide use in the market or in some other way in society.

But who has the skills to make innovations? First a company has a need for an idea for a new product; to achieve an innovation the idea has to be brought to wide use. Thus the idea has to be developed into a product that can be produced and brought to the market in profitable way. This means that the people involved in this chain of actions must have a variety of talents and skills [2]. In a simple case one person can take all the actions needed. For a bigger innovation people will needed be who possess a variety of skills. However there has to be someone who understands the entire process and is able to organize all the resources needed to achieve the desired result. In technology-based businesses, and especially in smaller and medium sized enterprises (SME's), it is not always possible to hire specialists for different tasks, so engineers within the company must be able to initiate the necessary activities.

The question then arises: in which phase of the development of their career should engineers be trained to manage innovations? One option is to gain basic knowledge during engineering education and real practice in companies. During the study phase various methods can be used to offer theoretical knowledge combined with as realistic practical exercises as possible.

During their life cycle businesses often come to a situation where to survive they must either find an idea for a new product or find a new method of production at lower cost. In technology based companies engineers are often in key positions to find and develop successful products in line with the

vision and strategy formulated by the owners. An important question for companies is how to find engineers who are capable of fulfilling this task. Engineers are educated in universities in many different ways. All of them have basic knowledge of mathematics, physics, chemistry etc. In addition different kinds of technical knowledge and skills will have been taught. There are many types of technology needed dependent on the industrial sector, but there are common skills that are needed to achieve profitable business as a whole. There is need to understand and apply economics, to run complete projects, to be able to think in terms of marketing, to understand how to find new ideas and finally how to introduce ideas to the market as profitable products. How and where can young engineers learn these necessary competences? That is why universities exist in every society.

Many company managers have stated that new ideas often come from project managers or sales persons working closely with clients. Such ideas are brought to the company where their viability must be evaluated taking account of all the activities needed to bring the idea to market. The cost of these activities has to be estimated together with marketing possibilities, including sales volumes and price. This way of finding new products is called market pull. If an idea that is new to clients has been invented within the company one can talk about technology push. Entrepreneurs are not multidisciplinary themselves so they do not command all the skills needed to handle the full chain from idea to market. That is why at least some of their engineers need to have a certain level of entrepreneurial thinking. Since the engineers have the responsibility of implementing rather than originating new innovations their capabilities can be seen as *intrapreneurial* assets. Though intrapreneurs do not own companies or control their policies they bring entrepreneurial attitudes to their work and will feel commitment to the success of their company beyond a simple wish to maintain an income.

2. TEACHING INNOVATION IN UNIVERSITIES OF APPLIED SCIENCES

2.1 Curriculum development strategy in universities of applied sciences

The most important issue controlling the knowledge and skills taught to engineers in universities of applied sciences is the curriculum. The basis of this, especially in mechanical engineering, is in mathematics, physics, chemistry, and computer science. Later in the study period the curriculum will include both technical subjects and subjects such as economics, management, project management, and marketing which enable technology to be applied economically in businesses. Normally a curriculum is formulated taking into consideration the needs of businesses in the surrounding region so that every university of applied sciences has a different curriculum in detail. In SME's, which rely on their own products, there is a need for young engineers who can run complete product processes as early as possible after graduation. This is true especially in businesses which are developing products which require new technical skills; the technology used in such products is not necessarily very advanced but the practical realization of the total process from idea to market is vital. SME's of this kind look especially towards universities of applied sciences which are perceived to be practically oriented. These issues are therefore of strategic importance for the management of a university of applied sciences to take into account when formulating a curriculum and thus choosing how to educate engineers.

2.2 Teaching and learning innovation

In addition to the curricular influences discussed above the attitudes and experiences of teachers and students have a major influence on the success of the educational process. Universities also perform R&D activities alongside teaching and there can be visible cooperation between universities and companies. This is one reason why universities need to be active in making arrangements for mutually beneficial development projects. Educationally the most important results can be seen in companies where the recently graduated engineers utilize their skills.

An important way of exercising taught skills is by means of a project. The question is then where in the educational process exposure to project work is best placed. It is widely agreed that somewhere in the middle of the studies is appropriate. A student then has tools to apply technical knowledge, and the maturity to understand larger ensembles in using technology to benefit a business. By experiencing realization of an innovation project students come to understand how they can use the knowledge and skills that they have received. At the same time they come to understand what they still lack to carry out a real innovation process. After a project they have time and motivation to study subjects which will help them to work in real innovation projects in businesses.

