EDUCATING GREAT T-SHAPED ENGINEERS

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ABSTRACT

Work of an engineering professional in the technical innovation process with its open-ended nature and implicit wide responsibility bears many similarities to managing a company through competitive environments. That led to the introduction of the "T-shaped" principle for design engineers and their education: the integrated specialist and generalist in one person. During research and practical experiments several crucial issues in the teaching process were revealed.

The analysis of Collins' "Good to Great" on companies that consistently outperformed their competition provided further logical evidence on how to tackle the educational challenge to deliver those innovative engineering "T-shaped" graduates, prepared to make a difference in industry. These insights are now being implemented in the new courses at the Innovation Centre of the University of Technology of Compiegne, France and at the Hanze Institute for Technology of the Hanze University of Groningen.

Keywords: Technical Innovation, Engineering Design Education

1 INTRODUCTION

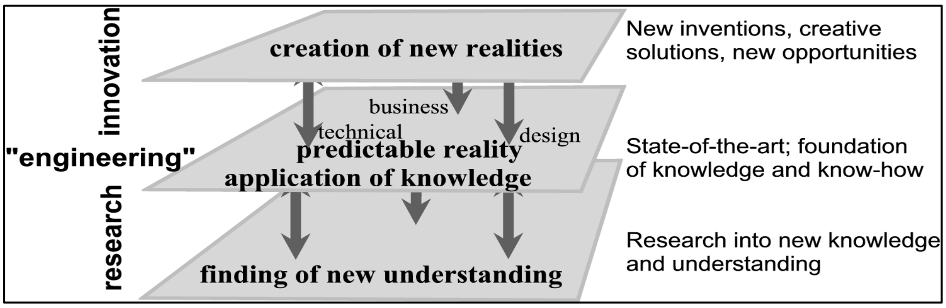

Figure 1 Research, Engineering and Innovation

It is a common misunderstanding, and not only in European politics, that innovation in industry is and must be coming from research. National innovation efforts are calculated from the R&D-expenditures and any innovation funding is directed almost solely towards the universities carrying out promising research programs. However most of the new successful products and processes are based on existing technologies often available already for years and years, only a few are based on newly developed ones. In all cases, old or new knowledge must be applied in a new, clever way to create something really new: an innovation. Technical innovation or innovative engineering (fig 1, the 2 upper levels) has its own different nature, rules and language, quite

different from science and research. That is why so few successful inventions and innovations come from the research institutes; but most originate from industrial organisations, where they spark off from clever knowledgeable key people or are diligently created in well-planned multidisciplinary project teams (fig 2).
One of the binding factors of the European Network of Engineering Design, later combined in the ODD (Open Dynamic Design)-project [1] is the joint aim of educating

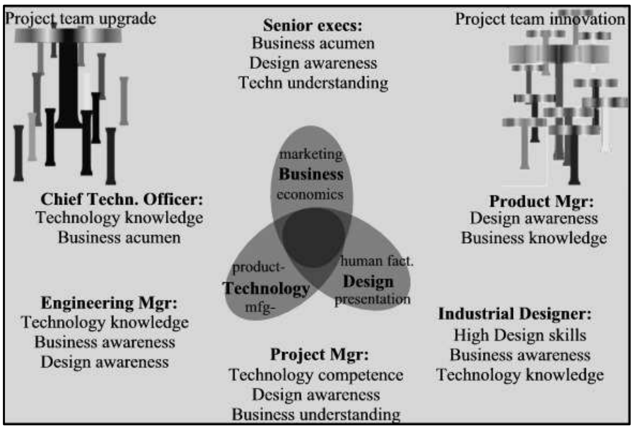

Figure 2 T-shapes in context of industrial practice.

engineers for exactly this challenging task, being fully aware that only offering extra creativity courses is not enough. Within the group an intensive exchange of experience, ideas, staff and students took place, and many integrating projects, intensive programs, dedicated modules were developed and formally integrated in curricula of the partners.
In consequence of Hansen and von Oetinger's T-shaped manager [2] with the double responsibility, at the ASEE-conference [3] the profile of the T-shaped engineer was proposed, having an adequate set of knowledge, know-how and competences.
The methods to prepare the student for that complicated task followed from the experience within the network (including the Aalborg experience on project based, problem oriented learning [4]) and the ODD-project (research into effective practice of industrial innovation projects). The disappointing effects of the New Learning in the Netherlands, with its strong focus on competences, were observed as well.
In the next chapters the authors will discuss the issues they found when educating T-shaped innovative engineers, and give some explanations and initial recommendations.
The similarities and logical consequences of the research described in Collins "Good to Great" will then be discussed and the implications on the specific new courses of Compiegne and Groningen.

2 ISSUES RAISED WHEN RAISING T-SHAPED ENGINEERS

In the ODD project the industrial practice of technical innovation was very deeply and closely observed by direct participation, on the spot could be recognised which methodology was used, which resulted in successful solutions, which didn't. The data on (early) failures of projects were even more revealing than the ones on successful innovations: lack of theoretical and practical knowledge and experience is the main factor [1].

