Creativity: Can It Be Taught? The Case of Engineering Education

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SUMMARY *Creativity in higher education is analyzed as an intentional act and related to a number of ideas from cognitive psychology. It is claimed that the culture of engineering education entails a too narrow view on creativity and is based on outdated learning theories. The deeper philosophical implications of creativity, i.e. the quest for meaning, will have to be readdressed if engineering education is to prepare its graduates for future tasks.*

1. Caveat

The empirical foundation, on which this article rests, is a decade of staff development within an institute of technology with a strong research bias and an undergraduate curriculum of a hierachical structure of subjects.

2. Introduction

Can creativity be taught as part of engineering education? No, says Francis T. Evans [1], and claims "You cannot teach creativity, but you can kill it". If this is true, why bother teaching? And why bother writing—and reading—an article like this one?

There is a great deal of controversy about the meaning of the word creativity, particularly in a university setting [2]. The literature is enormous and spans a number of disciplines:

(1) Psychology has focused on the individual's creativity and tried to identify the cognitive capacities and/or traits of personality that make up a creative person.
(2) Social psychology has studied the process of creativity as an interaction within a given context.
(3) Sociology (and organization theory) has emphasized creativity as an environmental process and studied efficient communication networks made up of prominent personalities with broad and deep knowledge.

It is important to distinguish between these approaches if one wants to discuss engineering education. If one believes that creativity is constituted by a set of traits of personality only, testing for those traits at entry level would seem to be a necessary and sufficient means to ensuring future creativity. If, on the other hand, one believes that the social context in which technology is shaped is important, and that the notion of an independent inventor is being phased out in favour of that of an efficient networker, interpersonal skills will have to be developed as part of engineering education.

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3. Intentions

There are, however, other ways to approach the phenomenon 'creativity'. One way is to find answers to the following questions. What are the driving forces behind creativity? What intentions do people have for creative work? There are at least four different answers which are relevant to engineering education, differing with respect to the intentions for creativity:

(1) It is man's inherent urge to be creative. The personal satisfaction in coming up with something new is enough reward for *Homo ludens*, the playful man; it is sheer fun to be creative. Here, creativity is a process towards, but not governed by, a possible outcome. The intrinsic rewards keep the process going.
(2) Man's struggle for survival is the source of creativity. Usefulness is now the supreme virtue. Since neolithic man turned a stone into an arrowhead or a tool for scraping and cutting animal hides, we have created new things by combining already existing ones in response to a perceived need. Here only the product counts. *Homo ludens* becomes *Homo habilis*.
(3) More recently, creativity has been heralded as the solution to the (perceived) world economic crisis. "If necessity is the mother of inventions, secure affluence seems to be its dysfunctional stepparent" [3]. Or, more bluntly: "Creativity is a critical asset in today's business environment, giving us that competitive edge that helps us stay ahead of the pack" [4]. This is the customer-oriented motive of *Homo economicus*.
(4) In research-oriented (academic) settings, fame is likely to be a motive for creativity. Many scientists have experienced the unique feeling that comes from knowing that you have seen (discovered, made) something never seen (discovered, made) before, and getting the credit for it. A possible term for this sort of identity would be *Homo excelsior*. Frequently, it takes the more vulgar form of a publish-or-perish rat race.

Obviously, reality is a mixture of these four archetypes, though not a static mixture. For example, *Homo excelsior* often pretends he is a *Homo habilis* or a *Homo economicus* by stressing the importance of basic research for the 'applied' sciences. *Homo ludens* claims his unquestionable birthright to be what he/she is, resisting attempts by politicians to convert him/her into a *Homo habilis*. These charades have to be understood before any attempt is made to put creativity on the agenda for engineering education. This is not primarily a question about subject content and modes of learning, but rather a question about the culture of the engineering schools: are today's research-oriented engineering instructors able to help their students to become creative engineers in their future workplaces? Obviously, there are local variations, but there seems to be consensus in the literature about an imbalance between research and teaching, between specialist competence and practical experience. It is indicative that a number of attempts have been made to justify the importance of research as a base for undergraduate teaching by searching for correlations between good research and good teaching. However, no positive correlation has been found [5].

4. Engineering Education: A Knock-out Game or an Experience for Life?

One peculiar feature of student life at the Royal Institute of Technology, Stockholm, is the student-based initiation rites called *Nollning*. Through a number of symbol-laden activities the new students, called *Nolla*—meaning zero—qualify for studentship proper.

This is all arranged by the older students, with little if any input from the faculty. In a study of the role of *Nollning* we interviewed a number of games-masters about their motives for spending months of unpaid work organizing these activities [6]. Here is one answer:

> ... I myself had such a lot of fun when I went through *Nollning*, and I want my younger colleagues to get the same experience, since I know that during the five years to come there is not a lot of fun. The only creative thing I have done so far—and I am just about to graduate—is my *Nolletask* ...

As there were many other answers to the same effect there is reason to be alarmed about the lack of challenge and creativity in the educational system in question.

The informant in the interview excerpt above points at the connection between joy and creativity. It is fun to be creative. And as traditional engineering education turns out to be "one long slog" [7], the students have to supplement for the lack of existential components in their education by organizing playful extra-curricular activities.

