A Debate on Mechanical Engineering Major and Its Cultural Characteristics

Authors:

Hong Wu, Østfold University College, Faculty of Engineering, Sarpsborg, Norway, hong.wu@hiof.no
Mathias Wilichowski, University of Wismar, Department of Mechanical, Process and Environmental Engineering, Wismar, Germany, m.wilichowski@mb.hs-wismar.de
Pavel Belohoubek, Brno University of Technology, Faculty of Mechanical Engineering, CZ 601 90 Brno, Czech Republic, belohoubek@uvssr.fme.vutbr.cz

Abstract *— Mechanical engineering has been an essential major for the traditional engineering education. For the post-second war generation, many business managers, industrial leaders and even governmental top officers were educated within mechanical engineering fields. In a way, this major represented an important aspect, not only in an educational sector, but also in an attentive part of the national economy and political systems for many European countries.*
This status has however, changed a lot for the past few decades, especially for high labour cost countries. The major of mechanical engineering faces huge challenges both in business, industrial and educational sectors. For the industry, the mechanical engineering activities are moving to low labour cost countries. For the education, general interests for this major have been noticeably reduced among the potential applicants for the higher education. The debates and practices on how to handle these challenges are also the important events for many engineering universities.
The current study is a comparative analysis on the mechanical engineering major for three sampled European universities of engineering education (Sarpsborg-Norway, Wismar-Germany, and Brno-Czech). All these three are traditional engineering universities and the mechanical engineering major is/has been their essentially teaching activities. The analysis focuses on their current status, debates, course designs/contents, practices and teaching philosophies on this major and how they handle these challenges mentioned above.
Though mechanical engineering is a standard major for the all, there are still cultural characteristics or practical methods to diversify this standard major in teaching activities. There are also different expectations and requirements from universities or teaching staff to these mechanical engineering students. These differences reflect again, cultural characteristics and current demands from the local industries of these countries. Like other majors, mechanical engineering is not only a standard major by its academic definition, but also a various major in teaching practices depended on its special circumstances around. This variation opens a continual and further debate, in its changing options, availabilities for industrial demands, cultural or national characteristics and global compatibilities, etc.

Index Terms *— Mechanical engineering major, comparative analysis, course designs/contents, cultural characteristics.*

THE DEFINITIONS OF MECHANICAL ENGINEERING

Mechanical Engineering (ME) has been an essential major for the traditional engineering education and industrial business. In fact, many engineering universities and colleges were born with this major. The importance and necessity of this major for engineering education are recognizable.

Like other majors, the teaching content of mechanical engineering has also changed and modified over time. The major of mechanical engineering faces huge challenges both in business, industrial and educational sectors. For the industry, the mechanical engineering activities are moving to low labour cost countries. For the education, general interests for this major have been noticeably reduced among the potential applicants for the higher education. There a need for changes and modifications. However, these changes have also initiated the questions regarding to the nature of this major. For example: What is mechanical engineering? How shall this major be taught? What content shall be defined as the essential parts of the syllabus? To open the debate, a number of definitions for mechanical engineering are introduced as below:

- The mechanical engineering domain encompasses the wide realm of motion, all forms of energy conversion and transmission; the flow of fluids and heat; the development, design and operation of machinery and equipment; material structure and properties; and transportation processes. Thus mechanical engineers are involved in almost every aspect of our technology [1].
- The mechanical engineering is……seen in anything that moves. This includes designing an aircraft, planning a building's ventilation system and improving a car's fuel economy. Mechanical engineering also saves lives through bioengineering technologies. The world's first artificial heart was partially designed, manufactured and implanted using mechanical

engineering principles. The explosive growth in computer power is harnessed by mechanical engineers for the design and development of new 'smart' and 'nano' products [9].

- Mechanical Engineering is the study of planning, designing and developing machines, mechanical plants and systems. Examples of topics in this detailed field include: analysing the effects of stresses and strains on machinery, plant and equipment, designing and drafting mechanical components and systems; developing, operating and maintaining mechanical systems; undertaking materials investigation and analysis [8].
- Mechanical Engineering is the branch of engineering concerned with the design, manufacture, installation, and operation of engines and machines and with manufacturing processes. It is particularly concerned with forces and motion [3].