The main conclusion on the methodology was: there are no universally best design methods: "it all depends" (that became the ODD-motto) on the context. The knowledge, skill and experience of the key people are much more decisive for the effectiveness of the projects. However the formal methods have a very important triple role in the process, additional to the legal one (CE) and text-book for young engineers, and so they must be learned and trained:

- Familiarize with the challenge and the essential issues in reverse engineering.
- Check in hindsight – on logic, on priorities completeness, on values;
- Communication means to transmit the logic behind the proposals.

The only design tool that (still) is universally effective is the simple tangible functional model, revealing intended and unintended movements etc, and triggering better ideas.
This conclusion of the ODD-research supports the approach of the IPDE-course in Groningen, with its workshops and projects, where the emphasis in the assessment is on the practical results and on the convincing and honest presentation to the management of the background company. The reports should cover the relevant technical, design and business details, to be judged by experts. It is more about the relevant issues than about the completeness of a procedural effort and it requires a good broad knowledge. Feedback from industry, alumni and partner institutes on the IPDE-way has been very favourable, but there are some issues that give concern:

2.1 Required knowledge and experience base

In the last decade Dutch education converted to the "New Learning" system, originally based on the learning theories of Kolb[5](fig 3) and the concept of competences (of companies), now put in a job-related competence-development system: 4C/ID [6]. In principle the system should be very well applicable to the education of the T-engineer, mastering that wide variety of knowledge and skills, in the mix of theories and practice. However, we found also in the IPDE-course, some negative effects.

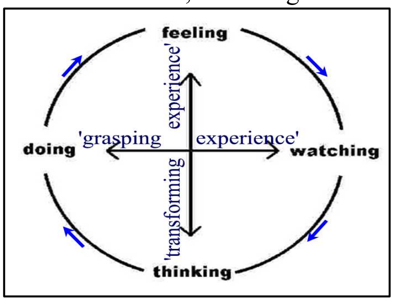

Figure 3 Learning circle

Maybe in the implementation of "New Learning" things went overboard and content became of minor importance to form; (like football training on offside-trap, but then without a ball), maybe it was because of decreasing available financial means, maybe also the changing interest of our youngsters played a role: fact is that the general exit-level of the students dropped. The industry started complaining about the technical level of the graduates (admitting the communication skills have improved). And early 2007 even the students themselves demanded formally better education, by more study pressure with more direct lecturing and teaching time, starting a hot political debate.
As the ODD-research showed that the main factor behind successful engineering and innovation projects exactly is the wide expertise and experience, this fading knowledge is even more painful: Doing an extensive integrated Failure Mode analysis without

technical expertise is no guarantee that the product will not break (competent without content). Actually it is extra dangerous, because it suggests a thoroughness it totally lacks. Supervisors – in education or industry - should check in detail, thus forcing the youngsters to go deep and learn to do it right, going the full Kolb cycle. But that costs.

2.2 Multidisciplinary Google mania

Partly because of the "New Learning", partly by the easy access to massive knowledge bases, it is now the prevailing (mis)conception that expertise and information would be the same. The effect is that all info –directly from internet or from the team members in multidisciplinary project groups - is taken on face value. Nonsense, irrelevant numbers are accepted as facts to found engineering design decisions upon. Similarly in such training projects facts are exchanged, but there are no explorations for best combinations because the lack of understanding.

Typically one can observe in projects that after a kick-off the team divides tasks among the members according to background and that everybody then hides behind his laptop. Only during project meetings progress is checked, and finally a report and presentation is prepared, hopefully with all elements, but with little real technical consistency and many hidden mistakes and missed opportunities. And like said before no time for the supervisors to correct all this – they have to stick to a process-check.

2.3 "It Depends"- adapt to context: too difficult for non-experienced engineers

Feedback from industrial practice and experienced experts on the ODD "it depends" issue with methodology in hindsight generally was one of recognition, relief and an Aha!-Erlebnis; however young engineers, lacking a solid reference of knowledge, situations and appropriate methods, could accept the wide variety of "good ways" but were not able to cope without experienced guidance.

The industrial example projects and case studies maybe did clarify the logic, but were not enough to familiarize the young engineers with the patterns that help recognise what is the essential cost factor in a product, what is the main "selling point", what gives a competitive edge, what are the risk and environmental issues etc. These factors, together with the available experienced expertise and set priorities, dictate how to innovate and design. Both in the projects and in the written exams students failed to get the right reasoning for such a design approach, even in very simplified model situations.

Probably the Kolb-circle has be run many times under guidance and from simple to more complex challenges before this aspect can be conquered.

