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Technical note

Mechatronics education at CDHAW of Tongji University: Structure, orientation and curriculum

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Abstract

Mechatronics is a new emerging discipline challenging the traditional engineering thinking and practices. The Chinese–German School of Applied Sciences (Chinesisch-Deutsche Hochschule für Angewandte Wissenschaften, CDHAW) is an educational project of the Chinese Ministry of Education (MoE) and the German Federal Ministry of Education and Research (BMBF), implemented by the Tongji University and a consortium of German Universities of Applied Sciences (UAS). Mechatronics engineering is one of its three majors at present. This paper discusses the structure, orientation and curriculum design of mechatronics engineering education at CDHAW of Tongji University.

Keywords: Mechatronics education; Curriculum design; International collaboration

1. Introduction

Mechatronics is a new emerging discipline challenging the traditional engineering thinking and practices. Many countries and universities are developing their mechatronics program and exploring the mode and way of implementing mechatronics engineering education during the last decade [1,2]. The Chinese–German School of Applied Sciences (Chinesisch-Deutsche Hochschule für Angewandte Wissenschaften, CDHAW) is an educational project of the Chinese Ministry of Education (MoE) and the German Federal Ministry of Education and Research (BMBF), implemented by the Tongji University, one of the leading universities directly under the MoE in China, and a consortium of German Universities of Applied Sciences (UAS). Mechatronics engineering is one of its three majors at present. The project was motivated by the following factors: (1) to explore and develop a new mechatronics education mode, or even engineering education mode that serves as a national model through the introduction of German educational mode of UAS; (2) to meet the huge local industrial (including German companies in China) needs for engineers with strong practical solution abilities when China is becoming a world class manufacturing center. The objectives of mechatronics program are principally: (1) to train graduates to be competent in the field of mechatronics in areas such as automobiles, consumer electronic products and manufacturing automation systems; (2) to enable them to apply the relevant knowledge and technologies for the design and realization of innovative systems and products; (3) to endow the graduates with solid communication skills in the circumstances with a multidisciplinary, multicultural and multilingual nature. This paper discusses the structure, orientation and curriculum design of mechatronics engineering education at CDHAW of Tongji University.

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2. Structure

2.1. Organizational structure

The mechatronics engineering education at CDHAW is supported by its organizational structure shown in Fig. 1. There are three key roles in it during its implementation, i.e., Tongji University to which the CDHAW belongs, German partners of UAS headed by Esslingen University of Applied Sciences, and industrial consultant committee that offer to help in establishing necessary liaison with local industrials, and also is a significant feature of mechatronics education at CDHAW.

The German higher technical education system is basically divided into two parts: the technical universities (Technische Universitat) and the universities of applied sciences (Fachhochschule-FH). The philosophy of Universities of Applied Sciences (UAS) is to offer study programs which link state-of-the-art technology and scientific theory to a practical, hands-on approach to learning. The wide popularity with students and employers has proved its success.

2.2. Faculty structure

Faculty at CDHAW consists of three parts (Fig. 2): (1) Tongji University, including teachers from College of Mechanical Engineering, College of Electrical and Information; (2) German professors from UAS partners who will take on approximately 30% of the teaching tasks of specialized courses beginning from the third semester; (3) Engineers from industrials. Input from industry in the form of real life design and development projects and supervision of such projects by experienced engineers is the feature that a sound mechatronics engineering program should have [2].

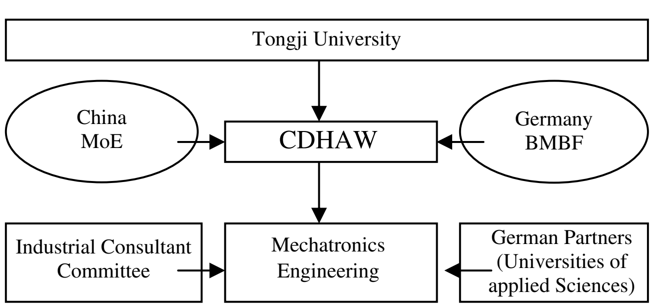

Fig. 1. CDHAW organizational structure.

