THE GRONINGEN IPDE-COURSE: EVOLUTION INTO TECHNICAL INNOVATION

P.M. Gerson and J.E. de Jong

ABSTRACT:
This paper deals with the unique, but natural, development process of a final year in Bachelors Mechanical Engineering at the Hanzehogeschool Groningen. It developed into a Masters level international course dedicated to training already well educated engineers to make commercially, economically drastic or incremental innovations in the way that is suitable for that specific company in that specific situation.
.

Keywords: Curriculum Development, Industrial Collaboration, International Exchanges, Design Theories and Education

1 HISTORICAL, NATIONAL BACKGROUND:

During the late 80's and early 90's, Dutch professional higher education in mechanical engineering, also at the Hanzehogeschool Groningen, concentrated on mechanics related subjects, theory and practice and manufacturing engineering. In the Netherlands more than anywhere else, the mandate, competency and responsibility of academic and professional institutes are strictly separated: the focus of the professional higher education institutes was strictly application oriented and is not supposed to do research.
The taught theories in professional education generally are derived from the academic world, the practice is much towards the business, result-oriented approach. [1]
In the (future) work area of operational engineering and applied research, where understanding, mastering and controlling technology is the main task of the engineer, this may not differ so much from the scientific world. In product and process creation however, these differences [2], (Figure 1) become large and essential.

ACADEMIC / SCIENCE	BUSINESS / ENGINEERING
Goal: pursuit of knowledge + understanding for own sake	**Goal**: creation of successful artefacts and systems to meet people's wants and needs)
Key scientific **processes:**	**Key** engineering **processes:**
Discovery by controlled experiments	**Invention**, design, production
Analysis, generalization and synthesis of **hypotheses**	Analysis and synthesis of **designs**
Reductionism, involving the **isolation** and definition of distinct concepts	Holism, involving the **integration** of many competing demands, theories, data and ideas
Making more/less **value-free** statements	Activities always **value-loaded**
Search for and theorize about **causes** (fe gravity,el.magn')	Search and theorize on **processes** (fe control,info,power)
Pursuit of **accuracy** in modelling	Pursuit in **sufficient** accuracy for success
Drawing correct **conclusions** from good theories and data	Reaching good **decisions** from rough data and models
Experimental and logical skills	Design, construction, test, planning, quality assurance, problem-solving, decision making, communication skills
Using predictions to judge and **improve** theories or data	Try to ensure even poor decisions work **successfully**

Figure 1. Some differences between science and engineering – derived from JJSparks [2]

Industrial practice is a prerequisite to become a chartered, registered, full-grown, engineer. In the Netherlands the situation is interesting: the official bodies of chartered engineers and the educational have a now long standing agreement: the necessary

industrial experience is integrated and controlled within the curriculum, and at graduation the young Bachelor (Dutch: Ing) at once is “chartered”, and is allowed to put the Ing. in front of his/her name.. How the change to the Bachelor-Master structure will influence this, is not yet clear.
An essential element of this situation is the unique, intensive cooperation between Dutch industry and professional education with an extensive system of industrial placements. Students are learning the industrial reality under co-supervision of industrial and educational tutors, mostly in semester long full-time projects. There, IN industry , in the real organisational and technical environment on real assignments, they are tested on their ability to perform as self-managing, capable (young) engineers, – again under co-supervision of the industrial and educational tutors.

For the Groningen situation some special circumstances were important for the development of the curriculum:

- It happened to be that within Mechanical engineering about 50% of the teaching staff had long industrial experience; this exceptional high percentage is – by strategy – kept so high over the years. Partly it explains the strong shared motivation in the staff for result-oriented curriculum approach. It is also the determining factor in the strong mutual personal contribution in industrial and educational developments.
- The good interdepartmental relationship with the neighbouring university: RuG. In combined teaching projects, the different supplementary approaches were optimised.
- Traditionally in Groningen consequent analysis and logical reasoning was built in: during the first fundamental years of the curriculum and in the final specialisation phase of constructive design engineering the design methodology of vd Kronenberg is taught. This methodology is closely related to the Pahl & Beitz design process (Figure 2), prescribing a systematic, logical and functional step-by-step procedure.