Because innovation projects require a variety know-how sectors, they offer the possibility of learning in a practical way how different kinds of people work together and how important it is to learn the principles of team work. The problem becomes more complex when the project and team are international. Cultural differences are present and all members have to recognize and to understand

these differences and be able to adapt to circumstances. It becomes apparent that different organizations have different methods and principles of work. The knowledge base can be different; scheduling is normally different; methods of negotiation and decision making are different. After this kind of experience graduates are better fitted to work efficiently in innovation projects in businesses.

2.3 International collaboration in curricula

When planning an international collaboration and especially an international innovation collaboration as described in this paper, it is important to address questions that underline the different approaches in curricula in partner universities of applied sciences. One very important issue is the possibility for students to communicate with each other since without proper communication the possibility of success is poor [3]. This covers both the possibility of a personal meeting at the beginning of the project, and the technology used to communicate during the project. Because universities have different strategies for developing their curricula, it is to be expected that students will be differently prepared for the work in the project. The participating universities have to be aware of this difference.

This paper describes an international innovation project plus steps taken to identify criteria that support a smoothly organized and well working international project on innovation development, so building up the knowledge and skills of students to become innovators in their future careers.

3. RESEARCH

3.1 Focus of the research

The aim of this research is to investigate how to develop the skills needed to achieve new innovations, leading to new successful products, in an international context especially with relevance to exports. The specific focus reported is to find out how effective current education methods are in doing so. The method adopted was to analyze the experiences of students participating in an international project where the aim was to find an idea, and to design a product based on it including making a prototype and testing it. As a part of the research the supervising teachers, other teachers and the management of universities were interviewed. As important stakeholders, key-persons in companies were also interviewed. Two groups of students, one in Oulu University of Applied Sciences in Finland (OUAS) and one in Fontys University of Applied Sciences in the Netherlands (FONTYS) were given the task of finding a good idea which would be wanted in the market and which could be realized as a working prototype, all during a period of one semester. In FONTYS this kind of project is part of the normal curriculum but in OUAS students performed it in parallel with their normal studies.

3.2 Research method

The method used is of a qualitative and inductive nature, in which relevant stakeholders are interviewed about the relevance and effectiveness of an educational innovation project. The opinions of different stakeholders from and around Oulu and Eindhoven are compared with one another to find ways to improve the quality of such a project. The outcome of this constant comparison of opinions of participants needs to lead to a set-up of the organization and execution of an innovation project that enables students from both countries to learn about achievement of innovation. The data collected is from a project that was executed between November 2013 and April 2014. This kind of research is often called action research. The research method and theory behind this method is that of ‘grounded theory analysis’ as described for example by Glaser & Strauss [4] and by Bryant and Charmaz [5]. During active research, cooperation between researcher and participating parties in the practice area takes place. The parameters evaluated here are similarities and differences of opinions about educating innovation to students using the project format described. From the similarities and differences guidelines can established that lead to an organization and set-up of a project for students and teachers that works well in an international setting.

4. DEVELOPMENT PROJECT

In this research there was an international project having the aim of enabling students to address how to identify and achieve an innovation. Because of restricted time and resources, the extent and depth of the project was limited. Nevertheless it was possible to set up a situation where students reached their limits both concerning knowledge of technology, and communicating with people from a different culture and different formal working system. It was possible to use modern digital communication means but to see its limitations, and to appreciate the need for convenient means to exchange information and to collaborate in decision making. The aim was also to let them realize what they still need to learn during their remaining study years. Finally they had to face the human factors arising from the varied characters and ways of working of different persons.

4.1 Preparation of the project

A group of three students of mechanical engineering was selected in OUAS and a second of four students in FONTYS. One FONTYS student had a specialization in mechatronics. Data were collected by observing, and by questioning students, teachers, university management, and businesses around the universities. The project was prepared and supervised by two teachers, one in OUAS and one in FONTYS. Planning included overall scheduling and the communication technology to be used. The main communication technology adopted was Adobe Connect Pro software with which one can share voice, video, and documents and all communication can be stored. Normal phones, SMS and e-mails were also used. Previous experience showed that because there would be students from different countries, cultures and organizations, it would be helpful to arrange a personal meeting before the start of the project. This meeting took place at Eindhoven, in the Netherlands.

4.2 Implementation of the project

Planning of the project included the timing during the study year. The idea was to start early enough to be able to finish the project before a busy time in OUAS in the end of the winter semester, so that the total workload for the students was rather even. The search for the students was evaluated to take three weeks. To make it possible to realize all actions there was need to agree the budget with the management of the department of the university. It was arranged that the students from OUAS could visit their counterparts in the Netherlands. The intention of the meeting of the two groups of students was to let them get to know each other so as to make it easier communicate effectively later in the project. It was also agreed that teachers would make a basic presentation about the project to the students. The students were told about the aim and the conduct of the project. The main topic was about innovation and the methods available to find and evaluate good ideas for a product. The students were prepared for project management and the meaning of the milestones was emphasised. Decision making was one of the focuses. The students had followed a basic course in project management but they don't normally have any experience of running a project.

