Where have all the inventors gone? The lack of spirit of research in engineering education

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The European Union has declared 2009 the European Year of Creativity and Innovation. Facing tremendous problems, creativity and innovation were seen at the heart of the strategy to transform Europe into a knowledge-based society that is able to cope with ongoing and future problems.[1] For example, new techniques to tackle climate change are urgently needed, new ideas on how to retain mobility of people, new concepts for energy production without fossil fuels. Engineers play an important role in addressing these challenges. Their ideas, their inventions, their creativity have brought Europe's prosperity, and it will depend on their inventions and creativity to ensure that progress in the future.

This raises the question in what way universities contribute to educate creative engineers nowadays. The results of the German research project "Da Vinci – fostering creativity in higher education" (supported by the German Federal Ministry of Education and Research BMBF, 2008-2011) show, that creativity in higher education (across all disciplines) consists of six different aspects (Haertel/Jahnke 2011a; Haertel/Jahnke 2011b; Jahnke/Haertel/Winkler 2011; Jahnke/Haertel 2010):

(1) self-reflective learning – learners break out of their receptive habitus and start to question any information given by the teacher. An internal dialogue takes place and knowledge becomes "constructed" rather than "adopted".

(2) independent learning – teachers stop to determine the way students learn. instead, students start for example to search for relevant literature on their own, they make their own decisions about structuring a text or they even find their own research questions and chose the adequate methods to answer it.

(3) curiosity and motivation – this aspect relates to all measures that contribute to increased motivation, for instance the linking of a theoretical question to a practical example or presenting.

1 http://ec.europa.eu/enterprise/magazine/articles/innovation/article_7381_en.htm (3/13/2012)

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(4) learning by doing – students learn by creating a sort of "product". Depending on the discipline, this might be a presentation, an interview, a

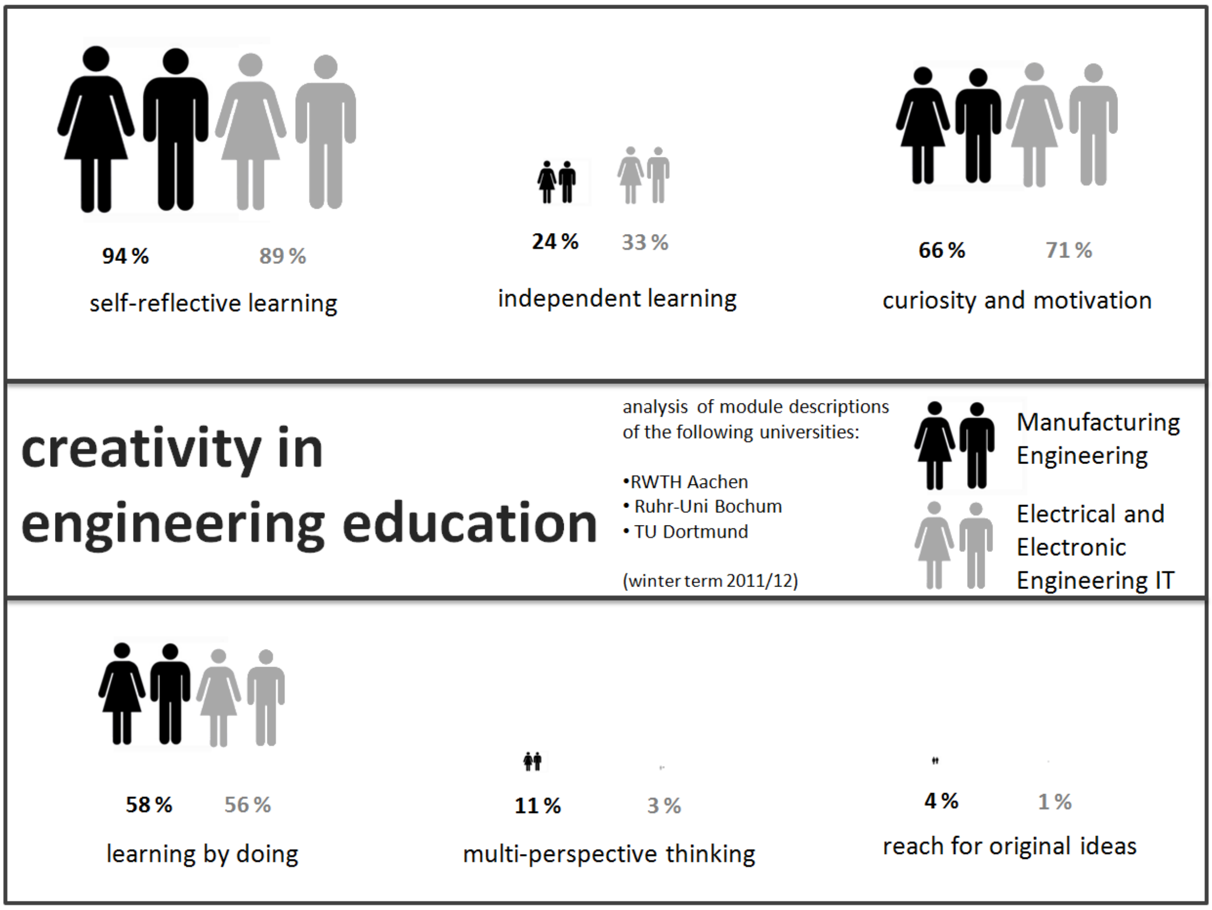

Fig. 1: creativity in higher education: analysis of module descriptions

questionnaire, a machine, a website, a computer program or similar. Students act like "real" researchers.

