Enhancing Engineering Students' Innovation Skills through Innovation Pedagogy – Experiences in Turku University of Applied Sciences

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Abstract — *The learning conditions in Turku University of Applied Sciences (TUAS) are exceptional in many ways: the students carry out their studies in an environment designed to be multidisciplinary from the very beginning. In this environment, engineering, design, business and sustainable development students tackle common development problems already during their studies. The setting provides various interdisciplinary contact surfaces and, consequently, opportunities for cultivating professional skills needed for producing innovations. Innovation pedagogy can be defined as "an approach to learning which gives a new definition to how knowledge is adopted, produced and used to enhance creating innovations". In this paper, we provide justification to this new concept and explain its background. There are already many case examples where the principles of innovation pedagogy have been applied. The paper analyses nine documented course cases relating to innovation pedagogy and discusses how they reflect the different phases of the concept's development in TUAS.*

Index Terms — *innovation pedagogy, new creating learning, universities of applied sciences, co-operation with working life*

INTRODUCTION

The Finnish industry gave new employment to 500 000 people in 2007. One fifth of the working population works in industry while goods exports account for approximately 80 % of the total Finnish exports. Technology industries are the largest export sector constituting over half of the goods exports. The Finnish technology industries consist of three main subsectors: electronics and electro technical industry, mechanical engineering and metals production. Out of the total industrial production in Southwest Finland 70 % can be accounted to technology industries whereas 60 % of the personnel in industry is employed by it. Technologies industry covers 90 % of exports from the whole region of South-West Finland. Thus, being able to develop new and innovative solutions to the needs of export markets is vitally important to Finnish economy. This fact has also been appreciated by the Finnish government, which launched its innovation strategy in 2008. The rapidly intensifying competition challenges Finland's competitive advantages, which have traditionally been based on our high quality educational system, long-term investments by enterprises and the public sector in research and development. These rapid changes in the environment call for both demand-based as well as supply-based innovation policies. [1]. The educational sector plays a crucial role in the implementation of the innovation strategy.

TUAS is a regional university covering the whole area of southern Finland and also one of the largest Universities of Applied Sciences in Finland. It has around 9000 students in 37 different study programmes. The organisation of TUAS was completely reshaped in August 2004. The new organisation comprises of six units with their own research and development (R&D) departments and personnel, but the different study programmes that belong to them are not bound by their organisational division. This means that all the units are fundamentally cross-disciplinary, thus providing various surfaces for the students to engage themselves in activities which enhance innovative thinking. One of the aims in the implementation of this organisational model is to encourage all kinds of co-operation across the boundaries of individual study programmes both in education as well as in R&D. At best, this co-operation results in the discovery of new spearheads which produce novel, unexpected innovations. The production of innovations ultimately depends on individuals and on how they are able to co-operate with other individuals. In the case of southern Finland, the well-being of the whole region is very much dependent on the competence of our future engineers. They have to possess the necessary skills to help in the creation of innovations for the needs of the industry. This requires a totally new attitude towards engineering competence. Being able to understand the customer becomes vitally important.

The questions this study attempts to answer are: what innovation pedagogy is and how the new concept is perceived and accepted in the faculty? The first section of this paper introduces the reasons for the need of new pedagogical thinking. The second section forms a connective path around concepts of learning, knowledge and innovation in order to present a framework for generating innovations through learning. After the presentation of the study context and methodology, the results are summarised. Finally, the overall contributions of the study are discussed.

DRIVERS BEHIND THE INNOVATION PEDAGOGY THINKING

According to the act stated in 2003, Finnish universities of applied sciences have an obligation to engage themselves in R&D activities. This responsibility directs them to operate in environments where knowledge is applied to practice; when assessing universities of applied sciences, applicability and usability of results in working life are among the key criteria. Practical know-how, the recognition of problems and the ability to solve them need to be included in learning processes in addition to mere theoretical knowledge. The prerequisite for success is a continuous interaction, which encompasses all the actors involved and in which breaking borders between fields of know-how and organisations is encouraged. [2].