During the project the participating students made their own project plan, realized the ideation stage, and designed and made a prototype independently and in a self-steering way. The teachers supervising the groups monitored progress and kept each other informed on a regular basis. They helped to solve communication problems and misunderstandings caused by the different arrangements of the two organizations. The teachers also helped the students to find the knowledge that they needed to realize the design and manufacturing. One of the sub-goals of the project was to learn about technology relevant to their engineering studies. In the end of the project the prototype was presented to an audience consisting of other students and teachers in OUAS. There was also a written report and a poster presentation.

Students were advised to search for business sectors where usable ideas were possible using the so-called Search Field Method [6]. A sector is chosen, e.g. transport, health care, energy, etc., and is divided into smaller part sectors from which one is chosen. Again it is possible to divide this into smaller sectors. One can then search for ideas or again subdivide into further smaller sectors. In this way certain sectors can be scanned and new ideas come up in an organized way compared to unfocused brainstorming. The supervising teachers helped the students to choose the idea to be taken into the development process. The students did not have enough experience to know in advance how much the candidate ideas would take in terms of time, effort and required resources.

When a range of suitable ideas had been gathered, they were evaluated to decide which was best for the project. During the project an evaluation method was created which used criteria relevant to the aim of the project. These criteria were movement, control, manufacturability, and real need. These criteria were scored and the scores were added up, the total of the scores showing the quality of the idea. On the ground of best scoring the idea finally selected was a grip glove, which is a technical arrangement to help strengthen the grip force of the hand.

The first step after having chosen the idea was to specify the needs that the product had to fulfil, following which the students researched different technical solutions to fulfil the needs. They used the morphology table method. After proposals and negotiations the group agreed on a particular technical solution. The next phase of the project was to divide tasks to precisely design the prototype.

The students decided that the finger part of the grip glove should be designed in OUAS and the control system including mechanics and electrical parts in FONTYS. During the design work the students negotiated about the details which were somehow affected by the construction of the other group. The procedure advanced by doing detailed mechanical solutions, calculations and small, simple prototypes of plastic and cardboard.

Finally the project was at the stage to build final prototypes. The groups in OUAS and FONTYS each produced two examples of their part of the prototype. One example was exchanged so that each group had a full prototype. A practical problem was that some of the parts of the control system were ordered from companies outside the university and they were not delivered in time so that a work-around had to be created. Final machining and assembly took place in OUAS after the final changes to the project. Some technical changes had to be made and new parts acquired. Finally the prototype was ready and the final presentation was given to an audience of students and members of staff.

5. INTERVIEWS

To investigate the situation of teaching innovation in universities of applied sciences in the context of the project various stakeholders were interviewed. These stakeholders were the students participating in the project, the supervising teachers, other teachers in the participating universities, managers of the universities and key persons of companies around the universities. Because understanding of the term 'innovation' can vary from individual to individual, all interviewees were given the definition of the term as used in this investigation. The number of participants in the interviews by stakeholder type and country is given in *Table 1*. below.

Table 1. Number of participants in the interviews

	Students	Teachers involved	Teachers not involved	Companies	Management
Oulu	3	1	6	4	5
Eindhoven	4	1	6	5	3

5.1 Questions posed

The following questions were posed to individual stakeholders. The students were asked about their experiences while performing the project. The supervising teachers were asked about their experience of it. The university managers were asked for their view of the need for innovation education. The key persons of companies were asked about innovation development in their businesses.

1. **Students**
   a. Why did you choose this project?
   b. What were your experiences of cultural differences?
   c. What worked well during the project
   d. What went wrong?
   e. Did you learn more about innovation during the project?
2. **Supervising teachers**
   a. Did the collaboration between the two institutes have the results expected?
   b. What were the differences between the ways of working of the students in the two countries?
   c. What are the key elements of such collaboration that need careful organisation?
   d. Why is contact between the teachers important?
   e. What is your assessment of the outcomes of the student's work?
   f. What is your understanding of the teaching of innovation in your university? Do your colleagues understand what innovation is?
   g. What influence did different teaching/studying methods in the participating universities have on the project?
   h. What kinds of team working phenomena were seen amongst the students?
   i. Were the resources adequate for the project?
   j. How successful do you feel contact keeping was during the project?
   k. What were the principal lessons learned by the students?
   l. How well did the students manage to carry out the project alongside their other study work?
   m. How well suited to the experience were the students selected for the project?
3. **Teachers not in the project**
   a. Are students normally taught about the full innovation process or just parts of it?
   b. Do you feel that there should be more teaching about innovation?
   c. How could 'innovativeness' be better taught?
   d. Are the innovation skills of graduate engineers important for the enterprises in your region?
4. **Companies**
   a. What are the indicators of 'innovativeness' in your company?