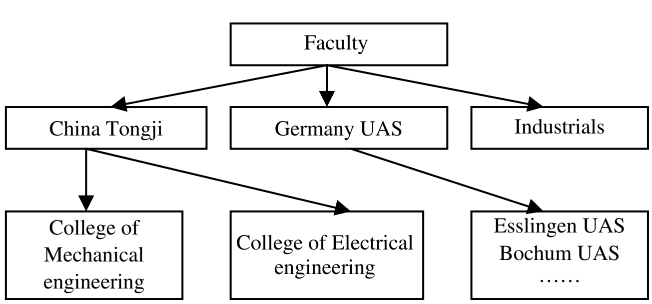

Fig. 2. CDHAW faculty structure.

Semester		
1	China Tongji University (All lectures given by Chinese teachers except German)	
2		
S1		
3		
4	China Tongji University (Lectures given by both Chinese teachers and German professors)	
S2		
5		
6		
S3		
7	Germany UAS (TestDaF PASS)	China Tongji (TestDaF FAIL)
8		
	Dual Bachelor Degree	China Bachelor Degree

Fig. 3. CDHAW semester structure.

2.3. Semester structure

The mechatronics bachelor degree at CDHAW includes 8 regular semesters and 3 short semesters, which are located between semester 2 and 3 (namely S1), semester 4 and 5 (namely S2) and semester 5 and 6 (namely S3), respectively and last 2 to 5 weeks. In the first 6 semesters, all students will study in China, but those passing the TestDaF test will continue their study at Germany and may obtain both Germany and China bachelor degree at the same time, those failing this test will remain in China to finish their study for the last 2 semesters (Fig. 3).

3. Orientation

Mechatronics engineering possesses a very big platform, so the specific orientation of mechatronics education is very important for its success and should tend to reflect the needs of local industries. Despite world wide interest in mechatronics, it is still not certain that there is a clear and consistent understanding of what mechatronics is and how it should be taught. A review of the published literature [3,4] concerning mechatronics education will rapidly result in a number of definitions. Although different definitions may seek to emphasize a slightly different aspect of the mechatronics concept, most of the definitions do manage to agree in some way that mechatronics is concerned with the integration of its core technologies (see Fig. 4) to generate a new and novel technological solutions in the form of products and systems in which functionality is integrated across those core technologies. Integration is

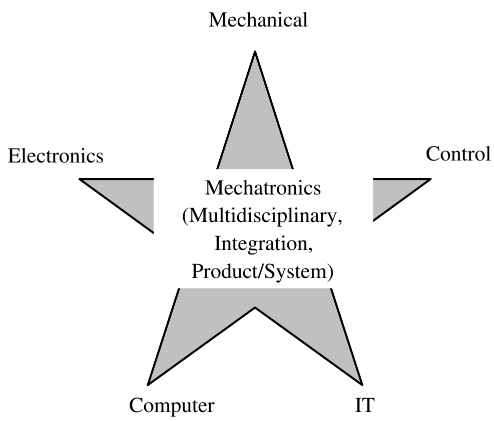

Fig. 4. Core technologies of mechatronics.

the nature of mechatronics. So three key words about mechatronics definition could be extracted: multidisciplinary, integration and products or systems.

- *System-oriented*. Manufacturing systems automation is the key technological area of mechatronics and brings together a wide range of mechatronics technologies, including the hard technologies such as drivers, actuators and sensors and soft technologies such as software engineering and information technology as well as industrial robots and materials handling systems [5]. Manufacturing systems automation is inherently mechatronics, and generally can be categorized as five levels (see Table 1). Based on industrial requirements and the strength of German UAS partners, the focus of mechatronics education at CDHAW should be below 1–3 levels.
- *Product-oriented*. Consumer products like washing machines, DVD, mobiles are typical mechatronic products that consist of mechanical components such as structures, enclosures and mechanisms, combined with electrical components such as printed circuit boards, embedded systems, etc. Design and fabricating such products require collaboration between many engineering disciplines. In a sense, it embodied to a most degree the philosophy of mechatronics, so this is also what our mechatronics should be focused on, and the needs of industrials as well.