As actors operating closely with local economic life, universities of applied sciences can have an influence on the activities of companies in their region. This can be achieved by raising new generations of professionals, whose conceptions of producing, adopting and utilising knowledge make innovative thinking and creating innovations possible. According to the Finnish National Innovation Strategy [1], this kind of proficiency is needed and demanded. Until now, Finland has thrived well in international competition and is, at the moment, one of the leading countries in the world regarding innovativeness and the quality of companies' operating environments. However, the basic dilemma of the Finnish innovation activity is in determining in which field of know-how the country is able to produce additional value in global value networks. In that same field, tapping into Finnish know-how should produce profit for investors. Also education and its reinforcement emerge as vital points in this context.

Knowledge workers are an important resource for R&D, because their cognitive assets are the fundamental source of innovation [3]. In the past, a highly competent group of engineers would perform new product development while technical knowledge accumulated on an individual basis. Today, the participatory approach [4] joins many different stakeholders in the innovation process. In this situation, individual knowledge is still important, but sharing the knowledge is crucial. Therefore, teamwork skills are essential competencies required in working life.

Education, R&D and working life co-operation should form a solid and interactive whole, which should be able to respond to dynamic and ever-changing expectations. Embedding pedagogical knowledge in innovation activities might be able to offer a long-desired theoretical basis for developing knowledge-based competitiveness in the co-operation between working life and education. Kettunen [5] emphasises internalisation of an 'innovation pedagogy mindset' instead of dogmatically following its principles. According to him, the cornerstones of innovation pedagogy are interdisciplinary operations, R&D, curricula and internationalisation in addition to entrepreneurship and service activities.

CONNECTIVE PATHS OF LEARNING, KNOWLEDGE AND INNOVATION

Learning is a gradual process, which consists of collecting, assimilating and adapting new information. In other words, learning happens when new information is added to existing mental data structures in the learner's mind. According to innovation research, knowledge and skills of knowledge application play a crucial role when creating innovations. Thus, creating new services, products and organisational or social innovations requires knowledge and skills, which are applied in an innovation process. Traditionally, the role of education has been to give knowledge-based readiness, which later would be applied in practice to various innovation processes in working life. However, simultaneously applying the principles of constructive learning theory and innovation theory in education could lead to an operational model, through which it would be possible to determine how to support the development of students' innovation skills from the very beginning of their studies. Consequently, the traditional gap between 'theoretical teaching' and 'practical requirements of working life' would be filled, enhancing the professional growth of students during their studies. For instance, innovations can be created already in the educational context by working in multi-disciplinary teams together with companies and other organisations; additionally, innovation skills can be scaled more accurately to adapt them to future working environments.

Learning

Learning can be defined as a process where behaviour changes as a consequence of experience [6]. The humanistic way of understanding people as the creators of their own future forms the philosophical foundations of innovation pedagogy.

Innovation pedagogy also includes assumptions which are in congruence with cognitive learning. Cognitive theory defines learning as a behavioural change based on the acquisition of information about the environment. Through diverse learning environments, active learners are exposed to new situations where new insights can be gained in a dialogic process. The basic assumptions of constructivism argue that humans generate knowledge and meaning from their experiences. This means that knowledge is always tied to the person who possesses it. [7].

Cultural ways of behaviour guide the learner; thus the process of learning can never be separated from the specific culture by which it is surrounded. Innovation pedagogy reinforces the development of understanding and learning, which

in turn supports the central idea of innovation pedagogy: producing, further cultivating and finally commercialising innovations in higher education.

Knowledge

When learning is understood as a learner's conscious knowledge formation process which takes place in a certain cultural and social context [8], knowledge is considered to be an object, which has certain characteristics enabling it to be used when internal cognitive models are being built. These models are born as a consequence of learning.

