AC 2007-1579: PREPARING SWEDISH MECHATRONICS ENGINEERING STUDENTS FOR A GLOBAL INDUSTRY

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Abstract

The subject of mechatronics is defined to be cross-disciplinary, based on the concept of synergy and synergistic use of knowledge and skills in underlying subjects. To master the subject means, according to the analysis in this article, to be skilled in applying the subject rather than having vast knowledge. The mechatronics engineers therefore tend to work as an integrator, as project coordinator or project manager. Mechatronics engineers also tend to work with applications, with systems rather than components and with synthesis and design rather than analysis.

In the perspective of globalization the skills required of the mechatronics engineer has to be valid on an international market, and "international skills" ought to be included in the curriculum. This article presents experiences from different modes of integration of international skills into capstone courses and curriculum in mechatronics at KTH, the Royal Institute of Technology in Stockholm, Sweden.

In conclusion, international collaboration in the settings described can provide experiences of working in a global setting in order to prepare students for future work in a multinational company. International collaboration is also more directly related to the special identity of the subject of mechatronics, and the experience of working with global, diverse teams is valuable preparation for a future career in a global market.

Introduction

Mechatronics has been taught at KTH, the Royal Institute of Technology in Stockholm, Sweden, since 1984. The Mechatronics engineer is characterized by cross-disciplinary work, by utilizing competencies in various areas such as electrical engineering, mechanical engineering as well as functional skills in programming, control etc. In prior studies of relations between educational programs and professional roles, the Mechatronics engineers (at least in Sweden) are more associated with project management and broad system design than comparable engineering programs[1].

Mechatronics as an academic subject has existed since the 1960s, and has since then evolved from being a combination of a subset of MECHAnics and elecTRONICS to a subject that is defined as "the synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes"[2]. Authors such as Adamsson[3] have identified and analyzed the professional role of the mechatronics engineer in studies of engineers and their roles in companies. Since mechatronics is an integrative and synergistic subject, the mechatronics engineer in many cases is an integrator, a project manager, a technical coordinator or a designer of complex cross-disciplinary systems[4].

International skills, in the context of international understanding and international competence, involve issues such as the comprehension and understanding of "our place and our potential in the world”. Also, international skills include insight into foreign societies and international issues including cultural issues[5]. Since most companies today act on a global market there is a need to include a global awareness in mechatronics education as well as in the role of the mechatronics engineer. Due to the identity of the subject, and due to the identified role of the mechatronics engineer, this need is further more apparent in mechatronics engineering education than most other comparable engineering educations. The purpose of this article is therefore to discuss this need further and to present research undertaken into the area.

The main collaborative nodes of the KTH Mechatronics group as of today are: Stanford University, Boston University, Harvard Medical School, Sydney University, Tokyo Institute of Technology together with other nodes, mainly in Tokyo, Singapore and Europe. At some of these nodes, the Mechatronics group at KTH has established more or less permanent bases with continuous long-time student collaboration. Besides the collaborative projects presented in this article, mechatronics students are usually offered an opportunity to spend six months at a foreign node, typically to perform a master thesis project.

The larger collaborative projects, however, are based on international collaborations in existing settings, without major student relocation, which also constitutes the focus of our current research. A number of research publications have been published presenting data from various settings. Two of the most advantageous settings involve large student projects with either international corporate sponsors or collaboration with an international student team. These settings all reflect a work-like international distributed setting and require students to focus on internationalization and distributed work. Typically, the projects are organized in the form of large capstone projects with open ended design tasks and industrial corporate collaborators. These projects have been studied, evaluated and improved since 1984, with a continuous expanding interest from students and collaborators.

The subject of mechatronics

The subject of mechatronics has been defined, analyzed and discussed in several previous publications[6, 7]. These analyses are based on the theoretical framework introduced by Dahlgren[8], where a four dimensional tool is used to analyze and describe the subject according to four variables, or dimensions. The first two dimensions regard the identity and legitimacy of the subject, which in combination gives an illustration of the subject. The identity of a subject varies between two extremes; from disciplinary to thematic. A disciplinary subject is an established subject, where a consensus exists in the society. The identity is clear, defined and mostly agreed upon. In a thematic identity, the identity is rather based on a theme, a phenomenon, a movement or an idea of cross discipline. Themes or examples are used to explain the identity and typically each and every university, researcher and educator has his/her own definition of the subject.

In the case of mechatronics, everything started with an idea of how to synergistically integrate mechanics and electronics. The idea was based on the idea that the combination is greater than the sum of the parts, an idea that a mechanic product could be made better and cheaper by adding electronics and control systems. The identity is thematic, and the theme relates to the concept of synergy.

The legitimacy is defined as the relation between the output of the educational organization and the demand put forward by the society, for example the hiring industry. The legitimacy is mapped between the two extremes of either functional or formal, meaning that either functional demands in terms of skills and experiences are put forward from the hiring industries or formal demands are put up by the government, by the university or other organizations.

In the mechatronics case, the hiring companies define the needs and competencies of the mechatronics engineer. This relates to the thematic identity; no uniform identity is established, there is no consensus regarding the identity of the subject. Instead, functional skills are asked for, skills related to the ability to perform synergistic integration of knowledge and skills into product development of mechatronic products.