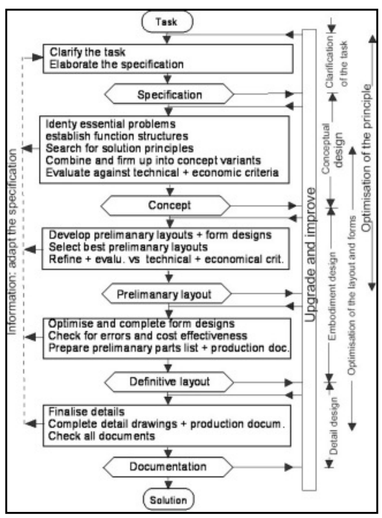

Figure 2.The analytical, problem solving, design process of Pahl & Beitz [3]

These systems - vd Kronenberg with its emphasis the morphological charts and decision matrix (Kesselring) – are very suitable for understanding the structural build-up of technical systems as a logical consequence of their functional requirements and restrictions. They help to bring design problems to a higher level in abstraction, or to dissect a mixed problem into separate ones.

2 FIRST STEPS INTO INTEGRAL DESIGN ENGINEERING

Based on the industrial experience of the lecturers, the direct personal input from the industrial partners and the discussions with the RuG-colleagues, the need was established for an integrated industry-practice based design engineering curriculum.[1].
Within the then conventional lecturing, workshop/ laboratory and assignment structure an attempt was made to introduce industrial design training – by instructors of the Art & Design School, Minerva. The culture gap between industrial design and mechanical engineering proved to be too large and the experiment had to be stopped.

The experiment to include the business practice in the design methodology was more successful:
Engineering design assignments and projects were introduced and assessed, ultimately on their likely business success, their "Design Value" [4]; just going through the "right motions" of the design was not acceptable. Students were expected to learn and deal in an integrated way with the technical base, technical and design (engineering) creativity and methodology; and with the basics of the business issues on cost and financing, marketing and sales, communication and acquire managerial & entrepreneurial sense.
The main aim was the B2B (business-to-business) industry with its complex technical functional relationships – like in the automotive supply chain. For easy problem identification by the students however, many examples of a more consumer product nature were used in projects and lecturing-always with a strong technical background in product and manufacturing. The main focus in human factors was in the area of control and handling – both in manufacturing, service and use.

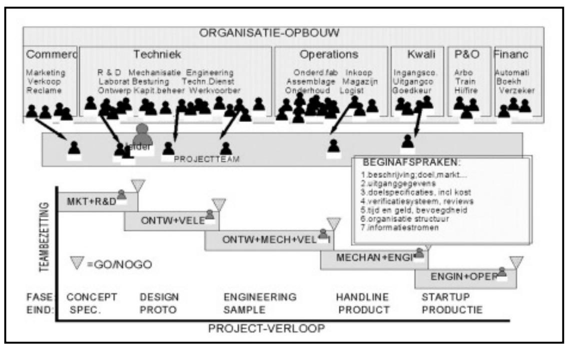

Figure 3.The phase-gate, design review, Go/NoGo industrial design process to control long running, multidisciplinary, and/or risky projects - derived from company handbooks

As project structure the Phase-Gate or Design-Review model from industrial practice – automotive, Philips FCP/PCP, Ullman [5]- was chosen in which the committed, convincing, hard-fact based report, presentation and business proposal is crucial: a jump in thinking from the vd Kronenberg value-free method.
Like in industry, the two methods seem to contradict each other, and the change-over caused deep discussions within the staff and industrial advisory board. The final consensus – supported by industrial experts, and later again proven in the ODD-research [6] – was and is – that methodical design is **a, not the** forceful method within the phased-gate project structure: other methods, like the Pugh approach [7], or Tuomaala-way [8] can be valid as well and fitting within phases of the business-decision based structure of industrial multidisciplinary engineering projects. (Figure 3)