Gibbons et al. [9] and Nowotny et al. [10, 11] distinguish two different modes of producing knowledge. They make a distinction between academic scientific knowledge and the knowledge born in situations originating from the need to solve practical and application problems. The concepts of expert knowledge, know-how, tacit knowledge and intuition are important in contexts relating to application. Professionalism requires making tacit knowledge explicit and developing it further in a triadic interaction process between students, teachers and working life.

One of the basic assumptions regarding innovation pedagogy is that the knowledge produced and accumulated in learning environments challenges the traditional way of understanding knowledge.

Innovation in pedagogical context

There is no one and only way of defining innovation. Schumpeter [12] discusses innovative entrepreneurship and argues that it can lead to better performance in business. Rogers [13]states that an innovation can be defined as an idea, object or a way of doing things which is considered new. According to him, an innovation does not have to be new in absolute terms, but the individuals involved must consider it as something new. A report of Sitra [14] suggests that an organisation possessing excellent innovation ability is able to constantly channel the creativity, know-how and all other resources of its personnel, service producers and customers to new solutions and innovations, which results in financial benefits. In Finland's National Innovation Strategy [1], 'innovation' refers to utilised competence-based competitive advantage. An innovation is generated by a combination of different competencies. An innovation can be radical or incremental [15]. Innovation has also been mentioned together with education. Tella and Tirri [16] define educational innovation as a product or a process which didn't exist before. Innovation can also be considered as constant improvement. When discussing innovation pedagogy, Kettunen [5] defines innovation as an idea utilised in working life. Pedagogical innovations sometimes lead to technological innovations, which can be patented.

In the context of innovation pedagogy, innovation is understood as the process of constantly improving know-how, which in turn leads to new ideas, further know-how or other practices applicable in working life. In universities of applied sciences, learning can occur at the university, in working life or at the interface in between. Virkkunen [17] presented a model about the development of occupational education, which was based on the above mentioned learning contexts. Hyrkkänen [18] considered the model from the viewpoint of individual's learning and introduced a refined two-dimensional model as depicted in Figure 1.

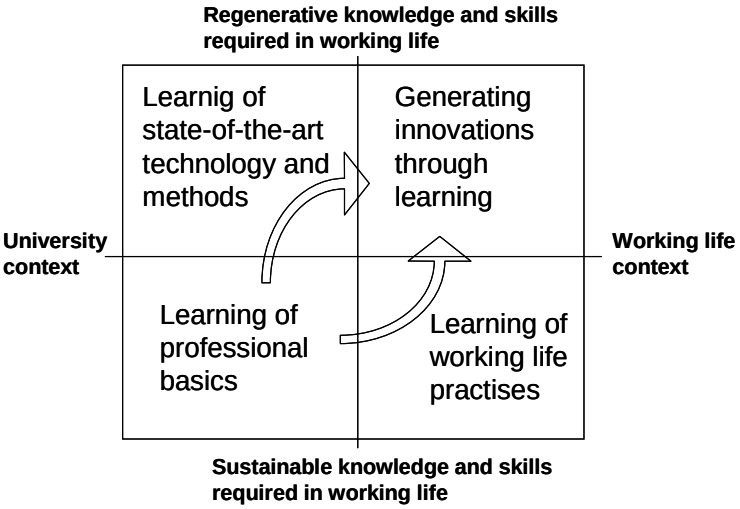

FIGURE 1:
FRAMEWORK FOR GENERATING INNOVATIONS THROUGH LEARNING (ADAPTED FROM [17, 18])

Firstly, the learning context can be the university or working life (horizontal axis). Secondly, working life requires both sustainable or regenerative skills and knowledge (vertical axis). The left hand side refers to traditional learning in a university context. Students learn professional basics at the beginning of their studies and the state-of-the-art technology

and methods later, when they are finalising the studies. The right lower hand quadrant refers to learning in close co-operation with working life, such as during the training periods. In that case, the main learning target is related to working life practises. When generating innovations through learning is targeted during the studies, the upper right hand section should be pursued. The concept of innovation pedagogy presented in this paper can be positioned in this quadrant. There, new regenerative knowledge and skills are required in order to achieve innovations for working life purposes. It can be seen as an end point for the two optional connective paths that originate from the learning of professional basics.