In order to differentiate from traditional Chinese bachelor education and vocational education and training in mechatronics education, while catering to the needs of industrials, our course should also have good academic standing considering the higher quality of the students who usually scored higher in national college entrance examination at CDHAW. So the students can either go directly to industrial companies or choose to study further to pursue a higher degree or do some research work after graduation.

Table 1
Levels of manufacturing automation

L1	Device level	Actuators and sensors, transmitters, etc.
L2	Machine level	CNC, AGV, robots, etc.
L3	Cell or system level	Production line, group of machines connected by a material handling system, etc.
L4	Plant level	Shop floor control system, MRP, etc.
L5	Enterprise level	Corporate information systems, CAD/CAM/PDM, master production scheduling, etc.

4. Curriculum

4.1. Design philosophy

Curriculum design is crucial for success in mechatronics education and many literatures discussed it [2,3,6]. In general, the courses developed tend to reflect the needs of local industry, the individual backgrounds and interests of faculty members involved, students perceptions and interests, and availability of resources, particularly human and financial [4]. In principle, our developed curriculum should meet both China and German UAS requirements for bachelor degree in mechatronics engineering. This means we may have more courses, and such a case is compounded further by the studies of both German and English languages. Therefore three semesters are inserted into our semester structure (see Fig. 3).

From the system engineering point of view, our curriculum design is based on the following three dimensions (Fig. 5): (1) Knowledge dimension: what knowledge (including technical and non-technical knowledge) should be taught? (2) Method dimension: how should it be taught (e.g. problem-based, project-based, product-oriented and team organized teaching)? and (3) Logic dimension: how to organize these courses and in what sequence should the courses be taught?

Our design philosophy can be further described in IDEF0 (ICOM, i.e., input, control, output, mechanism) modelling method (see Fig. 6). The input (requirements) of this activity includes objectives and requirements of the curriculum design. In terms of our orientation mentioned above, basically the desired curriculum should give

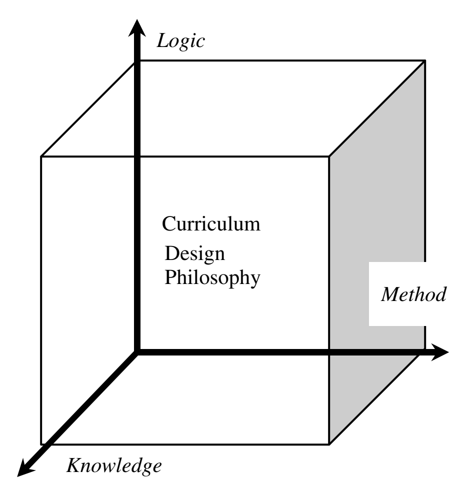

Fig. 5. Curriculum design philosophy.

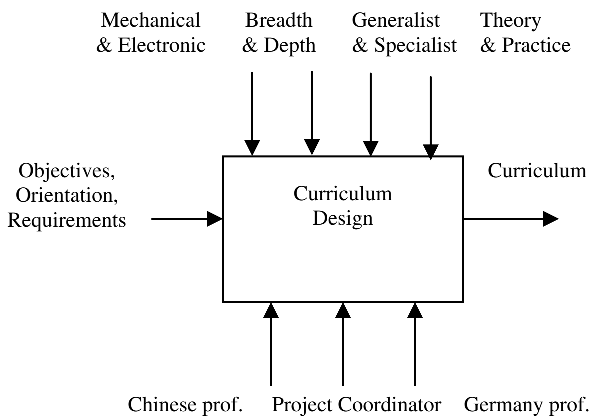

Fig. 6. Curriculum design methodology.