To summarize the definitions above, the definitions of mechanical engineering can be divided into these aspects:

1) A theoretical aspect: A science concerning substance, force, motion, heat, energy
2) A system aspect: A study of developing, installing, operating, manufacturing and producing systematically large quantity of products
3) An innovative aspect: Designing of new products, components, or systems, as well as developing of new and cross-sectional fields, such as biomechanics, mechatronics, robotics, etc.

This is only one of many options to classify the major of mechanical engineering. In reality, there has to be many more actual categories to divide this major. Almost every university's or college's faculty of mechanical engineering has few departments or sections. It is therefore quite a common phenomenon that many aspects or specialities are represented at these subunits. Hence, the mechanical engineering is a standard major for many engineering universities and colleges, but it also has diversity and variety in different education institutions. The current study intends to compare mechanical engineering major at three such institutions and plans to examine their similarities and differences in different aspects.

A COMPARISON ON MECHANICAL ENGINEERING MAJORS FOR THREE EUROPEAN UNIVERSITIES

The three European university units of engineering education are selected to this comparison. The comparative analysis has mainly focused on qualitative and descriptive parameters, as current status for these units, most recent debates among the staff members, sections and departments, practice, teaching philosophy and how they are handling to challenges. These three units are:

- Østfold University College, Faculty of Engineering (short name: HIOF-IR) at Sarpsborg, Norway, http://www.hiof.no/
- University of Wismar (short name: HS-Wismar) at Wismar, Germany, http://www.hs-wismar.de/
- Brno Technical University (short name: TU-Brno) at Brno, Czech Republic, http://www.vutbr.cz/

All these three institutions are traditional engineering universities or faculties. The mechanical engineering major is/has been their essentially teaching activities. However, the sizes of these three units are quite different, from very small (HIOF-IR) to very large (TU-Brno). It is therefore more reasonable to undertaking comparative analysis on qualitative and descriptive parameters. Table I has summarized the current status and active debate topics for these three units.

TABLE I
A COMPARATIVE ANALYSIS ON THE MECHANICAL ENGINEERING MAJOR FOR SAMPLED EUROPEAN UNIVERSITIES – CURRENT STATUS AND DEBATES

Institution	Østfold-Norway	Wismar-Germany	Brno-Czech Republic
Current status	Decline numbers of applicants. Lack of interest among youth. Limited resources and staff. No new student in 2003 and 2004 Current student number: 15	In 2003 increasing number of applicants. Most applicants preferred traditional Diploma than Bachelor. Since 2004 only Bachelor/Master degree courses are offered. Both courses are accredited by the ANSI. Current students: ca. 200	Large interest of a study (app. 1 500 students in the year 2004 will be accepted) based on good tradition of study (app. 100 years of tradition of TU Brno). Limited resources.
Debates	Industrial companies want generalists in high technical level. Government wants rationalizing teaching budget. Students want fun and easy ways to learn. Also a debate for way of teaching in "tradition classroom lecture" vs. "project based or problem related".	The government pushes the universities to switch over from the traditional diploma degree to the BEng/MEng-degrees. Uncertainty about the quota of Bachelor students who will continue with the Masters course. Uncertainty about the acceptance of the Bachelor degree by the industry (Is a BEng a real engineer?). Government wants rationalizing teaching staff. Students want to finish their study as soon as possible to earn money.	Frequent and rapid changes in the Czech industry demand flexible students with high level of knowledge and ability to work in change surroundings. It is necessary good foresee how students prepare by the teachers for the new conditions.

As table I indicated, the current status is different among these three units. It seems that HS-Wismar and TU-Brno applicants are interested in mechanical engineering education, and their numbers of applicants are in a good shape. On the other hand, HIOF-IR has experienced decline number of applicants, lack of interests among the youth for mechanical engineering study. Aside of this negative trend, there has also been limited staff resources for teaching and research.

