INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8 & 9 SEPTEMBER 2011, CITY UNIVERSITY, LONDON, UK

CHANGING MINDSETS: IMPROVING CREATIVITY AND INNOVATION IN ENGINEERING EDUCATION

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ABSTRACT
This paper summarizes an initiative undertaken by PIEp, KTH and Stanford University to stimulate Swedish engineering faculty to embrace methods and tools for integrating creativity and innovation in higher engineering education. Ultimately, building on previous experiences of successful workshops held by PIEp and KTH within this context, the overall ambition is to establish a change in mindsets, and by so influencing key participants to directly leave endurable footprints onto their respective Swedish engineering education programs. The paper has a descriptive character blending 'best-of-both-worlds' concepts as it reveals how a nationwide Swedish initiative has set up a learning hub overseas together with Stanford University. Utilizing this source of entrepreneurial and inspiring environment the ambition is to equip Swedish faculty with experiences, success stories and lessons learned to enthusiasm and challenge existing program and curricula design. Overall, this paper entails the set-up, reflections and actions outlined by Swedish university representatives to address implementation of more transferability between innovation characteristics in respective education programs.

Keywords: Product innovation engineering, curricula, course program, redesign, creativity, innovation

1 INTRODUCTION

Universities need to reconfigure and rethink existing engineering beliefs in order to keep promoting students that can target and capitalize on tomorrow's opportunities. When addressing new ways to fundamentally intercept the current education setting, the idea to rethink learning processes and what should be the take away for future university graduates have come to a pause. A proposed lack of creativity and innovation puts emphasis to better acquiring and applying knowledge and skills that matches authentic use of prerequisites [1]. This puts pressure on promoting the best possible engineering education, which means continuant upgrades and revisions to existing curricula and faculties' pedagogical methods and processes. This paper addresses some of these fundamental attention breakers as a "mind bending experience" was planned, executed and evaluated with participating scholars. Searching for elements to acknowledge, emphasis or drastically remodel existing boundaries provided an open ended approach. Characterized by prerequisites towards fundamental changes at university level (i.e. program and courses) the aim was to document initial steps taken and effects caused by either experienced change mechanisms. The paper also summarizes the experiences and lessons learned from a nationwide initiative to rethink and redesign existing engineering programs towards more traceable innovative practices. In the next section we present the study's design set up and documentation efforts made with a focus on the "before and after perspectives" (i.e. pre- and post views). Then, a background and rooted mechanisms are presented that tries to enable this desired change before stating some concluding remarks.

2 FOUNDATIONS TO A CHANGE IN MINDSETS

The actions taken towards fostering a change in mindsets follows a series of pre-workshop roundtable discussions (i.e. moderated focus groups) were all KTH program coordinators were invited at three

separate occasions. Before joining the actual workshop, participants applied by writing a motivational letter where they addressed the need for changes in their respective domain. Table 1 expresses details about the separate occasions as they are labeled in correspondence to their location; 'KTH Salongen', 'Lidingo' and 'Kista'. Two months after returning home from the Stanford workshops, the participants were offered to participate at a focus group and be part of a first evaluation of the workshop. A confirmation status or implementation query was also sent out to pin-point the level of implementation among all participants upon returning home. This e-mail was destined to cover the few KTH individuals (3) that were unable to attend, however this was also an effort to broaden the picture of the achievements made by all workshop participants, including the PIEp participants.

Table. 1 Design set up for focus groups and supportive e-mail query

Pre-/post Occasion	Date	Moderator	'Secretary'/ Recording	Invited	Participants or Responses	Pre- and Post Workshop Responses
'KTH Salongen'	2010-01-25	Y	Y/N	35 (7*)	35	
'Lidingo'	2010-05-18	Y	Y/N	60 (16**)	8	
'Kista'	2011-01-12	N	Y/N	30	6	49 (48 unique)
Post meeting	2011-02-14	Y	N/Y	12	6	
Post status query	2011-02-28	-	-	17	12	18 (12 unique)

* The round-table format with limit to 7 seats per session (10min). Five sessions were conducted 5*7 participants.
** The round-table format with limit to 8 seats per session (20min). Two sessions were conducted 5+3 participants.
^ This session were conducted with teachers not participating in the workshop and thus classified as a preconception.