students the relevant knowledge and abilities of mechatronics, for example, (1) the fundamentals of mechatronics engineering; (2) the hands-on lab experience; and (3) the application of the fundamentals of mechatronics engineering in design and manufacturing in specific industrials. The "control" factors which are great challenges for curriculum design are focused on the balance or compromise between different elements. Key balances include:

- *Breadth and depth*. In terms of the development of mechatronics education, the concern in course design has always been that of how to achieve a balance between providing the necessary depth of the core technologies and the ability to develop solution integrating them. Mechatronic engineers must have broader backgrounds but with specialized knowledge of a discipline and abilities to operate in a multidisciplinary project team. Therefore the engineering education systems for mechatronics should not only provide broader background than conventional undergraduates program, but also accommodate depth at least in one of the major disciplines. Expanding breadth but preserving depth can always be a paradox in curriculum design due to the limited time.
- *Generalist and specialist*. To be a generalist or a specialist? This question is similar to the first one. Different from traditional engineering education system that is oriented towards producing specialist engineer with narrow and deep specializations, in addition to having a sufficient depth in certain technical area as a specialist, mechatronics engineer must be able to speak the language of the individual specialists and hence act as an interpreter to ensure the correct communication of ideas and concepts (a generalist) [1,2].
- *Mechanical and electrical*. As implied by its name, mechanical design is a major component of mechatronics. The level of integration between mechatronics and mechanical design is an area that is seen as being critical to the success of mechatronics education in the future [4].
- *Theoretical and practical*. Mechatronics courses usually rely heavily on laboratory excises, and are in most cases project-organized and problem-driven. So practice makes perfect. The concept that the students should create, program and run a mechatronic product where the mechatronic product consists of mechanical parts, electrical parts and ubiquitous microcontroller sees to be dominant [1].

4.2. Curriculum structure

The curriculum is designed according to our philosophy as an integrated system of learning, combining the fundamentals of mechanical and electronic engineering as well as information technology, control and computer to meet the needs of industries involved in automotive, factory automation and related areas (see Table 2). Basically, the

Table 2
Mechatronics course at CDHAW

Year	Description
1	*Lecture topics (required)* Math German C/C++ Physics & experiments Engineering drawing & CAD Materials science Practical work Preliminary industrial practice (6 weeks) Electrical practice (6 weeks)
2	*Lecture topics (required)* Mechanics (theoretical & technical) Electronics & digital technology (1) Circuits Automatic control[a] Manufacturing technology[a] English
3	*Lecture topics (required)* Electronics & digital technology (2) Mechanical design Product design methodology Business & quality management Computer networks & industrial communication Sensors & actuators[a] System design & simulation[a] Microprocessors Programmable logic controller[a] Driving technology Practical work Mechanical design project (2 weeks) Project & project management (6 weeks)[a]
4	*Lecture topics (elective)* Tongji module Finite element method NC programming Robotics Each German UAS has its own elective modules Practical work Industrial practice (3 months) Thesis (3 months)

[a] This course is taught by German professors.

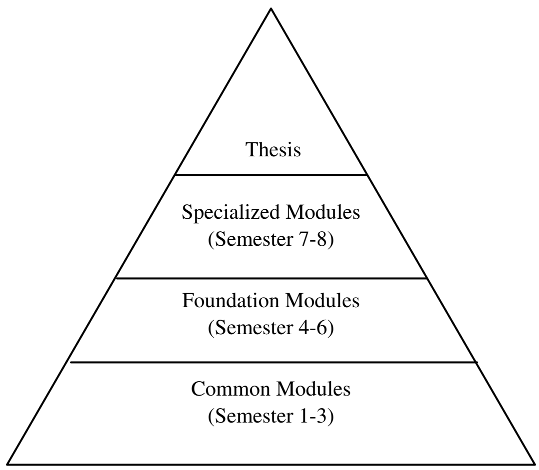

Fig. 7. Three level course structure.

course structure could be divided into the following three levels (Fig. 7):

- The first level of the course represents the basic studies in engineering, including math, physics, materials and so on.
- The second level provides broad-based studies in the foundation of mechatronics, including sensors and actuators, automatic control, PLC, networks and so on.
- The third level tries to give students a little depth in certain technical area such as manufacturing automation systems, process control and visualization, CAD/CAM and NC machining, mechatronic product design and fabrication, etc. Different universities (Chinese Tongji and German UAS partners) may have different elective modules representing their strength, and students may choose what they are interested in.
- The final year thesis represents the culmination of the mechatronics education as students apply the wide range of skills and knowledge acquired. Before that students will undergo deleted three months of attachment to industry to apply their knowledge and to gain valuable hands-on industrial experience.