Several creative persons have testified about how playfulness and unbridled curiosity work as sources of creativity. Richard Feynman tells us about how he, in a state of depression and improductivity, started to think about why a plate (from the cafeteria at Cornell University), when thrown in the air, rotated twice as fast as it was wobbling. Freed from the crippling urge for usefulness, he soon became obsessed by his research on wobbling plates [8, 9].

> It was effortless. It was easy to play with these things. It was like uncorking a bottle: everything flowed out effortless. I almost tried to resist it! There was no importance to what I was doing, but ultimately there was. The diagrams and the whole business that I got the Nobel Prize for came from that piddling around with the wobbling plate.

It is obvious that this sort of creativity, the *Homo ludens* sort, comes close to artistry: to create something personal and original out of 'next to nothing' (*cum nullum*) for the sheer pleasure of it. My sad conclusion from what is known about modern engineering education is that only in architecture and design education has a component of *Homo luden's* creativity been retained. Samuel Florman, a practising US engineer, supports this view, blaming:

> ... the stultifying influence of engineering schools where the least bit of imagination, social concern or cultural interest is snuffed out under the crushing load of purely technical subjects [10].

5. Old Knowledge in New Situations

A quick look at today's modes of engineering education makes us realize that a hybrid of three approaches, i.e. general faculty, drill and practice, and conceptual understanding, is the predominant philosophy. These approaches are answers to a question which is the core of creativity: How does old knowledge become relevant in new situations?

5.1 General Faculty

One of the earliest attempts to formulate an educational principle on which to organize learning was: by making sure that the 'old knowledge' taught and learned is as general and thus as widely applicable as possible. In medieval education the *trivium* and *quadrivium*, i.e. grammar, rhetoric and logic, arithmetic, geometry, astronomy and music, formed the knowledge base supposed to suffice for any situation in life. These subjects represented the distilled achievement of Western thought, thus they defined reality. More recently, geometry and Latin have served as spring-boards for general faculty.

5.2 *Drill and Practice*

As a reaction to the one-sided emphasis on formal knowledge, the behaviourists stressed the importance of drill and practice in real life. Although the main components of behaviourism (or at least the behavioural theory of Skinner) were largely discredited as general truths in the 1970s, the principles of contiguity, repetition, reinforcement through feedback and motivation are still recognized as important in the processes of learning (see Entwistle [11]).

5.3 *Apprenticeship*

The idea of the old guilds about apprenticeship has also been advocated as a model for formal, i.e. school room-based education. John Dewey's thinking, sometimes expressed in the maxim 'learning by doing', has had an important impact on curriculum development by stressing the situatedness of experiential learning [12].

5.4 *Conceptual Understanding*

The increasingly abstract nature of working life, and the need for transferability of knowledge and skills, was highlighted by Wertheim and others. According to them the learner will have to apply a bird's eye view on reality: scientification of life is a necessity, abstract concepts of great generality are needed to make sense of our experiences.

Most engineering schools require their students to study mathematics and physics under the guidance of subject experts for one or two introductory years. The official reason is that these subjects promote general faculty and conceptual understanding. Of course, engineers do need high-level analytical skills, but studying mathematics and physics out of (engineering) context is not necessarily conducive to the development of such skills. Physics, for instance, is notorious for being taught as a closed discourse which does not foster the divergent thinking so essential for creativity. Such an over-scientification can then easily make learning deteriorate into drill and practice, in particular when combined with work overload.

Furthermore, to many physicists the context is considered more or less a nuisance. In engineering, however, there is a need for handling increasingly complex problems involving people's emotions and environmental sustainability. This calls for 'problem-sensitivity' in addition to technical virtuosity, a mental capacity most traditional engineering education systems are ill-prepared to foster. There are, however, other philosophies of education allowing for more creative work, which are described next.

5.5 *Genetic Epistemology*

Jean Piaget brought the developmental aspects into focus by showing that some mental operations were impossible for children below a certain age. He invented a series of developmental steps through which the enquiring mind progresses. This research has, among other things, highlighted the importance of individual differences in the learner.

Subsequent studies of learning styles and approaches to learning among tertiary level students have, during the last 20 years, cast light on how the students create meaning during learning. In the US, where Piaget's work was acknowledged long before it gained recognition in Europe, it fused with the humanistic psychology of Abraham Maslow, Carl Rogers and others, and developed into constructivism.

5.6 *Constructivism*

Constructivism emphasizes the importance of the knowledge, beliefs and skills an individual brings to the experience of learning. It recognizes the construction of new understanding as a combination of prior learning, new information and readiness to learn. Individuals make choices about what new ideas to accept and how to fit them into their established views of the world. The fact that constructivism is based on the assumption that knowledge is constructed by learners as they attempt to make sense of their experiences adds another dimension to the concept of creativity.