(5) multi-perspective thinking – learners overcome the thinking within the limits of their disciplines or prejudiced thinking. They learn to look automatically from different points of view on an issue and they use thinking methods that prevent their brain from being "structurally lazy"[2].

(6) reach for original ideas – learners aim to get original, new ideas and prepare themselves to be as ready-to-receive as possible. Getting original ideas cannot be forced, but by the use of appropriate creative techniques and by creating a suitable environment (that allows making mistakes and

2 According to Spitzer (2000) brains are used to work with mental patterns. The more successful such a pattern is, the stronger it becomes and the more often it is remembered and used again. Considering Spitzer's theory, for example most adults' brains have saved a very strong mental pattern for brushing their teeth. Regarding the brain, this is very helpful and effective, because those adults don't need to figure out each morning anew how to brush their teeth. Regarding creativity, this is obstructive, because those adults won't ever invent a new, maybe more effective way of brushing teeth.

expressing unconventional ideas without being laughed out or rejected), the reception of original ideas can be fostered.

Everything that was said by teachers[3] about creativity in higher education fits in one or more of these six aspects. This suggests that these six aspects in their entirety describe what constitutes creativity in higher education. But it was also shown that different disciplines tend to focus on different aspects.

Against this background, we analyzed the module descriptions of two engineering courses (Manufacturing Engineering and Electrical and Electronic Engineering IT) of three German universities (Aachen, Bochum, Dortmund) in order to get to know which aspects of creativity are fostered in today's engineering education.[4] As a result, fostering the creativity-aspects 1 (self-reflective thinking), 3 (curiosity and motivation), and 4 (learning by doing) is highly developed in both courses of all three universities. With one exception these aspects have shares of over 50%. On the other hand, the aspects 2 (independent learning), 5 (multi-perspective thinking) and 6 (reach for original ideas) can be found only in small proportions with percentages below 50%, in aspects 5 and 6 with one exception even below 10% (see. fig. 1).

To sum up, the analysis of the module descriptions shows that in the considered courses students were encouraged to think critically and self-reflective. They had to demonstrate motivation and commitment in their courses and they were trained to "create" something, to work practically. Independence, collaborative development of ideas and the exchange with other disciplines and for open-minded discussions, scenarios and experiments, however, were almost not required and promoted. These results need to be treated very cautiously; they depend on a very small, arbitrary sample of only 2 courses from three different universities. Further studies need to be done urgently. But together with empirical experiences in engineering education a picture of diligent students, who rather work conscientiously on given tasks than finding new problems, questions and solutions on their own and in discussion with others, is emerging. Also, the fact that in some of the courses the students were not free to choose the topic of their thesis reinforces this picture. Instead, they have to choose it out of a pool of given topics developed by the teachers. In this way, many learning processes that require creativity weren't done by the students, but by the teachers: the detection of relevant research questions, the deliberation whether an issue is workable, the creation of a structure and the assessment of eligible methods. Due to this, students aren't able to see "big picture" of their discipline,

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3 Within the DaVinci project, 20 qualitative expert interviews and an online-survey of all teachers from three universities in the Ruhr area were conducted.

4 These works were part of the ELLI-project ("Exzellentes Lehren und Lernen in den Ingenieurwissenschaften") 2011-2016 funded by the German Federal Ministry of Education and Research (BMBF) in combination with the project "TeachING LearnING.EU" 2010-2013 funded Stiftung Mercator and Volkswagen Foundation.

which is only seen by the teachers. They don't get in touch with the "spirit of research": the (collaborative) reasoning about current issues in the community, setting up and discussing new (and sometimes as well risky) theories, the making of own decisions and seeking collegial advice. When students are able to see the "big picture", they get a felling about the value and importance of their work. Through these findings, the question arises whether this understanding of fostering creativity in engineering education is appropriate. However, students seem to have a different understanding of creativity. A (interdisciplinary) survey (n=320) at TU Dortmund University (Germany) shows that students regard "openess", "freedom", "stimulation", "inspiration" and "empowerment" as factors that promote their creativity. Fortunately, there already are some beneficial approaches that meet these requirements. The didactical concept of the "Platform for E-Learning and Telemetric Experimentation" (PeTEX) (Pleul et al 2011; Terkowsky et al 2011a; Terkowsky et al 2011b) is one example. PeTEX combines a tele-operated experimentation platform (material testing, particularly forming, cutting, and joining) with a collaborative learning environment. It provides three different learning levels: Students in the beginner-level are guided through the learning platform and are asked to carry out predefined experiments. In the intermediate-level, learners have to transfer their knowledge to given real-world scenarios and are encouraged to perform self-directed experiments. Learners at the advanced level have to design own research questions and to develop the appropriate experiments. The more the students have worked with PeTEX, the more freedom they get to define their own research problems and to find the answers on their own. Furthermore, PeTEX provides collaboration, not only with other students (from other universities and even other countries), but also with lifelong learners. In summary, PeTEX offers an important contribution to foster the "spirit of research". Regrettably, it is only a flagship project, of which there are indeed several. But altogether they still represent an exception in the reality of engineering education.