All courses and projects will be taught with constant reference to the above mentioned philosophy of mechatronics. The importance of mechatronic design philosophy should be stressed at all levels in the teaching. After completing the courses, students will have not only a sound mechatronics foundation, but also some background in non-technical areas such as business management, languages, interpersonal skills that are also significant factor for their career success.

5. Conclusions

5.1. Characteristics of mechatronics education at CDHAW

- Mechatronics education at CDHAW provides students with a multicultural, multilingual and of course multidisciplinary environment which is very helpful for students to improve their communication skills and team-work spirits which should be important factors for their future career success when world economy tends to be more globalization.
- By incorporating the educational mode of German UAS, mechatronics education at CDHAW pays more attention to the way of cultivating students' ability to solve practical industrial problems, narrowing the gap between theory and practice. So mechatronics education at CDHAW is characterized by a high degree of practical orientation and problem and project-based learning to make the graduates adapt quickly and efficiently to real industrial environments. For them their professional career does not start from scratch but is rather a continuation of what they have learnt and experienced during their studies.
- Compared with mechatronics education in regular universities and in new vocational education schools in China, mechatronics education at CDHAW will try its best to forge its characteristics that, on the one hand, are more practical-oriented than regular university; and on the other hand, have more solid theoretical studies than the vocational education schools.

5.2. Current status

Mechatronics engineering education at CDHAW is an ongoing project that there is still a long way to go. In order to guarantee the quality of teaching, we increase the enrolment of students step by step. We saw both our first and second intake of 30 students in 2004 and 2005 respectively. We have 45 students in 2006 and will reach the maximum of 60 students in 2007. Among the first 30 students, 26 students who have concluded the required courses and passed the Germany language examination TestDaF will go to 6 German UAS (i.e., HS Esslingen, FH Aachen, FH Wiesbaden, FH Bochum, FH Brandenburg, HS Zittau/Görlitz) separately to continue the study of last year in fall of 2007. Up to now, there have been nine German professors coming to China to give lectures on manufacturing technology, classic automatic control, digital control, sensors and actuators, system modelling and simulation, industrial communications, mechatronics capstone design (project and project management), and so on.

In the same time, we have established close relationships with some world-class German companies, including Siemens, Festo, Bosch, Phoenix, etc. On the one hand, they can act as students internship sites; on the other hand, sponsored by these companies, several advanced labs have been built up, i.e., sensors lab, driving technology lab, FMS lab, PLC and industrial communication lab which is also called "Tongji University-Siemens Ltd., China A&D Group, Advanced Automation Technology Demonstration Laboratory Center". In addition, we have a VPD (Virtual Product Design) lab with CAD software and simulation softwares such as Adams, Nastran/Patran, which can be used to design, analysis and simulation of mechatonics product.

5.3. Challenging issues

Some of issues encountered that may be unique for this project or generic for multidisciplinary courses up to now are as follows:

- Difficulty in arriving at an agreement on the course contents and hours due to its multidisciplinary or multicultural nature and resources available.
- Adjustment of course contents or/and teaching mode to adapt to mechatronics education at CDHAW.
- Development of new laboratory experiments and student project in mechatronics.
- *Students awareness*: An intensive recruiting effort needs to be launched to make prospective students understand the nature of mechatronics and the characteristics of mechatronics education at CDHAW.
- The effective way of communication and coordination among teachers with different academic or cultural backgrounds.
- Organization, and efficiency and understanding of lectures given by German professors who usually stay in China for 4–6 weeks.

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