3 A SYSTEM CHANGE TOWARDS CREATIVITY AND INNOVATION

The Swedish Product Innovation Engineering Program (PIEp) and the Royal Institute of Technology (KTH) in particular have a long tradition of successful exchanges involving research and education [2]. PIEp is committed to a system change towards innovation and entrepreneurship in institutes of higher education and research [3]. From PIEp an organized network of senior researchers, PhD students, lecturers and students is seen as the seed for this change [3, 4]. Activities are conducted in three areas; research in product innovation, education for product innovation and industrial collaboration for product innovation [2]. Turning away from one-timer and mere embryonic attempts, PIEp visions a systems shift through long term dedication to influence higher engineering education curricula design [5]. KTH is currently performing a revision of all engineering program to fit the European Bologna higher education restructuring process. Encompassing both undergraduate and master level studies, the integration of engineering syllabus imperatives strive to converge with the internationally recognized CDIO standards and the new Swedish national degree specifications. KTH CDIO is an institutionalized initiative that works on four parallel tracks; communication, teamwork, endurable development and innovation, to support a university accredited CDIO restructuring process. Innovation constitutes the common denominator for both PIEp and KTH, with distinctions on attention level, i.e. national/local.

3.1 Innovation in Education

The main vehicle of PIEp's long term change is the concept of students as agents of change – making tomorrows engineers better prepared for product innovation. PIEp runs a national network of educators; providing funding and mechanisms for inspiration and exchange of experience and best practices. Within the context of this network, PIEp has offered – and continues to offer – a number of workshops and activities such as the effort outlined in this paper. Innovation in education can be twofold: on one hand PIEp strives to increase the number of educated students with a greater understanding of innovation; mechanisms for (and against) innovation, entrepreneurship and creativity. On the other hand PIEp also strives to increase the output in terms of innovators; the number of students graduated from universities capable of innovating. The first aim is deemed to be the easiest to achieve – characterized by a trend were universities have already adopted programs and courses that incorporates innovation and entrepreneurship. This is very much appreciated, as the

realization that there is a need for these engineers, but it is not apparent that these programs educate neither innovators nor entrepreneurs – but rather individuals with knowledge about innovation and entrepreneurship.

3.2 Systematic Faculty Development

In an evaluation by the Swedish National Agency for Higher Education it was declared that the pedagogical development projects being performed at Universities were missing out on a supporting mechanism that could facilitate this process [6]. Several projects were performed by individual faculty members that got classified as enthusiasts. The conclusion was that single pedagogical development projects rarely lead to a sustainable improvement or change of engineering curricula, programs or courses. Faculty prioritized research ahead of teaching, partly since incentives for acknowledgement are mostly resided in research. Changes were needed! During the time this evaluation was performed, the KTH Learning Lab was established with the overall purpose to rethink and promote the way pedagogical development units was functioning and organized at technical universities, and ultimately how the quality and attractiveness of engineering education should be improved. As a cornerstone in the work to create a new way of education development, the Wallenberg Global Learning Network (WGNL) was a driving force for improving engineering education by focusing on the students and faculty members in an institutional context [7]. By focusing on the balance between individual faculty members pedagogical development and the institutional responsiveness to change in a global university context could be made. In the aftermath to this initial change process, the 'CDIO Initiative', an innovative educational framework for producing the next generation engineers was started in 2000 supported by Knut and Alice Wallenberg foundation [8]. The framework provides students with an education stressing engineering fundamentals set in the context of real-world systems and products. Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment. CDIO collaborators recognize that an engineering education is acquired over a long period and in a variety of institutions, and that educators in all parts of this spectrum can learn from practice elsewhere [9].

3.3 Faculty Preconceptions of Innovation

Innovation in engineering education is not the easiest thing to approach. Perspectives may differ tremendously depending on background on contextual relevance. Creating an understanding of teachers' perspective rather than forcing them to incorporate existing definitions opened up a series of sessions that in retrospect took the views towards a more tangible area of relevance from teachers' respective background. To set the states of teachers' expectation and views of innovation in education two focus groups of teachers discussed the role of innovation in education and the content of the concept innovation. The aim was to make an inventory of the teachers view on and knowledge of innovation in general or more specific innovation in engineering education. In the discussion there were also opportunity to discuss in which ways innovation skills could be a part of the curricula and how innovation could be integrated in subject courses with progression during the whole program. The teachers that took part in the focus groups all had difficulties to clarify and define what 'innovation in engineering education' would consist of. In the focus group discussions it more or less was norm to define innovation as something at the very right on a polarized axis where creative upraises and business ventures could be found in either end of a conceptual image.