2.4 Integrating the additional disciplines

One of the main challenges designing a curriculum is arranging the subjects in such a way that the knowledge and competences builds up in an effective, useful way. In conventional lecturing the subjects have already a natural or accepted coherence within the disciplines. Modern combined technical disciplines (call it broadly I-shaped?), like mechatronics or sensor technology are still looking for the right mix and order of subjects to teach towards integrated knowledge and wide emotional understanding. For T-design engineering this deep mastering of many technical subjects is evenly important.

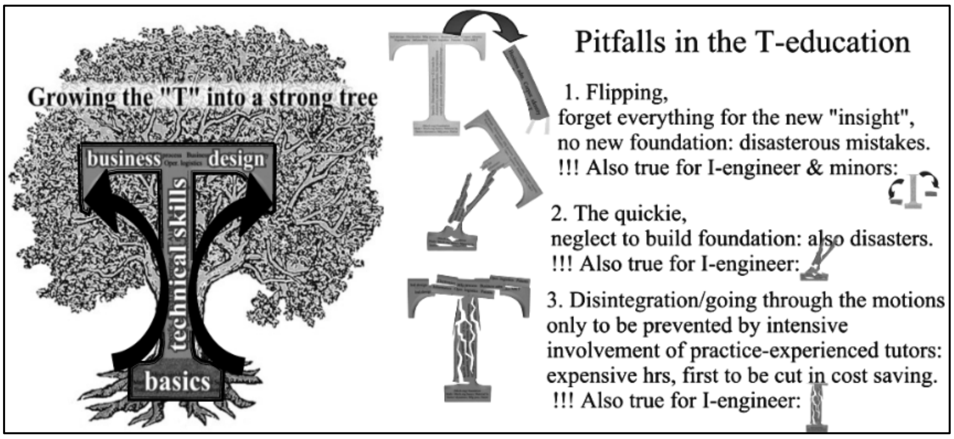

Figure 4 Integrating more disciplines

For a T-shaped curriculum with the additional dedicated non-technical subjects, like finance, marketing, design, there is more danger of disintegration into separate unrelated domains, chances on going overboard, or superficial understanding.
In any case it was found that the widening up was best done at the end of the curriculum, when the mastered expertise in a core discipline gives enough confidence to take aboard new, seemingly unrelated, ways of thinking-hence the tree metaphor (fig 4).

3 IMPACT OF COLLINS' GOOD TO GREAT IN MASTER COURSES

In "Good to Great" Collins described the research done in industry on the key factors for extraordinary sustaining company performance [8]. Analyzing his characterizing of the key people, their T-shape, their way of working together, their passion, management and decision making style, their consistency and their non-ego character the similarity with the issues of innovative engineering is striking. Many of the above mentioned observations were confirmed and clarified by his work:
Crucial is not a generic formal system, but the team itself and the quest for the root essence of the company (compare the essence of a product) where company strength, economic motor and shared passion meet (same, but more focus on technical side). That goes beyond negotiating and compromising, it is a shared committed search for a final elementary full truth and requires the deep mutual "T-shaped" understanding. In a **learn-by-doing** mode in workshop-like intense direct confrontations the expert team members quickly learn the additional disciplines and master the language and values under a strong but facilitating fully involved supervision (**teach-by-participation**). That this is such an effective natural way can be explained from the "Csikszentmihalyi's Flow"-character of the process with a state of super-concentration and consciousness, in which lessons learnt by going through Kolb's circle really stick so deeply [9].
Following the pattern of the IPDE course and using the Good-to-Great insights, the new master courses at Compiègne's Innovation Centre and at Groningen - Hanze Institute for Technology offer a carefully built-up package of dedicated modules to already strong, motivated engineers to expand their expertise. An important role will be in integrating, industrial innovation projects and intensive workshops under expert supervision with committed direct participation. Thus shots of "experimental flow-" learning environment can be created, alternating with periods of theory and analysis-learning. Typical modules cover the technology subjects with emphasis on the

mechanical and manufacturing/quality engineering – because of the direct link to cost-, enough electrical and electronics to master all kinds of drive, sensor and actuator issues, and informatics to deal with the data management issue. In integrating projects of increasing complexity products are developed by teams of max 6 students, always up to a model, a cost price, a market prediction - all realistically well-founded. Assessment is done in a "Dragon's Den" way-on the basis of what would be best for the company. That pressure alone helps creating the concentrated "flow"-effect

Business, Design, Management and Creativity issues are given in the combination of workshops and back-up lecturing and each cover an aspect, later to be included in the integration projects. Introduction to industrial design - 1 week full time -; Finance and power in innovation – 1 week -; concepts for markets – 1 week - are good examples..

As there are not many academically and industrially experienced tutors, during the workshops also future supervisors are trained in a master-trainee mode

4 CONCLUDING REMARKS

Education for innovative engineering must have depth and width, it requires a cleverly set-up package of subjects, projects and workshops, but most of all it requires an active, committed and knowledgeable participating supervision, which might be expensive in time and required expertise, but gives a huge return on investment in the end.

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