Implementing cross-disciplinary learning environment – benefits and challenges in engineering education

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Abstract

Nowadays, the way of working includes that problems are solved and innovations are created in groups and networks. Equally also the tasks at work many time require knowledge and skills which do not belong to the scope of one and only discipline. Therefore also students graduating from any engineering programme should possess such kind of knowledge, skills and attitudes that they can contribute to the creation of the innovations by working in cross-disciplinary teams and networks. We believe that innovative solutions are created through social learning in diverse surroundings and discuss the boundary crossing approach in higher education. With the term boundary crossing we go a step further in innovation development, embedding the cross-disciplinary learning environment in boosting of innovation competences, and discuss why and how to build a successful approach for boundary crossing collaboration in higher education.The implementation of cross-disciplinarity has many challenges and it can meet strong opposition especially by the faculty staff but also by the students. In our paper, we discuss the typical objections met and present some practical implementations of cross-disciplinarity in higher education.

The essential contribution of our experiences is that cross-disciplinarity can boost innovation competencies towards the direction expected from work places, i.e. businesses and other organizations. However, the implementation of boundary crossing in studies requires careful planning and open communication in order to be successful.

Keywords: *Cross-disciplinary, boundary crossing, innovation, learning environment, innovation competence*

1. Background and purpose

In businesses and organizations, the way of working includes that problems are solved and innovations are created in groups and networks. At work places there usually are people from many different fields and disciplines who are expected to work effectively together. Equally also the tasks at work many time require knowledge and skills which do not belong to the scope of one and only discipline. Therefore also students graduating from any engineering programme should possess such kind of knowledge, skills and attitudes that they can contribute to the creation of the innovations by working in cross-disciplinary teams and networks. The aim can only be reached by making sure that the graduating students, also in engineering, are able to participate in the different innovation processes in their future working life positions and bring added value to these processes. The success of most organizations depends on the ability to create innovations, which means that they need employees who possess these competencies essential for enabling them to participate in the different innovation creating processes of their organization.

We believe that innovative solutions are created through social learning in diverse surroundings and discuss the nature of boundary crossing in engineering education. With the term boundary crossing we go a step further in innovation development, embedding the cross-disciplinary learning environment in boosting of innovation competences, and discuss why and how to build a successful framework for boundary crossing collaboration in higher engineering education. However, the implementation of cross-disciplinarity has many challenges and it can meet strong opposition especially by the staff but also by the students. We discuss the typical objections met and present some practical implementations of cross-disciplinarity in higher education and their contribution to the students, to the businesses and the society, and to the educational institutions.

2. Cross-disciplinarity and boundary crossing in innovation competence development

Innovation pedagogy is a learning approach, which defines in a new way how knowledge is assimilated, produced and used in a manner that can create innovations. The goal is the type of approach to one's own learning that enables participation in the innovation processes of future work organizations. After graduation, the students are innovative and oriented towards various kinds of development tasks, which means that they have acquired, in addition to the expertise on their own field of engineering, innovation competences required by all working life environments. Innovation competences enable students to take part and contribute in innovation processes in these environments.

Innovation competences are learning outcomes shared by all study fields, and they refer to knowledge, skills and attitudes needed for the innovation activities to be successful. The innovation competences follow the European Qualifications Framework set by European Commission and comprise three levels: individual, interpersonal and networking competences. The individual level includes independent thinking and decision-making, target-oriented and tenacious actions, creative problem-solving and development of working methods as well as self-assessment and development of one's own skills and learning methods. The interpersonal level focuses on the abilities to co-operate in a diversified team or working community, to take the initiative and to work responsibly according to the targets of the community, to work in research and development projects by applying and combining knowledge and methods of different fields, to work along the principles of ethics and social responsibility as well as to work in interactive communication situations. Finally, the networking level covers the abilities to create and maintain working connections, to work in networks, to co-operate in a multidisciplinary and multicultural environment as well as to communicate and interact in an international environment. Innovation competences are learned gradually as new information is added to our knowledge structures. [1]