Radical Consequences

It remains unclear whether these points also play an important role from the perspective of the teachers and, furthermore, parts of the society: Does our economic society indeed need diligent professionals who execute given tasks instead of developing their own initiatives? What is the role of a new thinking culture? Does our industry require graduates that are used to think multi-perspectively? Are open experimentation and trying out new ideas, the search for the unknown new really important for a society in a globalized world economy? What wishes and visions do teachers, researchers, industry representatives, professional association representatives have with regard to the education of tomorrow's engineers and to their creativity and their "spirit of research"? What kind of education will be needed, if a society wants to bring up future inventors who are able to cope with the problem mentioned by the European Union? These questions should soon be discussed in a broad social debate.

The core of the questions raised here can also be found in a parable told by Hans-Jörg Bullinger on the opening of the ball of the Association of German Engineers (VDI) 2005: "Our students found the lectures on the meaning and purpose of DIN standards only limited fun. In a nice irony they told the story that a mathematics student and a physics student had just met an engineering student. They could not agree on the volume of a golf ball. So everyone picked up the methodology which corresponded to his field. The mathematician measured the diameter and the indentations on the surface and began to count. The physicist put the ball in a full glass of water and determined the displacement of water. And what did the engineer? He looked in the DIN standard for golf balls."[5]

Bibliographie

Haertel, Tobias / Jahnke, Isa, 2011a: Wie kommt die Kreativitätsförderung in die Hochschullehre? In: Zeitschrift für Hochschulentwicklung, Jg. 6, H. 3, S. 238-245

Haertel, Tobias / Jahnke, Isa, 2011b: Kreativitätsförderung in der Hochschullehre: ein 6-Stufen-Modell für alle Fächer?! In: Jahnke, Isa / Wildt, Johannes (Hrsg.): Fachbezogene und fachübergreifende Hochschuldidaktik. Blickpunkt Hochschuldidaktik, Band 121, Bielefeld: W. Bertelsmann Verl., S. 135-146

Jahnke, Isa. / Haertel, Tobias / Winkler, Michael, 2011: Sechs Facetten der Kreativitätsförderung in der Lehre – empirische Erkenntnisse. In S. Nickel (Hrsg.), Der Bologna-Prozess aus Sicht der Hochschulforschung, Analysen und Impulse für die Praxis, Gütersloh: CHE gemeinnütziges Centrum für Hochschulentwicklung, Arbeitspapier Nr. 148, S. 138-152

Jahnke, Isa / Haertel, Tobias, 2010: Kreativitätsförderung in Hochschulen - ein Rahmenkonzept. In: Das Hochschulwesen, Jg. 58, H3, S. 88-96

Pleul, Christian / Terkowsky, Claudius / Jahnke, Isa / Tekkaya, A. Erman, 2011: Tele-operated laboratory experiments in engineering education – The uniaxial tensile test for material characterization in forming technology. In: Javier García Zubía and Gustavo R. Alves (Eds.): Using Remote Labs in Education. Two Little Ducks in Remote Experimentation. Engineering, no. 8. University of Deusto Bilbao, Spain, 323-348.

Spitzer, Manfred, 2000: Geist im Netz: Modelle für Lernen, Denken und Handeln. Heidelberg u.a.: Spektrum.

Terkowsky, Claudius / Pleul, Christian / Jahnke, Isa / Tekkaya, A. Erman, 2011a: Tele-Operated Laboratories for Online Production Engineering Education. Platform for E-Learning and Telemetric Experimentation (PeTEX). In: International Journal of Online Engineering (iJOE). IAOE, Vienna, Vol.7 (2011) Special Issue: Educon 2011, 37-43.

Terkowsky, Claudius / Jahnke, Isa / Pleul, Christian / Tekkaya, A. Erman, 2011b: Platform for E-Learning and Telemetric Experimentation (PeTEX) - Tele-Operated Laboratories for Production Engineering Education. In: Auer, M.E. , Al-Zoubi, Y & Tovar, E. (Eds.): Proceedings of the 2011 IEEE Global Engineering Education Conference (EDUCON) – "Learning Environments and Ecosystems in Engineering Education". IAOE, Vienna, 491-497. Awarded the "Most Innovative Paper" regarding Engineering Education: Best Paper Award.

5 http://wiv.vdi-bezirksverein.de/mitbrief0604.htm (1/23/2012)