HIOF-IR is not the only one experienced this problem in Norway. The Norwegian national 2003 statistics [6] indicated total 2493 persons (282 females) applied for mechanical engineering education at 10 different university colleges in Norway. Comparing with other engineering professions, there were totally 17547 persons (2875 females) applied for engineering education in 2003. The same statistics also noticed total 299 persons (22 females) started as mechanical engineering students in Norway, in comparing with total 2088 started as engineering students (321 females) in 2003. This national figure is relatively weak when compared with HS-Wismar and TU-Brno. There is a need for promoting mechanical engineering, or even engineering education for future applicants in Norway.

However, the debate topics are very much the same for all three units, see details in table I. Changes and demands outside is one certain fact for everyone. The Norwegian industry demands future engineers as generalists in higher technical level. The Czech industry also demands flexible students with high level of knowledge and ability to work in change surroundings. The industrial societies' general expectations for the future engineers seem to focus on abilities to learn new skills and perform tasks quickly. This direction requires more learner focused teaching approach. Another similarity is that both Norwegian and German governments want rationalizing of teaching budget or staff. The same situation applies for TU-Brno where the staff resources are also limited. This situation remains us practicing of scientific management principle into higher education institutions. The debate topics among the staff members of these three units are therefore much related to changing teaching content and budgeting of resources.

The debate in HS-Wismar mentioned for the uncertainty about the acceptance of the Bachelor degree by the industry (Is a BEng a real engineer?). The similar issue has also disputed in HIOF-IR, Norway. A number of students concerned about the bachelor degree of engineering may not be valued as high as the traditional diploma degree (høgskoleingeniør in Norwegian) by the Norwegian industry. However, experiences with Norwegian industry so far are not showing any evidence of special preference for one degree over the other.

TABLE II
A COMPARATIVE ANALYSIS ON THE MECHANICAL ENGINEERING MAJOR FOR SAMPLED EUROPEAN UNIVERSITIES – SECTIONS AND PRACTICES

Institution	Østfold-Norway	Wismar-Germany	Brno-Czech Republic
Sections or departments	Product development Construction and machinery	Basic Education (Mathematics, Physics, Mechanics, Computer Science) Section for Energy Engineering Section for Production Engineering Section for Construction Section for Material Technology/ Plastics Engineering Section for Process and Environmental Engineering	Institute of Mathematics Institute of Physical Engineering Institute of Solid Mechanics, Mechatronics and Biomechanics Institute of Materials Science and Engineering Institute of Machine Design Energy Institute Institute of Manufacturing Technology Institute of Metrology and Quality Assurance Testing Institute of Production Machines, Systems and Robotics Institute of Process and Environmental Engineering Institute of Transport Engineering Institute of Aerospace Engineering Institute of Automation and Computer Science Department of Foreign Languages Heat Transfer and Fluid Flow Laboratory
Practices	Project based teaching. Students will have to work with at the least one project each year.	Practical placements in industrial companies within the semester holidays (a certain number of weeks in total).	Laboratory, grade and diploma papers.

Table II listed up sections or departments under the branch of mechanical engineering of these three institutions. There are only 2 sections at HIOF-IR, 6 sections at HS-Wismar, while 13 institutes, one department and one laboratory at TU-Brno. As table I indicated early, there are a large number of students enrolled at TU-Brno, it is therefore reasonable for TU-Brno to have many institutes. The opposite example is HIOF-IR, where only 2 sections available and approximately 15 students are currently enrolled. For 2003 and 2004, there was no new student because of low numbers of applicants to HIOF-IR. The section of product development was established in 1994 for attracting more potential applicants. There are still debates on the whether section of product development or section of construction and machinery shall be focused on among staff members.

HS-Wismar has 6 sections with key aspects of basic, energy, production, construction, materials, and process. This emphasis indicates the mechanical engineering is still very much traditionally focused, and it is a substantial part of the German economy. At the same time, HS-Wismar also considers mechanical engineering as a broadly varied and innovative branch of industry. The modern mechanical engineering industry needs well trained engineers with specialized technical, social and management skills as well as sense of responsibility for its acting. This requires a high measure of specialized knowledge, creativity, flexibility, capability of cooperation and mobility as well as the readiness for learning from life-experience of other engineers. The HS-Wismar's mechanical engineering has confronted these challenges with modern equipped laboratories and flexible study programs, combined with innovative teaching and training methods including information and communication technology, interdisciplinary and internationality as well as close cooperation with the industry.