A learning environment is most frequently understood as the physical or virtual surroundings meant and built for learning purposes. In innovation pedagogy the social aspects of working and learning are emphasized and group processes where learning happens in multidisciplinary teams form an essential part of the whole process of learning. A social learning environment is formed by people with different talents and competences and by the interaction enabling collaborative learning. Equally, also the tasks in working life often require knowledge and skills which do not belong to the scope of a single discipline. [2] [3]

The concepts of boundary crossing, multidisciplinarity, interdisciplinarity, and transdisciplinarity lack a single comprehensive term, which would bring together all their variations. However, all these areas share the same goal of producing something new, unexpected and innovative through collaboration of people with different backgrounds. Each individual involved in this type of co-operation contributes his/her knowledge, history, experience, intuition, expertise, know-how and creativity to the social learning environment

According to Max-Neef, educational institutions should shift their focus on improving boundary crossing collaboration for example by offering courses that are really multidisciplinary [4]. "Interdisciplinary education exposes students to research in multiple disciplines, trains them in collaborative methods through team research and promotes new forms of communication and collaboration among disciplines" [5]. The aim of innovation pedagogy is to generate environments in which competitive advantage can be created by combining different kinds of know-how, since in a multidisciplinary environment, it is possible to evoke regional innovations and increase entrepreneurship through research and development. Also the transfer of knowledge from university environment to actual working environment becomes more efficient. In the end, one of the biggest challenges for innovation pedagogy is actually to teach the students how to step out of their comfort zone and how to tolerate insecurity and not to be afraid of leaving behind familiar ground.

3. Challenges in implementation

The attitudes of the participants are crucial to the effectiveness of boundary crossing co-operation; "the crucial aspect is the involvement of participants who are ready and willing to learn from other disciplines" [6]. Participants who are very defensive of their own ideas and knowledge base tend to harm collaboration by not opening up to differing thoughts and therefore innovative solutions through mixing different areas of knowledge are not fostered. “Facilitating conversation from multiple disciplines is a tough job, requiring not only awareness of one’s own disciplinary bias but also the ability to manage power dynamics among highly successful and often egoistic participants” [7]. Therefore leadership plays a key role in building a social learning environment which leads to positive results.

To understand the language of other disciplines takes time. In general, as the world of knowledge is very diverse indeed with contradicting views, terms and ideas, boundary crossing collaboration requires a setup where there differences are discussed and perhaps even solved. “Differences in research methods, work styles, epistemologies must be bridged in order to achieve mutual understanding of a problem and to arrive at a common solution” [8]. “Integrating a team’s capabilities depends as much on the individual abilities to work together as they do on their individual expertize and skills [9]. Communication is maybe the most important factor, as beneficial communication at the same time helps to avoid the accumulation of new social problems and brings collaboration closer to its goals. ”New way of working cannot simply be imported to the team but it can only emerge and develop through intense interactions” [9].

In working life the way of working includes that problems are solved and innovations are created in groups and networks. However, in universities the students typically study by memorizing lectures and reading. Collaboration in learning is not appreciated and sometimes even forbidden. Educational research has noted the transfer problem where learning cannot often be recalled and applied in working life [10]. The transfer problem is recognized: the learning in one type of setting is not accessible when the learner is moved to another setting. This problem can be, at least in part, avoided by creating identical elements in education and working life [11] [12] [13]. In working life there usually are people from many different disciplines who are expected work effectively together. Equally also the tasks in working life many time require knowledge and skills which do not belong to the scope of one and only discipline. Boundary crossing during studies is one of the means to solve the transfer problem. When students get used to working with people from different disciplines and learn to accept that they have to be interested in subject matter belonging for many different disciplines transfer of knowledge at work place becomes easier.

The implementations and challenges of cross-disciplinarity concern also the staff, not only the students. When innovation pedagogy first was introduced to Turku University of Applied Sciences it was not automatically accepted by the personnel.