Within this industrial practice also other techniques were introduced: FMEA, Taguchi, cost calculation; model making and Design Value.[9]
The project based, problem oriented education that is still en vogue was altered into: Project Based, Result Oriented Design Engineering education.[1]

The majority of the design engineering students, after initial confusion, rose to the additional challenge. Actually, the realistic nature of the projects provided an extra incentive for better creative solutions. Feedback from our industrial partners, confronted with a new brand of students in their in-house project teams, was quite favourable; it also included very worthwhile suggestions for further development.
At the other hand, as we found in a very open-ended, innovative introductory training project, the ability of dealing with creative uncertainty is strongly character-dependant. For some it is really not on.

To learn and share experiences we looked for similar integrated design engineering courses in Europe and found similarities for instance in the design engineering (or engineering design) courses in Loughborough (post graduate MSc) and Glasgow (B.Eng & M.Eng course Mechanical Engineering and Industrial design). [10]
With these and kindred institutes a design engineering network was set up. Design engineering techniques that were introduced in the curricula, like FMEA, QFD, DfXXX, Taguchi, VA/VE were compared in their industrial importance and on the impact on the students' (and later engineers') capabilities.

In a modified way we implemented this integral business philosophy in an introductory course for the RuG – technical business science on the full product development process. The feedback from that learning process of students of a different background was used directly into the "own" courses.

3 IPDE: LEARNING FROM TEACHING INTERCULTURALLY

The next phase included the implementations of basic industrial design with its presentation elements and of the international character. It was created under direct influence of the cooperation and exchange with the PDE-M.Eng course of the University of Glasgow and the Glasgow School of Art [10] and the inputs of the industrial and educational design engineering partners.
This IPDE course, being the final year of the Ing/Dutch Bachelor's curriculum, included a semester of lecturing and training in the institute and a semester full-time industrial project in industry both for Dutch and foreign students. The course acted as the 4th (European) year of the 5 year Glasgow M.Eng PDE course; the double degree arrangement provided the Scottish students both the Dutch Bachelors' and -a year later- the Scottish Masters degree. The other partners had similar arrangements.
This English-taught IPDE-course took in students from about 10 different countries, free-movers and from partners. They shared a similar (Bachelors level) Mechanical Engineering background and differed more strongly in culture background.

Elements of the Pugh approach [7] were included in the curriculum, thus by then covering the full scope of design engineering activities and theories. Hofstede's culture research and theory were introduced as a mean to understand the different design theories and approaches and of course the different attitudes within the classroom and society [9]. Industrial design, culture and conceptual thinking was incorporated by intensive workshops, and were an integrated part of the project assessments.

The modification of teaching and assessment methods- towards intensive workshops, inter-teaching project teams, assignment-driven learning, design-review presentations - was also needed because of the diversity of background of the students.

Figure 4.The design workshop: working at a lady robot

The implementation of industrial design–training was carefully done in a full-time workshop of a week, derived from the Glasgow experiences, adapted to the mind of the "straight forward" engineer. It included 3D-sketching, colour, human dimensions and perception and creative model building, with exercises to open up the engineering mind. Interesting is the fact that the initial reluctance of the participants "to let go" changed over the years into positive anticipation: the word got around..

The second workshop of a full-time week aims at the conceptual design for and together with a company. It includes cultural training related to market research, target groups and organisational issues and opens the link to the main design theories. Several dedicated experiencing games are devised for this end.

Although the background of the course participants differs, by direct knowledge exchange in project teams a certain common technical level is present in the IPDE course; it was noticed however that some subjects were needed for a practical balance: Efficient production technology, polymer engineering, patents and internet-issues; these were developed especially for IPDE.

Two Dutch trends have to be recognised as being counteracting the integrating nature of IPDE: the early implementation of competence-training and engineering techniques in early education stages, unfortunately at the expense of basic engineering knowledge. The other one is the trend to introduce international thinking as a taught module in stead of direct mixed-team experience.