b. Which kind of innovations you would like to achieve in your company?
c. What are, in your opinion, are the necessary competences for new employees working to innovate?
d. Is the company seeking highly educated personnel to find new innovations?
e. What do you feel is the best method to have innovative people in a company – to train them in the company or to try to employ people who are already innovative?

5. University Management

a. Do you accept the importance of including innovation teaching as part of the curriculum?
b. What is the image value to the University of teaching innovation skills to engineers?
c. Does management see any possibilities for innovation teaching to strengthen contacts with companies?
d. Would management be interested in collaborating with foreign universities concerning innovation teaching?
e. What is the meaning of innovations for enterprises in the region?
f. Are there any particular plans to include innovativeness in the curriculum and teaching methods adopted?

5.2 Opinions of students in the project:

The students were volunteers so their motives were good. They found the project challenging, the process for finding a product interesting and the international context attractive. Cultural differences arose especially in connection with communicating and decision making. They felt the work climate to be good which they attributed to the face-to-face visit at the beginning of the project. Communication had been a problem with language causing lack of clarity during videoconference meetings. The communication technology was not running properly which caused occasionally confusion and frustration. The conduct of meetings caused problems, especially because minutes were not properly kept and later it was unclear what had been decided. Even though the project was challenging and they faced practical difficulties, the students said that they had learned a lot. The most important aspect identified was that they had experienced the full process from identifying an idea, through design and test of the prototype, to making a presentation on the work done. They also felt that experience of practical project management in an international context had been important. Finally they strongly stated that after graduation they would like to work in a project to find, develop and achieve new products.

5.3 Opinions of the supervising teachers

In the questioning was asked about the phenomena which were arisen during the project. The common observations were that communication within an international team is challenging. There are difficulties because of different cultural attitudes to communication and decision making. Methods of communication have to be well prepared so that there are no delays or difficulties to impede understanding between the parties. The initial stage is important from the point of view of the operation of the group; to ensure good team building the participants need to meet face to face. This makes it easier to communicate, to understand and to be understood. The difficulties caused by separate locations were ameliorated by having weekly discussions between the supervising teachers. This also helped to avoid friction due to different habits of work organization and work culture. The teachers were able to solve various crises before they disturbed the progress of the project.

The supervising teachers could observe the persons engaged on the project and see differences in attitude towards the work. The opinion of the guiding teachers was that it is crucial to choose the right participants since the project is different to, and wider than, projects carried out as part of normal studies. In OUAS they had to carry out the project in addition to normal studies.

The role of supervising teachers was important in the early stage of the project when the students had to search for and select the product for development. For the students it was difficult to know what degree of difficulty was suitable for the project. In fact in the project there were many necessary choices which were difficult for students. Because of the time constraints there had to be someone to take responsibility to ensure keeping to the set timing and the allocated budget. When the project ended, the students seemed satisfied with the strong role of the supervising teachers.

5.4 Opinions of teachers not participating in the project

It was clear that each teacher understood the term ‘innovation’ in different way. While responding to questions about innovation teaching, each teacher generally started to talk about their own courses. Many of them adopted a defensive attitude and claimed that they are indeed teaching innovation, though in fact in most cases they were teaching courses which are part of technical product development. The discussions in many cases moved on to consider where their students would work

following graduation. Most of the teachers interviewed came to the education sector from large companies. It seemed that their impression of the newly graduated engineers is as designers working in a large company. They do not clearly envisage the entire path from idea to the market, because they never have experienced it themselves.

A general observation is that most teachers feel that there are not enough courses on innovation. Many of them feel that there should be a wider variety of courses describing the path from an idea to the market, whereas currently the main attention is directed at teaching of technology. The opinion of most of the teachers was that in education there should be more emphasis on creativity, marketing and total projects beginning from search for an idea even as far as planning how to reach the market. It is normal that study of the issues around innovation ends at the prototype stage; commercialization aspects are missing. Some of the teachers assumed that universities must teach underpinning technology and that the remainder of training and learning would happen in companies.