A teacher’s profession has traditionally been very independent. Cooperation or sharing of teaching material or other ways of delivering it has not been common among faculty members. As innovation pedagogy calls for interaction and networking among students it soon became evident that there must be interaction, cooperation, sharing and networking among faculty members as well. Connections to working life organizations needed intensification as assignments for student work were expected to represent real world situations and problems. The process of implementing innovation pedagogy in the faculty actually meant introducing a totally new culture to the faculty. According to Schein, organizational culture can be divided into three levels: in artifacts which are visual organizational structures and processes; in espoused values such as strategies and goals and in basic underlying assumptions which are taken as granted beliefs, unconscious perceptions and feelings and thoughts [14]. When the culture is seen like that it is quite sure that the change cannot take place without resistance.

When the first ideas of innovation pedagogy were launched the artifacts which had to be questioned were the ways how people worked. The teaching profession has traditionally been very independent requiring only individual input. Innovation pedagogy challenges the individual way of working and instead emphasizes the importance of interaction and networking among faculty members, students and the surrounding economy. The new way of doing things was experienced first as a threat among the faculty members. The espoused values concerned mostly producing graduates of good quality which meant that the teacher had to make sure to speak all necessary and important things in front of the class. Learning was understood to be guaranteed when the subject matter to be learnt had been mentioned and handled during a lecture. The everyday discussion among the faculty teachers used expressions like “have you already spoken this subject matter to the class?” or “the students have learnt the topic because I have spoken that to them”. Almost all the interest was put to the teachers’ actions. Learning was understood to take place as a consequence of what the teacher did or did not. The learning process of the student was not that much emphasized.

The underlying assumptions in the faculty were mostly beliefs and thoughts about the students and their learning. Present students were compared to the previous ones and the present were said to become poorer and poorer every year. Their science skills were questioned and they were even stated to be so poor that is probable that they will not learn the necessary content as they should. As a matter of fact these beliefs could not be considered as true or existing. However, they were very harmful for the motivation of the students and thus the atmosphere in the faculty was sometimes negative and even aggressive.

When introducing the new innovation pedagogy approach and culture all the basic assumptions of the faculty members were taken under consideration. The most important thing in the beginning was to create forums where people could meet and learn to know each other. There must be space for criticism but there must be space for innovative and solution oriented thinking as well. The faculty members were encouraged to get acquainted with other faculty members unfamiliar to them and gradually start realizing what the new ideas were all about. The biggest mistake in the beginning was made by the developers of innovation pedagogy, being so confirmed about the success of this new approach that they didn't leave enough space for the staff first to question the approach and thereafter enough time for gradual approval. Instead, a lot of resistance had to be overcome because of the enthusiasm of the developer group. More space for open and critical questioning should have been left for all the faculty members to explore and accept the new ideas. However, after a painful period of rebelling and fighting back progress has been made and the ideas of innovation pedagogy appear now in the everyday life of the faculty

4. Examples of implementations

The curriculum structure has an impact on the aspects of cross-disciplinarity. A module based curriculum used by TUAS refers to wide study modules, not based on traditional subjects or disciplines but being more working life based, and therefore requiring the expertise of several disciplines. This prerequisites often co-planning and co-teaching, because many real life organizational issues are not to be solved with the expertise of one discipline. This forces, or encourages, the engineering teachers, as well the teachers of other disciplines, to co-operate more closely than earlier, and as stated earlier, to understand the language of other disciplines can take time. This concerns also all development work done; the pedagogic and curriculum development work has to be learned to conduct in cross-disciplinary teams.