4 THE ODD-PHASE: IT DEPENDS, BUT ON WHAT?

The recent phase of the curriculum development of the IPDE course is deeply connected with the 5 year Leonardo da Vinci-funded projects ODD (Open Dynamic Design) and DODD (Dissemination): Together with a large group of industrial, educational and scientific partners research in engineering design theory and methodology is done, giving the bridging theories and practices that are needed for effective product development. A very close and direct experimental research was achieved, because of the participating observation during mixed teams in-company projects, coupled with direct expert feedback [11]. Even more than expected it was found that the applicability and effectiveness of design methods depends on non-technical context factors [6],[12].

The educational implications were and still are equally essential for a successful further development of the course and its students.
Both in the on-site observations and the experiments IPDE-staff and students played an important role, together with the partners staff and students: they were the participating observers and the participants in experimental set-ups on learning tests: the workshops.

An interesting outcome was: that the understanding and recognising of the determining context factors is very simple and obvious for experienced engineers and managers, for young inexperienced engineers and students it is almost impossible without help; combined project evaluation is a forceful tool for that. The final projects therefore now include 2 full-class ODD-inter-evaluations of the individual projects.

The ODD-conclusions that are implemented in the IPDE theory and practice–at limited success for the inexperienced students- were among others [6], [12],[14]:

- Natural development of a person or a organisation is; from concrete to abstract, from making/manufacturing to designing to: (ultimately, and only if there is a suitable character/culture available) inventing.
- The nature of inventive design engineering is essentially different than the structured, predictable process, descriptive (C-K) models are available [13], no prescriptive ones.
- There are 5 main theoretical design approaches available; their applicability is strongly context-related: technically/legally determined, organisation strategy and culture determined (risk avoiding), personal experience, common language, inter-company dependencies, nature of intended progress: technical functional, consumer feeling, step forward, incremental change, design "in/on"[15]…
- In practice most included design methods (QFD, FMEA, Kesselring) are only used in hindsight as a logic proving and a convincing communication tool.
- Design theories and methods could be applicable and valid, independently in one or more of the areas:

---for personal use or execution
---as a means for communicate/ check,
---and as a learning tool

- The strongest overall methods: <u>making models and hands-on experience</u>

Figure 5.Hands-on experience during a conceptual design workshop.

Both in theory modules and in the assignments these ODD-elements are integrated; training is provided in project cases and applicable design methods in the full design-matrix: industrial/mechanical and consolidating/innovative and secondary context factors are mixed in.
Due to the high complexity a 3rd full-time workshop was introduced, with full participation of industry.
But as stated above, for the inexperienced student, the complexity is too high:

At the moment it is seriously considered to modify the evolved IPDE-course into a Masters course Technical Innovation, and re-establish the Bachelor of Design & Construction.

This practical, flexible and total approach, including a very wide and integral responsibility for the (innovative) design engineer had and has some counter-forces around – apart from the youth's shifting interest away from technical detail:

- At the national/European level: "Status aparte" of Dutch professional education, one of the backbones of this strong industrial focus, will be lost in the effects of the Bologna Bach-Master developments.
- There is a strong tendency to build up the curricula in easily interchangeable modules at local departmental and international level: building by stacking, not integrating.
- In the Design Engineering world at Design society level: Science as Holy Grail of ultimate truth is prevailing over the former self-observation methods.[16]
- Specialising in stead of integration-holistic approach: a trend can be detected for more dedicated, intermediate or translating inter-disciplines, covering more trendy and attractive specializations.

5 CONCLUSIONS

A very specific design engineering course has been developed – at professional masters level; crucial for the survival of the European industry, but only applicable for a limited amount of engineers at a limited amount of situations.

For such a course there is a strong prerequisite on knowledge, know-how of at least bachelors' level as well as a motivation and talent for entering new disciplines and thought-areas.

Interestingly the development of such a course follows the same natural pattern as is advised for organisations and individuals on their way to innovative creative entities: expanding the working area a-concentrically from "executing" engineering skills to abstraction and creative work.