STUDY CONTEXT AND METHODOLOGY

The faculty of Technology, Environment and Business in TUAS is a multidisciplinary faculty with a yearly intake of 300 engineering students, 100 business students, 50 design students and 50 sustainable development and fisheries students. The environment in which the students begin their studies is fundamentally cross-disciplinary. Due to the industrial structure surrounding the faculty, there is an external pressure for our engineers, in addition to their core engineering competences, to be able to co-operate and tolerate insecurity, to be internationally minded and culturally literate as well as to have good language and presentation skills. Additionally, the industry also expects the students to be able to contribute to innovations and to be open and broad-minded when performing their engineering tasks in the future.

The first step of the study was to find the theoretical basis for the new learning and teaching approach that aims to enhance engineering student's innovation skills. A multidisciplinary approach was selected. The focused literature review from the pedagogical and design science's point of view was conducted by the various combinations of the key words such as: 'learning', 'teaching', 'knowledge creation', 'innovation' and 'product/service development'. The novel framework, called 'innovation pedagogy', was then inductively conceptualised by combining the principles supporting learning and innovation from the existing solid theories.

The concept of innovation pedagogy was then discussed and interpreted with the teachers and other personnel in TUAS. After three months of discussion an inter-organisational call for papers was announced in order to publish a book regarding the course cases to which the principles of the innovation pedagogy had already been applied. There was a need to assess how the new concept was perceived and accepted in the faculty of Technology, Environment and Business.

Finally, nine published articles about the innovation pedagogy cases were analysed based on the previously discussed framework adapted from [17] and [18].

RESULTS

Theoretical framework of innovation pedagogy

Innovation pedagogy does not start with knowledge and move later to its application; new information is applied to practical situations immediately, even before the information is assimilated. Innovation pedagogy combines learning with information creation and its application. By definition, *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.*

Figure 2 illustrates the framework of innovation pedagogy. The model helps to bridge the gap between the educational context and working life. The learning processes are deepened and strengthened, when the previously gained knowledge is continuously applied in practical contexts where representatives of working life are involved. The circle of continuous improvement ensures the professional qualifications of students. This professionalism is responsibility-centred as well as development-oriented; it encourages actors to absorb and create new knowledge, which supports innovation creation in working life. In surroundings like these, learning and teaching methods are developed more expediently, operations and competitiveness regarding working life are enhanced and new innovations are potentially created.

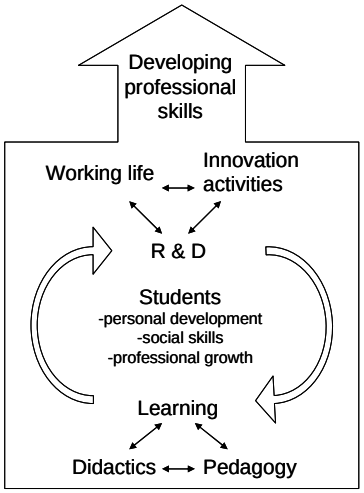

FIGURE 2:
FRAMEWORK OF INNOVATION PEDAGOGY

On a practical level, innovation pedagogy refers to an approach to learning and teaching from the perspective of emphasising working life and R&D skills. This means applying existing learning and teaching methods in a creative, value-increasing way. Simultaneously, new methods are developed and put into practice while ensuring that students take responsibility for their learning and that they actively pursue their learning objectives. As a result, graduating students have professional skills and qualifications, which are both innovative as well as development-oriented. Therefore, innovation pedagogy moves further from traditional theoretical learning, to application of learned skills to practical development challenges.