TU-Brno has the most extensive disciplines under the mechanical engineering major. The speciality institute varies from the most basic one as mathematics to most periphery one as languages. However, the most of institutes are typically traditional mechanical engineering related, such as materials science, machine design, manufacturing technology, production machines, systems and robotics, process and environmental engineering. Aside of these, there are quite few cross-sectional specialities, such as solid mechanics, mechatronics and biomechanics, transport, aerospace and automation. With such extensive disciplines and variety of the specialities, TU-Brno is the one that capable to work on mechanical engineering scientifically.

When comparing practices among these three, it seems to indicate a difference that HIOF-IR has integrated practice into its ordinary teaching courses, HS-Wismar has organized practices as independent placements in companies, while TU-Brno has used laboratories extensively as practices.

TABLE III
A COMPARATIVE ANALYSIS ON THE MECHANICAL ENGINEERING MAJOR FOR SAMPLED EUROPEAN UNIVERSITIES – TEACHING COURSES AND RESEARCH NETWORK

Institution	Østfold-Norway (Bachelor of ME)	Wismar-Germany (Bachelor of ME)	Brno-Czech Republic (B.Mechatronics)
Teaching courses	Discrete mathematics and linear algebra, mathematic methods, communication-environment-chemistry, physics, computer techniques, manufacturing technology, mechanics Engineering mathematics, project economy-student entrepreneurship, CAD-3D, material science and plastic composite, innovation and product analysis, technical thermodynamics Product development and quality control, machinery, industrial design and marketing, final project work (12 weeks)	Scientific and scientific-engineering principles. Compulsory subjects are continued and students are also obliged to choose major subjects according to their selected direction of application. Product development and plastics engineering, Computer science in mechanical engineering, Industrial Project (12 weeks) Diploma Semester (operating time 10 weeks)	Compulsory for 1st year: Chemistry, Computer science I, Mathematics I+II, Introduction to mechatronics, Design fundamentals I+II, Theoretical fundamentals of technical measurement, Electrotechnics, Physics I , Materials I Optional for 1st year: Descriptive geometry, Adv.mathematics, Physical exercise, Winter sport course, English, German, Numerical methods I, Computer science II, Adv.physics, Summer sport course 1, Physical exercise, Computer geometry and graphics
Research directions	Currently no research project directly related to Mechanical Engineering (ME). However, Faculty of Engineering has a number of research projects funded by the Norwegian Research Council, in entrepreneurship, innovation network of Norway, SME competence upgrading. There are also few other projects as science centre, technology for teaching education, online learning and teaching, and Uniska, an international cooperation project with Swedish universities and university colleges.	Product innovation, mathematical simulation and technological process development for mechanical engineering, precision mechanical engineering and the plastic processing industry Surface and thin-film technology Process and environmental technology	Institute of manufacturing technology: Research of progressive production technologies on CAD/CAM/CIM/CAE, Research of principles and material interactions in production technologies, Analyses of workability, formability, weldability and castability of advanced materials, Tool performance and its improvement on the base of PVD/CVD/MTCVD technologies, Surface integrity of machined surfaces for high loading conditions and extreme demands, Statistical analyses of production quality.

Teaching courses are the main educating content for these three mechanical engineering units. These courses are also good indicators for the institution's emphasis and focus in its educating programs. Reviewing these courses in table III, HIOF-IR seems to focus on applied sciences and mathematics, project, practice and economy related topics. Also, the course composition and overview appears to be more cross-sectional and general, less specific and in-depth.

The course composition for HS-Wismar is combined scientific principles (basic aspect) with product development and plastics (cross-sectional and applied aspect). Computer science is also used for mechanical engineering to updating the technology development. For TU-Brno, the current study uses 1st year's course program for bachelor of mechatronics to conduct comparison with two others. Browsing these courses, it is noticeably a heavy part of theoretical courses, such as chemistry, computer science I, mathematics I+II, Design fundamentals I+II, Theoretical fundamentals of technical measurement, electrotechnics, physics I+II , materials I, numerical methods I, computer science II, etc. There are also quite a few optional courses available for students. This makes mechanical engineering study at TU-Brno more substantial and supplemental in topics.