5.5 Opinions of managers in universities

The managers of the universities of applied sciences see innovation as an important part of education. The curricula include elements on the innovation process but the education is not comprehensive enough for total understanding to be created. The managers say that the external image of proper education in innovation is important especially when high-grade students choose universities in which to study, but also when a university wants to develop cooperation with businesses and particularly with SMEs. Innovations are considered to be important for SMEs but they don't have enough resources to complete a total process from idea search to marketing and market launch. International cooperation is believed to be necessary both for innovation and other education. Also the managers responsible for education in practice believe that education on innovation is important and that there is curriculum development happening. There is no clear plan to include the total innovation chain in the curriculum. Normally in technological education the process ends at a prototype. Marketing is not normally seen as part of engineering education.

5.6 Opinions of managers in companies

The managers in companies wanted to have innovation both for new products and for developing production. They also appreciated awareness of marketing. Generally most of the managers mentioned the importance of creativity and technical skills. A general opinion about the readiness of an engineer after graduation was that it would be important that he/she would be as ready as possible, but in most cases the managers also mentioned that there is need to educate recruits in the specific technology and work arrangements in the company. A common observation was that a young engineer should think independently and be willing to push their own ideas even though there might be natural resistance against those ideas. This supports the assumption that a young engineer should have a comprehensive understanding about the business and how to drive an idea to become an innovation. The word INNOVATION seems not to be very clearly understood which makes it a bit difficult to give very clear and strong statements about issues needed on the way towards a successful innovation on the market or in the production.

6. CONCLUSIONS

According to the research, there are a few suggestions to take into consideration when a university wants to use an international innovation project in education. To avoid surprising confusions there has to be explained to students how an international development process is proceeding, how the cultural differences appear. It is needed to give enough instruction and support in using communication technology. It is necessary to give strong support during the choice of an idea to ensure the progress of the development process according to scheduling and budget. The role of supervising teachers is important. By continual discussion about the progress of the project they can solve misunderstandings causing friction and delay. To minimize all distractions caused by cultural, organizational and geographical differences it is necessary to arrange a personal meeting in the very beginning of the project.

Students told that they learned a lot when they saw how a development project progresses in reality. When there are separate parties involved, unexpected matters happen and they have to be taken into consideration and the plan has to be changed to achieve the target which has been set originally. The students stated that after the project they understood clearly the path from idea to the product and they learned how the innovation project has to be carried out.

The perception of teachers is that there is not enough teaching about how to find, develop and achieve innovations. They feel that some elements are taught but no properly integrated training to understand how innovations can be achieved. A very clear opinion is that there should be more

education to offer the students the possibility of preparing themselves to work in innovative businesses. Teachers gave some suggestions how education could be improved, with their opinions clearly directed towards practical projects in which students could work along the whole path from an idea to the market. Teacher's perceptions about the need for innovation skills in companies were also clear. They saw it as a necessary prerequisite for the success of businesses in the region. There is a difference between the teachers and the management. The management has to think about money and they don't want to offer many kinds of education. On the other hand, teachers working continuously with students and also the management think more widely about the need to be able to train different skills.

The key-managers in businesses expressed clearly, that there is need for young engineers who are creative, well technically educated, and able to bring something new to the company. In most of the companies there is a vision to have their own product even though they are currently subcontracting. In universities of applied sciences the teachers were polarized. Some thought that teaching of technology is enough and that there is no need to teach a total chain of innovation. Most teachers thought that there should be more teaching concerning the achievement of innovation. The management of the universities expressed very clearly that there should be more practical education leading to readiness to work towards innovations.

The general perception of business managers is that they consider their companies somehow innovative by finding, designing and achieving new successful products or production readiness. Nevertheless they acknowledged that they need more innovation effort mostly to find new, better, successful and profitable products. To achieve this they mention that the qualities that young engineers should posses are creativity, out-of-the-box thinking and independent wider thinking. When asked about hiring young engineers in the near future they were cautious because of the current recession. In the more distant future they saw a need for young well trained engineers. When asked where and how innovation skills should be trained, the answers were not very clear. Some of the business managers suggested that universities should provide the necessary education and capacity. Others believed that only companies can give practical enough training for recently graduated engineers. Perhaps this expresses lack of confidence in the education provided by universities.

As general observation came up that all stakeholders felt that in universities there should be more teaching about the process achieving innovations. As an interesting observation was mentioned that creative students are guided preferably to studies of arts and not to engineering studies because the guiding persons don't understand that engineer work demands creativity as well as other sectors in the society. The designers of the education systems have to decide in which way the innovation is taught – how widely and how deeply. Here width means what proportion of students are educated to be experts in innovation. Depth means how many and how specialized courses are offered concerning the path from an idea to an innovation. This is a strategic decision.

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