Analysis of the course cases

Table 1 summaries the results of the course case analysis. Nine case descriptions, from the faculty of Technology, Environment and Business, are published as individual articles in [19]. Especially interesting indicators from the viewpoint of innovation pedagogy are the principal learning method, key learning substance, type of knowledge and skills to learn, learning context as well as working life participation. Learning methods include the versatile variations of methods, such as teamwork and problem-based learning. Learning substances also covered wide area of skills needed in engineering and economy professions. Type of knowledge and skills to learn were either sustaining or regenerating in terms of requirements of working life. The single learning context was university in four cases and working life in one case. Both the university and working life can be seen as learning contexts in three cases. Representatives from the working life were somehow participating in the courses in four cases and five courses were held without working life involvement.

Case	Authors	Principal method	Key learning substance	Type of knowledge and skills to learn	Context to learn	Working life participation
C1	Kanerva-Lehto, H.; Lehtonen, J. ; Jolkkonen, A.	Teamwork	Project management	Regenerating	University	No
C2	Lyytinen, S.	Multidisciplinary teamwork	Social skills, project management	Sustainable	University	No
C3	Hyyppä, V.	Interview	Networking, Exploration of professional's tacit knowledge	Sustainable	Working life	Yes
C4	Lehtonen, J.; Vierimaa, R.; Hänti, S.	Project work	Innovation process and product development	Regenerating	University and working life	Yes
C5	Hänti, S.	Project work	Sales skills	Regenerating	University and working life	Yes
C6	Falck, K.; Jalkanen, K.	Business simulation	Economical processes and desicion making	Sustainable	University	No
C7	Rantala, J.	PBL with software tool	Enterprise resource planning (ERP)	Regenerating	University	No
C8	Paanu, T.; Nieminen, K.; Nousiainen, P.	PBL by e-learning	Problem solving, project management	Sustainable	University	No
C9	Helmisaari, J.; Virtanen, V.	Project work	Civil engineering project	Regenerating	University and working life	Yes

TABLE 1:
ANALYSIS SUMMARY OF THE COURSE CASES

The results of the course case analysis summarised in Table 1 are mapped in the framework regarding new kind of learning (Figure 3) adapted from [17] and [18]. The placing of the nine courses into the framework spread in all quadrants. Cases C2, C6 and C8 are placed in the lower left hand quadrant that refers to learning of professional basics in the university context. Cases C1 and C7 are placed in the upper left hand quadrant that refers to learning of state-of-the-art substances that ought to regenerate technology and processes for use in working life. One case, C3, is placed in the lower right hand quadrant that refers to learning in close co-operation with working life, such as during the training periods. When generating innovations through learning is targeted during the studies, the upper right hand quadrant is interesting; the concept of innovation pedagogy is widely applied in the cases C4, C5 and C9.