When discussing innovation, creativity kept coming back, not surprisingly, as a fundamental root to innovation. However, this was also considered an aspect that is vague in expressing itself, not prioritized or simply forgotten when concretizing innovation in education. To manifest their own perspective, the teachers asked themselves '*what is innovation and how do we define it for the student?'* An overall answer was all but easy to grasp. The participants expressed having a limited knowledge about innovation and interconnected it with entrepreneurship even if they did not like that connection. Without stating any form of misconceptions participants forced themselves to disregard their current view of innovation where entrepreneurship was unanimous with innovation to pieces that more easily could be comprehended and fit existing course curricula. The concept of innovation and entrepreneurship occurs to be far too abstract and in that meaning the teachers could not see the usefulness and the importance of integrating innovation in the curricula. The preliminary analysis of the pre-workshop focus groups indicate that teachers 'current' view tend to favor an innovation definition that encompasses a tendency to industrial applicability and thus more towards a right part of

a continuum. From an educational perspective respondents proposed an ideal position where innovation could be more tangible and expressed through distinguished activities or methods. Thus, the teachers' 'ideal' focus looks at innovation as something that would relate more to elements of creativity and earlier phases of development (see Figure 1).

Figure 1. Teachers' preconceptions and views on innovation

To expand the teachers view of innovation to also include creativity do not solve all aspect of integrating innovation in the curricula but it was clear that the focus groups had much more easier to handle the problem. Table 2 summarizes teachers' preconceptions or current 'point of views' where innovation and implementation thereof is faced with a dilemma as part of engineering education. The latter part expresses examples of how innovation criteria are perceived to be integrated in line with the progression of the first three years in an engineering program.

Table 2. Educators Preconceptions of Innovation

Teachers definition of innovation in engineering education
Ability to model, analyze, identify potential opportunity for developing by handling open issues Ability to understand innovation processes, group interaction and social environments Ability to understand how innovation processes occurs
Innovation criteria year 1-3
Year 1: the student should be able to handle simple open problems and be able to discuss and explore different problems and compeer different types of solution. Year 2: the student should be able to identify problems where standard solution do not fit and be able to understand group dynamic condition in the innovation process. Year 3: the student should be able to handle open problems where different competences are needed.

3.4 Changing Mindsets @ Stanford University

Members of Swedish faculty were invited to a workshop organized overseas in collaboration with Stanford University. The reason why Stanford University was selected Stanford for the location of the workshop was a desire to be inspired by the entrepreneurial atmosphere in Silicon Valley. It was also important to get a cultural experience for participants to been able to embrace one of the most noticeable aspects of Stanford campus, the rich diversity. The workshop took place mid-December 2010 and comprised of five fully scheduled days including several specially invited speakers.

Table 3. Workshop program overview

Day 0	*Informal welcome dinner, connecting and setting the workshop mode – the atmosphere*	Overall daily *THEMES* and Descriptions
Day 1	Design thinking lecture and d.school tour CARS-lab visit Innovation journalism and entrepreneurship	Breadth – theme understanding, essential areas: *Design thinking, Innovation and Entrepreneurship*
Day 2	Foresight and innovation workshop The Joy of Creativity IDEO visit	*Tools for perceiving future challenges and understanding of Creativity*. Hands-on program redesign, 1st prototypes on curricula/program shifts and design perspectives on creativity
Day 3	Teamology workshop Prototyping presentation at Design X – BBQ	Teams as a way to create newness, *collaborative efforts, creating innovations and prototyping* program changes
Day 4	Instrumenting and measuring innovation Google visit	*Measuring and assessing innovation* through portfolio traceability
Day 5	Visit to UC Berkeley, Berkeley Institute of Design *Social closing, Alcatraz visit*	*Change in perspectives*, other ways in perceiving innovation and creativity in design projects

A total of 35 participants including speakers were contributing with experiences during the workshop. Of those, 17 participants were members of Swedish faculty from all Engineering disciplines, including

one from each PIEp member university and representatives from the invited nine KTH Schools. The remaining participants were guest lecturers, invited speakers and international guest faculty that joined the workshop. To create a change manifesto, a central take away from the workshop were the individual prototypes that were developed and presented during the week. By addressing specific concerns the prototypes addressed a desired scenario where innovative criteria were looked after in respect to each participant's course or program of concern.

3.5 Evaluation of the Stanford Workshop

The participant described in what sense the workshop had changed their thoughts about innovation and were asked to describe how much the prototype had been developed after returning home and what the next step in the process meant. The participants also pointed out areas where some problem had been identified. The wishful idea of establishing a change on both program and course level is perceived with fewer obstacles as the 'just-do-it'-approach brought forward during the workshop has eased the magnitude of such shifts. This was also paraphrased by a participant during the post-workshop session; *'Let it happen, Larry said'*. Based on participants' post-statements the Stanford workshop was responsible for having impact, stirring changes, approaches and plans. The participants describe a feeling of faith and believe in change. Even if some of the participants already had encountered obstacles they were positive in their mind. One participant said *'I have in mind the atmosphere of Stanford, my ideas I get from there are always there but unfortunately I have not make any change yet, but I will! I do not give up!'* The participants' had reached different level of adapting the prototype and thus put their conceptual ideas of change in to practice. Three types of 'situation' could be identified in the evaluation in each of this types are represent by an example and for every types also identified problem are given (Table 4).