The same profile can also be observed in comparison for research directions. Though there is no research project directly related to mechanical engineering, the HIOF-IR faculty has a number of research projects in cross-section or none-traditional engineering based fields. Many projects are innovation and entrepreneurship related, but with engineering approaches. Differently, HS-Wismar has both a direction of generality, as product innovation, and a direction of in-depth as surface and thin-film technology, etc. Thirdly, the research direction of institute of manufacturing technology at TU-Brno indicates a high profile of in-depth research projects heavily focused on mechanical engineering, such as research of progressive production technologies on CAD/CAM/CIM/CAE, analyses of workability, formability, weldability and castability of advanced materials, statistical analyses of production quality, etc. As a result, the research directions among these three are apparently different. The profile varies from HIOF-IR's cross-section and none-traditional based to TU-Brno's in-depth research and heavily mechanical engineering based, with HS-Wismar's combination of both in between.

TABLE IV
A COMPARATIVE ANALYSIS ON THE MECHANICAL ENGINEERING MAJOR FOR SAMPLED EUROPEAN UNIVERSITIES – TEACHING PHILOSOPHY AND HANDLING THE CHALLENGES

Institution	Østfold-Norway	Wismar-Germany	Brno-Czech Republic
Teaching philosophies	Learning by doing. More practice, combined with theories	Combination of lectures, seminars, labs and project work. Encouragement to self study.	Deep theory in mathematics, physics etc., deep practice especially in diploma paper
How to handle the challenges	Moving focus to new specialties, creating innovation and entrepreneurship Open for further discussions	Ongoing improvement of course structure. Open for further discussions.	Possibility of Reengineering application

Having compared facts and profiles, it is now important and interesting to analyze the teaching philosophies and future thinking of these three actors. Teaching philosophy is usually the essential motivation behind the teaching methods and content, and it may represent further values beyond the surface. It is a clear that HIOF-IR's teaching philosophy focuses much on "Learning by doing" principle and heavily practice based. On the other hand, TU-Brno's teaching philosophy emphasizes very much to the basic theory in mathematics and physics. However, the emphasis also directs to practice, especially in final project work (diploma paper). Thirdly, HS-Wismar prefers a philosophy of combination in lectures, seminars, labs, project work and self study.

How to handle the challenges is usually an opinion summary for staff member and this may display different ways of problem solving. For the last 5 years, HIOF-IR has initiated two new and extra study offers to compensate a low number of applicants to mechanical engineering. The two new offers are "industrial design" and "bachelor class of technology, innovation and entrepreneurship". It is therefore important and beneficial for HIOF-IR to moving focus to new specialties. Similar thinking is shared with colleagues at TU-Brno, while HS-Wismar is working with improvement of courses and opening for further discussions.

A SUMMARY OF ANALYSIS RESULTS AND CONCLUSIONS

For summarizing the results from comparative analysis, the current study has the following findings for mechanical engineering majors of HIOF-IR, HS-Wismar and TU-Brno, respectively in Norway, Germany and Czech Republic:

- The current status is troubled by low numbers of applicants, lack of interests for HIOF-IR, while HS-Wismar and TU-Brno are in relatively good shapes. There is however a common problem of limited staff resources for all three parts.
- The debates have the similar topics for all three parts, the industry needs generalists or flexible survivors, the government want rationalizing teaching budget and staff. Few students are sceptic for changing degree from diploma to bachelor.
- There is quite a difference in numbers of sections and specialties, as HIOF-IR has 2, HS-Wismar has 6, while TU-Brno has totally 15 institutes under the faculty of mechanical engineering, which makes TU-Brno-ME as a large organization.