Also interesting is the fact that the development follows seemingly a planned and logical pattern, that is only obvious in hindsight. During the process, like in product development, a much less systematic driving force is the main motivating agent: experienced intuition.

REFERENCES

[1] Ir. Ph.M. Gerson: Developments in Groningen Design Engineering or: Training in Result-Oriented Design, SEFI-conference, Compiègne Sept 1995,

[2] Sparkes, J.J., Quality in Engineering Education, Engineering Professors Conference, Occasional paper No.1, July 1989

[3] Pahl, G & Beitz,W, Engineering Design, A systematic Approach; Springer Verlag, London, ISBN 3-540-19917-9

[4] Gerson, P: Design, a dedicated act of faith ?; "Versnel uw produktontwikkeling" Euroforum symposium, Arnhem, April 1992

[5] Ullman, D. G., The Mechanical Design Process. New York: McGraw-Hill, 1992 ISBN 0-07-112871-9

[6] Gerson P. (2000, 2002). Open Dynamic Design: Influences of the Industrial and Institutional context on Product Development. ODD-Project No. NL/98/1/74055/EA/III.2a/FPI, Interim and Final Report to Leonardo da Vinci Programme.

[7] Pugh, S, Total Design, Integrated Methods for successful Product Engineering; Wokingham, Addisson-Wesley, 1961

[8] Tuomaala, J. Creative Engineering Design, Oulu, University of Oulu, 1998.

[9] Ir. Ph.M. Gerson: Ontwerpen 4/5 voor W4 OC, 1993. Handreiking voor I^3PD^2 - Integral, Innovative, Industrial Product Design & Development; and: Design/Ontwerpen, Reader 25-12, 1997; Part 1: The overview; Part 2: techniques, issues, exercises; Hanzehogeschool Groningen.

[10] Green G., Macdonald A. (1990). A Joint Course in Product Design Engineering. Seminar : Approaches to the Teaching of Design, Glasgow.

[11] Green, G. and Gerson, P., Open Dynamic Design: Towards a European Model for an Engineering Design Curriculum, EDE 99, The Continuum of Design Education, Proceedings of the 21st SEED Annual Design Conference and 6th National Conference on Product Design Education, Glasgow 7th-8th September 1999, pp 195-203, ISBN 186058 208 7

[12] Gerson P. (2003). Influences of context factors on product development: dissemination of Open Dynamic Design (DODD).-Project No. NL/01/B/F/PP/123115, Interim Report to Leonardo da Vinci Programme.

[13] Armand Hatchuel, Ecole des mines de Paris, Benoît Weil: A new approach of innovative design: an introduction to c-k theory: Proceedings of: International conference on engineering design, ICED 03 Stockholm, August 19-21, 2003; paper 1794; ISBN 1-904670-00-8.

[14] Eynard B., Ramond B., Green G., Gerson P., “First impressions between ICED03 and the ODD-project”, Addendum to Proceedings of International Engineering and Product Design Education Conference, Bournemouth, 2003.

[15] W. Ernst Eder, Professor (retired): A typology of designs and designing: Proceedings of: International conference on engineering design, ICED 03 Stockholm, August 19-21, 2003; paper 1004; ISBN 1-904670-00-8.

[16] Prof. Dr.-Ing. Lucienne Blessing: What is this thing called design research? Proceedings of: 14th International conference on engineering design, ICED 03 Stockholm, August 19-21, 2003; Keynote paper; ISBN 1-904670-00-8.

Contact Information:
Ir Ph. M. Gerson,
Department of Engineering,
Hanzehogeschool Groningen,
POBox 3037,
9701 DA Groningen,
The Netherlands.
Phone: +31 50 5954701
Email: p.m.gerson@pl.hanze.nl

Co-author Information:
Dr Ir J. E. de Jong,
Faculty of Technology,
Hanzehogeschool Groningen.
POBox 3037,
9701 DA Groningen,
The Netherlands.
Phone: +31 50 5954954
Email: j.e.de.jong@pl.hanze.nl