Table 4. Level of Implementation

	Implementation status	Difficulties and/or barriers
Type 1	Not started yet but planning. *"I would like to do something like the d-school at our school. I know it is possible"*	External artifacts and organization *"But like always, to make changes at KTH takes time…"*
Type 2	In the starting blocks *"The changes are so big and I have not started the course yet. But when I plan lectures my intention is to be more creative"*	Not yet *"It starts in the autumn semester. So the work has not started yet"*
Type 3	Up and running *"I make course development based on my prototype. When the course starts in the autumn it will be a whole new course"*	Nothing can stop me *"I had been forced to change some ideas in the prototype, but I think I was to tanning when I did it so it does not matter. I have no project room yet, but soon."*

In the e-mail query, the participants defined their current implementation level. They were also given the opportunity to explain and further develop experienced problems or barriers in the implementation process. Based on the perceived level of achievement, participants (n=12) in the post-evaluation categorized their status in distinctive categorizes. These match a motivational characteristic where a participant were in either of two extremes, either in a 'doing it' mode or 'to do' mode. Figure 2 illustrates these clusters and how far participants have continued with their inspirational change ideas.

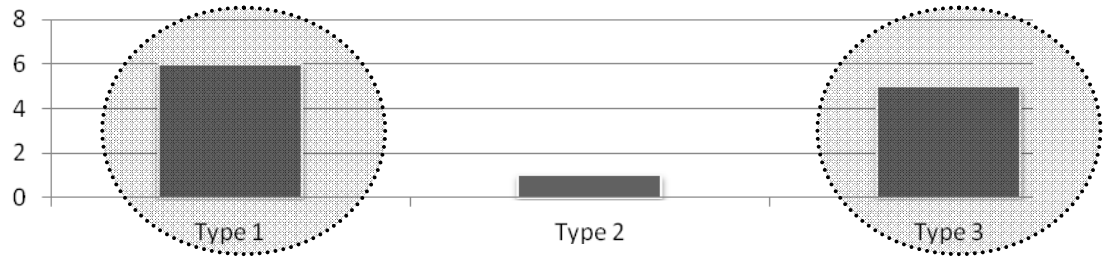

Figure 2. Status of Implementation Level

The type 1 respondents expressed ambitions to make *'some changes'*, however due to time constraints and future planning momentum had yet not been picked up speed at this stage. Type 1 respondents also described that discussions had been initiated to make changes happen and in some cases at least had in mind to make changes. Type 3 respondents had all started working on changes; plans for implementation were in place. Driven by inspiration towards, change difficulties and barriers seemed less constrained for type 3 respondents. Two types of behaviors towards making change efforts have been identified. Those that have actually started to redesign their existing programs and those that have not yet been able to get things started, although the willingness might be at a higher level.

4 CONCLUSIONS

Proposing change of any kind involves a certain degree of effort to be made. Changing the status quo in academia where structure and traditions need to be broken down involve a serious amount of efforts. Embracing elements that can radically reshape some of our existing program structure or placing attention of detail in a new direction pushes boundaries where resistance to such change is massive. Thus efforts that encompass this resistance to change need strong motivational incentives. Supporting a team of change agents rather than solitary individuals a proposed collaborative effort such as 'the changing mindset' workshop format could be a motivated way to influence to such initiates. Provoking or rather rephrasing preconceptions by breaking up beliefs and placing a mantra of newness in the hands of operational change agents (i.e. program coordinators) causes somewhat of an individual shakeup, or 'wake-up' in some cases. At this point a few promising attempts have already started to take form. Fueled with ambition the path towards change and incorporation of new practices is just beginning to pick up momentum. This paper gazes at an opportunity window that propose an activity driven agenda where responsible faculty are prepared to implement what they consider innovative change ideas. In more detail, more precise outlines and execution of actions would provide valuable insights for a larger audience in terms of possible good examples and lessons learned. The work towards program and curricula change and its later outcomes thus propose an incentive for further follow-ups among participants. Underlining that this is beyond the scope of this paper, future lessons learned and changes worth taking highlight of, should be looked at in a change continuum. If by any chance inspiration for this change could be back-traced to this relocated creativity and innovative changing mindset event, we hope a larger audience could set up or take part of similar events to strengthen the foundations for this change.

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