- HIOF-IR has integrated practice into its ordinary teaching courses, HS-Wismar has organized practices as independent placements in companies, while TU-Brno has used laboratories extensively as practices.
- While HIOF-IR has relatively cross-sectional and general courses, TU-Brno prefers with a heavy part of theoretical and in-depth courses, and HS-Wismar rather combines together the basic and applied aspect.
- HIOF-IR faculty has research projects in cross-section or none-traditional engineering based fields, while TU-Brno has a high profile of in-depth research projects heavily focused on mechanical engineering, and HS-Wismar has both elements.
- HIOF-IR's teaching philosophy focuses much on "Learning by doing" principle and heavily practice based, and TU-Brno's teaching philosophy emphasizes very much to the basic theory in mathematics and physics.
- HIOF-IR prefers to handle challenges in moving focus to new specialties, while TU-Brno thinks reengineering application, and HS-Wismar is working with improvement of courses.

While the similarities are existing in current status and debate topics for all three parts, more differences are identified in many aspects, as specialties, practices, focusing on teaching courses, research directions, teaching philosophies, etc.

It was interesting to notice even course curricula were emphasized differently. Traditionally, mechanical engineering majors usually have the similar curricula over times [10]. The current observation may raise a question in a cultural aspect of this issue again: Is mechanical engineering education standardized internationally or is it convertible locally or culturally? According to the theory of cultural divergence [4], every culture has own preference and indicators towards a value or the emphasis of quality content. The value of education is much depended on the quality of teaching curricula, which again, is depended on the criteria selected by people. These criteria are quite possibly different form one culture to another. Though there is no direct evidence that indicating the different course curricula is culturally related, it is still necessary to raise the question.

Aside of a cultural aspect, it is also reasonable to consider the current demands from the local industries of these countries, as the important criteria for differences. By integrating these local industrial demands, it opens the possibilities for changing curricula into more practice and project based teaching content. Recent studies has concluded positive experiences with such practical approaches, observed both in final student project [7], technical courses as product development [5], or even basic courses as mathematics [2]. It is more and more in common to introduce the practical approaches and methods as student participation, teamwork, learning process evaluations, project based teaching into mechanical engineering curricula. This change will presumably diversify the teaching curricula into locally and culturally related content.

As a conclusion, mechanical engineering is not only a standard major by its academic definitions, but also a various major in teaching practices depended on it s special circumstances around. This variation opens a continual and further debate, in its changing options, availabilities for industrial demands, cultural or national characteristics and global compatibilities, etc.

REFERENCES

[1] ASCED, "Mechanical Engineering", *ASCED Field of Education Definitions- The University of Western Australia,* Online Source: http://www.admin.uwa.edu.au/stats/Internal/Foepage/foel30307.htm#foe030701

[2] Borges, M, N, Do Carmo, M, Goncalves, N, S, Cunha, F, M, "Teaching and learning conceptions in Engineering Education: an innovative approach on Mathematics", *European Journal of Engineering Education,* Vol. 28 Issue 4, Dec2003, p523-535.

[3] Encyclopædia Britannica Online, "Mechanical Engineering", *Encyclopædia Britannica Article,* Online Source: http://search.eb.com/eb/article?eu=108131

[4] Hofstede, G, *Culture's Consequences. Cross-cultural research and methodology series.* Beverly Hills, Ca. Sage Publications, 1980.

[5] Kit F, P, Yam, R, C, .M, Sun, H, "Teaching new product development in universities: an action learning approach", *European Journal of Engineering Education,* Vol. 28 Issue 3, Sep2003, p339-353.

[6] NSD, "Information on Research and Higher Education", *The Norwegian Social Science Data Services (NSD),* Online Source: http://www.nsd.uib.no/english/

[7] Popov, A, A, "Final undergraduate project in engineering: towards more efficient and effective tutorials", *European Journal of Engineering Education,* Vol. 28 Issue 1, Mar2003, p17-27.

[8] UNL College of Engineering, "What is Mechanical Engineering?" *University of Nebraska - Mechanical Engineering,* Online Source: http://www.engr.unl.edu/me/aboutME.html

[9] UTMIE, "What is Mechanical Engineering?" *University of Totonto - Mechanical and Industrial Engineering,* Online Source: http://www.mie.utoronto.ca/undergrad/ME_whatis.htm

[10] Whiteman, Colonel Wayne E., "Mechanical engineering curricula: a baseline study for the future effects of ABET EC2000", *International Journal of Mechanical Engineering Education,* Vol. 31 Issue 4, Oct2003, p327-339.