5.7 *Ethnographic Perspective*

The discovery of alternative modes of cognitive activity, e.g. the way Brazilian street vendors count money, indicated the importance of the cultural setting in cognitive development. It contributed towards the post-modern interpretation of knowledge itself as local, contextual and even subjective. A special form of ethnographic perspective claims that 'enculturation is generalization'. The contribution of the socio-cultural perspective lies in helping individuals to view the scholarly and scientific disciplines as social institutions—groups of people functioning together by virtue of shared cultural practices [13].

5.8 *Situated Cognition*

The tradition of thought called situated cognition launched a critique of transferability: knowledge is situational, there is no transfer of knowledge from one domain to another (apart from pure trivia). Creativity cannot be taught decontextalized—out of context—as a special skill. As working lives becomes more and more abstract, the learner has to be exposed to a variety of contexts in order to develop a full repertoire of knowledge and skills. According to this view learning is a cognitive apprenticeship in which originally erected scaffoldings gradually have to be removed as the learner gains confidence in his/her trade [14].

Constructivism nowadays is something of a fashion among curriculum developers at primary and secondary school level and it could easily be extended to tertiary engineering education. (After all, engineering is nothing but constructivism!) If the students will learn to look upon themselves as inventors rather than copy-cats the chances that creativity comes as a consequence are enhanced. If the discourse is open right from the beginning of their studies and theorizing comes 'right in time', i.e. when it is needed, the sense of ownership and emotional involvement, so important for creativity, is likely to be promoted. However, the philosophical underpinning of constructivism has been questioned and many physicists are hostile to even milder forms of constructivism, as the so-called Sokal [15] affair has shown. Among physicists, the prevailing epistemology is still positivistic: there is a reality out there independent of our theories. This presents a serious problem for the role of physics in engineering education.

It should be stressed, however, that good comprehension of physics is indispensible for an engineer. Much unnecessary work by self-taught perpetuum mobile inventors (and by patent-officers) could have been spared had the second law of thermodynamics been properly understood. Rigour is an essential counterbalance to creativity.

6. Inferiority Complex?

There is another slightly disturbing aspect of the over-scientification of engineering education. Sharon Beder writes "A specialised knowledge base was also sought keenly by engineers as a basis for the claim for professional status. Although most engineers were employed, they believed in a social hierarchy which awarded power and influence to those with knowledge and skill and they sought to be recognised as professionals rather than workers. In particular, civil and mechanical engineers required science as part of their specialised knowledge base so that they would be differentiated from the technicians, mechanics and skilled craftsmen in the occupational hierarchy. Science and mathematics training is, of course, essential to an engineering career these days. The old trial and error design methods of the eighteenth and nineteenth century were gradually replaced by scientific and calculation based methods that were necessary for the more complex nature of modern technology. However, the heavy emphasis on mathematics and science in engineering courses was spurred and reinforced by the need for status amongst engineering educators" [16].

Beder quotes Ferguson: "It is usually a shock to [engineering] students to discover what a small percentage of decisions made by a designer are made on the basis of the kind of calculation he [or she] has spent so much time learning in school" [17].

There are other studies in support of such an analysis. Nespor [18] claims in his study that introductory physics courses for engineering students are "designed to weed out the students". He also refers to Hacker [19], who points to the practice in engineering programmes of simply suppressing the supply of graduates (in order to keep the demand up). Hacker quotes a professor saying "90 per cent of you would make good engineers, but only 40 or 50 per cent will graduate".

7. The Market

In the field of engineering new methods, processes, tools and machinery are the concrete result of the creative act. But novelty in itself is not sufficient for an artefact to succeed; the creative output must be accepted by the market. Nowadays, one out of 540 ideas result in a marketable product and eight out of 6000 new gadgets survive the first year. In this sense creativity is social construct—its products need public acceptance.

Bruno Latour [20] has in his autopsy of a costly project to solve Paris's transport problem by computer-controlled rail-bound minicabs, pointed out that had the engineers involved been better at sociology the failure could have been prevented. Latour is pleading for more successful parlay between technology and humanism, between the body and soul of technology. And as social problem-sensitivity can not be bought from others, it has to be part and parcel of engineering education.

8. Towards a Reformed Engineering Education

It is long overdue that engineers (and engineering educators) should shed their inferiority complex (particularly *vis-à-vis* Academica Proper) and restore the existential pleasures of engineering by designing a curriculum that reflects engineering as a social activity, thereby attracting a wider spectrum of students. This can be done by:

(1) requiring that all engineering instructors are conversant with, and able to apply, modern educational theory;
(2) making sure that all engineering instructors adopt humanistic attitudes, e.g. being more accepting and tolerant in their relation to the students as concerns, for example, their learning styles;
(3) utilizing more open forms of learning, e.g. problem-based learning;
(4) complementing the science-based engineering subjects with qualitative narratives, such as sociology, history of technology and anthropology;
(5) accepting the fact that is impossible for one individual to do good engineering research and, at the same time, foster future engineers. This, in effect, means allowing for a mixed faculty including experienced engineers who do not do any engineering research.

By implemented these points a creativity-as-a-life-style can be promoted, which in turn is likely to have an effect on future working life. Francis T. Evans' claim, quoted in the introduction, can now be seen as a special case of Carl Rogers' famous statement:

> I cannot teach you anything. I can only make sure that the conditions for learning are as good as possible.

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