When encouraging students to boundary crossing and at the same time applying innovation pedagogy Turku University of Applied Sciences (TUAS) uses methods which are called educational research, development and innovation projects. There are several different ways of carrying out these projects. These projects combine real life assignments, peer counselling and working in cross-disciplinary groups including the international aspect in all work. These projects often include different types of so called hatchery methods. The principles of carrying out the work in the hatcheries are approximately the same but the expertise level of student varies in the different hatchery types. A first year student is capable of handling less complicated assignments requiring not so much expertise whereas a third year student has much more content, often individual, knowledge to be used when participating in the hatchery work. Hatcheries bring the research done at the university to the proximity of every student. A student can participate in a hatchery several times during the studies and move from less complicated tasks to more complicated ones as the studies progress. Advanced project hatcheries bring the working life problems to the university to be solved by the students. They offer a great and easy access point to the surrounding environment and make it possible for the students to start building networks with working life partners already during their studies. The challenge with organizing this kind of project learning is how to ensure the regular availability of appropriate projects for the large number of students.

At TUAS, the Faculty of Technology, Environment and Business has included a project hatchery module in its study plan since 2008. The idea behind the project hatchery is to make all students of the faculty (engineering, business, design and sustainable development) working on designated project assignments in multidisciplinary groups during their first semester. The idea is precisely to familiarise the students already in their first year with learning situations in multidisciplinary groups, and often outside the subject area of the degree programme, which are based on an external assignment and aim to produce new visions and thoughts or, at its best, even new product and service ideas [15]. However, the implementation of hatchery methods is not trouble-free with the new, incoming students. The feedback is sometimes negative from these first project hatcheries; why to be forced to work with students from other disciplines when having entered a specific engineering programme? This kind of negative feedback will change later, when students learn to evaluate their own learning better, and this first 'obligatory' study unit can be considered as the most useful one; students learn to understand that learning takes place in various ways, as independent learning, through advice and guidance, with peer support as well as by observing the senior researchers' and students' work, and that individuals can reach better results and learning objectives together than by working alone.

Practical training is a compulsory part of the education in a university of applied sciences and it always takes place out at the workplace where contacts to real working life are natural. Thesis work is another compulsory part of a university degree, and it is preferably accomplished in close co-operation with working life, encouraged to be a step further after, or during, the practical training period. The thesis is traditionally conducted individually, but nowadays it is possible to do it in pairs or in groups. This can take place for example when a project has several research interests. These research groups, being based on the same project, can also be cross-disciplinary by nature, providing several viewpoints to the research topic. The feedback from participating students gives support for this approach; they get a wider viewpoint to the topic by learning to see the research question from various perspectives of e.g. customers, technical planners, designers, business controllers etc.

One example of cross-disciplinary learning is the international sales competition, which Turku University of Applied Sciences is pioneering for university students in Europe. Sales skills are evaluated on the basis of seller–buyer role plays. The aim of the competition is to develop students' sales skills and to train professional salespeople especially for industrial companies. A total of 30–40 engineering and business students participate in the European Sales Competition in Turku annually. They come from several European universities. The sales training and the competition bring new, added value to the competences of participating students, and that has proved to be an excellent recruitment reason especially for engineering students. The sales competences are understood to be a valuable part of engineering competences nowadays and thus it has not been difficult to motivate the engineering students to participate. It is important that your paper shows clear connection to engineering education and is useful to engineering educators.

5. Conclusion

The essential contribution of our experiences is that cross-disciplinarity can boost innovation competencies towards the direction expected in work places, i.e. businesses and other organizations. In addition, boundary crossing during studies is one of the means to solve the transfer problem in education; when engineering students get used to working with people from different disciplines and learn to accept that they have to be interested in subject matter belonging for many different disciplines, transfer of knowledge at work place becomes easier. However, the implementation of boundary crossing in studies requires careful planning and open communication in order to be successful. In our paper, we have discussed the implementation of cross-disciplinarity and its many challenges. As in organizational change situations generally, the finding is that strong opposition is probably met, especially by the staff but also by the students. However, we hope that our presentation on the typical objections met and some practical implementations of cross-disciplinarity in higher education encourages also other institutions providing engineering education to develop their pedagogical approach towards the working life expectations despite of the challenges caused by the new ways of action.

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