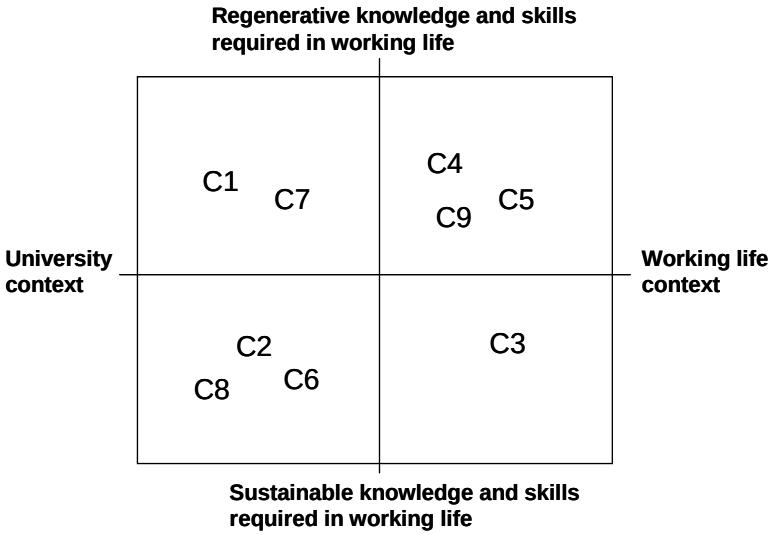

FIGURE 3:
COURSE CASES MAPPED IN THE FRAMEWORK FOR GENERATING INNOVATIONS THROUGH LEARNING

DISCUSSION

The aim of the paper was to present the new concept of innovation pedagogy developed in TUAS and to analyse nine documented course cases through which the concept was introduced. As defined in this paper, innovation pedagogy is a specific learning approach that supports innovation discovery via knowledge creation, adaptation and exploit. Thus the question regarding the nature of knowledge behind innovations becomes essential. The model for innovation pedagogy was constructed based on previous studies on pedagogy and innovation research.

Innovation pedagogy rests on knowledge the need for which arises from social and economic contexts. The starting point for producing this knowledge lies in practicalities congruent with views presented by Gibbons et al. [9] and Nowotny et al. [10, 11] on mode 2 knowledge. Similarly to mode 2 knowledge and R&D, innovation pedagogy strives for contextually emerging and cumulative knowledge, which is also boundary-breaking, practical and societally durable by nature. As a theoretical framework, it helps to understand phenomena such as knowledge cumulation and boundary-breaking from the viewpoints of innovations. Three of the analysed courses were intended for learning of professional basics and two of them for learning of state-of-the-art knowledge and methods. Knowledge cumulation is required on the path towards generating innovations through learning. Differently planned courses should support such a knowledge cumulation. One course was especially designed for enhancing working life participation i.e. boundary-breaking between university and working life. Three courses were identified to support generating innovations through learning, which is the ultimate goal of innovation pedagogy. These kinds of courses have great potential for creating innovations in collaboration with working life.

Creating innovations presupposes knowledge and the ability to apply it. The traditional view held by educational institutions is that students receive new information and skills as a student and only begin to apply what they have learnt after finding employment. This is exactly the way of thinking innovation pedagogy wants to challenge. According to this new approach, knowledge should be applied for creating innovations already while studying. In other words, knowledge should be accumulated and applied simultaneously. According to the principles of innovation pedagogy, individual expertise should be transformed into communal expertise, which promotes controlling knowledge and developing problem solving skills [20]. These arguments are also supported by Viljamaa et al. [21], who found that innovation processes must be based on a new kind of synergy and collective learning between local companies and the operational

environment. Innovation pedagogy can be seen as a pedagogical innovation in itself. Separated from the traditional view, a pedagogical innovation is based on the new outlook on learning and possibly utilises new technology in a fresh manner.

Innovation pedagogy underpins learning by favouring actual working life development challenges being brought under discussion, in which students, teachers and working life representatives all take part. In addition to efficient learning, innovation pedagogy strives for new ideas, operating models and innovations applicable in working life. These aims are consistent with sociocultural theory as discussed by Vygotsky [22], Wenger [23] and Hakkarainen et al. [24] in regard to the two-way interaction between theory and practice. Theory helps in solving practical problems and sometimes operating models born of practical contexts may evoke scientific breakthroughs, so why not innovations as well. Based on the findings of the course analysis, the learning method or substance itself is not a crucial factor in terms of innovation potential. In contrast, the context of learning and the types of knowledge and skills to learn are factors leading towards generating innovations through learning.

Being as recent as it is, the concept of innovation pedagogy offers various opportunities for further study. One of the most interesting objects of study would be specifying the factors of the innovation competence more closely. The innovation factors would be used to determine how to evaluate and measure executing innovation pedagogy. The innovation factors could be utilised as a shared instrument when evaluating the maturity of both working and educational communities. Additionally, modelling collaborative projects relating both to innovation pedagogy and the companies involved also offers an interesting research subject. This research illustrated the fact that the innovation pedagogy approach can be a powerful starting point in developing learning environments and technology as well.

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