The mechatronics engineer

Due to the identity and legitimacy of the subject, the mechatronics engineer commonly work with tasks that relates to integration of knowledge and skills, relates to functional skills and basically to getting things done and products working. The mechatronics engineer therefore commonly acts as project coordinator and project manager. The mechatronics engineer typically works with experts from the underlying fields, with experts in mechanical engineering, electrical engineering, control theory and software engineering. The need to integrate related skills into mechatronics engineering education has been apparent since the start of mechatronics, and most universities educating mechatronics engineers include aspects of teamwork, team management, human skills etc[9, 10].

The subject and engineer in a global context

Functional legitimacy implies that education should lead to functional skills within product development. Basically the entire industry dealing with mechatronics product development has an international market, and in the case of the major international companies deals with globally distributed work. Therefore, international focus in mechatronics education is likely to be useful in preparation for future work. International focus can also promote a number of intra-disciplinary skills as well as complementary skills such as communication skills. Also, enhanced student motivation is an effect that can relate to the results of an international focus[11, 12, 13, 14, 15].

The international focus is possible to achieve in a number of ways, from individual students studying abroad during a period or from directed activities aimed at students not participating in exchange programs or interested in leaving the home university. The advantage of studying abroad is primarily that by working with students from different universities, cultures, and disciplines, students can encounter different ways of approaching problems and can access a broader variety of knowledge and skills within one discipline as well as practicing language skills and widening their horizons.

The following examples of the situation within typical Swedish companies may help to illustrate the environment that a mechatronics engineer will need to fit in to:

- many of the companies hiring mechatronics engineers from KTH are large, multinational companies;
- most Swedish mechatronics companies have a global market;
- local research and development teams constantly collaborate with other teams within their multinational company.

These observations, together with the previously presented didactical analysis, lead to the following requirements for the mechatronics engineer:

- the ability to work with engineers and experts from traditional engineering areas, for example, mechanical engineering and electrical engineering;
- the ability to follow, and make use of, technical progress in the other disciplinary fields;
- the ability to lead multidisciplinary teams.

It therefore follows that the industry should require international competence of the mechatronics engineer, meaning:

- experience of working in an international team;
- experience of working with colleagues and competitors in, and from, various parts of the world;
- experience of working with colleagues from different educational backgrounds and from other educational disciplines.

Integrating international skills in campus education

During the last ten years a structure has been established at KTH together with international partners, all with the intention of integrating international skills into the campus courses. This structure is based on bilateral agreements with collaborative nodes and individuals across the globe. It is important to note though that these agreements do not contradict or compete with established programs such as the Erasmus program[16] which offers exchange mechanisms for individual students. The international collaborative projects in mechatronics are all based on research collaboration and a mutual exchange of resources and ideas.

The international collaborative projects are usually integrated into a large capstone course given at KTH, and this course serves as the framework for most of the international collaboration. The course studied, the capstone course in mechatronics (4F1162, mechatronics, advanced course), attracts approximately 40-50 students annually. The course begins in October and ends in June. The course is project organized and problem based, and is performed in collaboration with an industrial sponsor. In October, the industrial sponsor presents a task, a problem, or an idea of a product. In June, the student team presents a working prototype of the product or idea. In most cases, the industrial sponsor commercializes the idea and also hires some of the students. The student teams consist of between six to fifteen students, depending on the scope of the project.

The KTH teams are organized with individual roles such as project manager, manager for external contacts, manager for hardware architecture, etc. The responsibilities are organized by the faculty, and are rotated approximately four times during the project. Typically, each student is always responsible for two aspects: one relating to technical development (such as software) and one relating to the process of the project (such as design methodologies). Besides the industrial sponsor, the KTH teams are each assigned a team coach. The coach is typically either a faculty member or a doctoral student. The coach typically meets with the team once or twice a week.

The international focus is added in a number of different modes. Either the student team joins another student team at another university; to perform a project together for a third party, the industrial sponsor, or the student team performs a project for an international industrial sponsor. Both of these modes provide an international touch, but each provides different opportunities and obstacles.

Problem solving in globally distributed teams

This educational setting has been described in previous publications[9, 10, 17]. The idea is to connect two or more globally distributed teams, assign an industrial sponsor and provide global coaching. The teams are supported with equipment and tools for collaborative work such as videoconference systems and collaborative platforms. A typical setup is shown in Figure 1, where a student team at Stanford University acts collaborative partner. In the figure the five nodes are defined together with communicational channels showing the complexity of the setup.

The collaborative projects are typically integrated in courses at both universities, at KTH in the course described above, at Stanford in a large course "Team-based product design and development with an industrial sponsor" (ME310), given by the Design Division within the Department of Mechanical Engineering. This course attracts a similar amount of students and is organized similarly to the KTH course.

A typical student project involves the design of a new product, the solving of an identified problem or the exploration of a new technology or discovery. One example regards the development of a new control system for a cow milking robot; a Swedish company focused on equipment and machines for farming provided the student teams with the task of redesigning the control system for an existing robot tasked to milking cows. The existing control system was too expensive and based on older technology and the task for the students was to design and manufacture a prototype based on a new series of microcontrollers, signal processors and advanced control algorithms.

In the evaluations performed[9, 10, 17] the relative high complexity of the international collaboration also proves to be one of the most difficult obstacles to overcome. The difficulties also relates to the imbalance of having the corporate sponsor located close to one university and also with the different traditions and pedagogical practices which characterize the two universities. Results from previous research suggest that the differences in educational practices or academic cultures create an even greater imbalance between the two countries. In other words, the two sets of faculty often instruct their respective student teams differently. Therefore, the two collaborating student teams may receive different and at times conflicting ideas regarding what is expected of their collaboration, the results, and final deliverables.

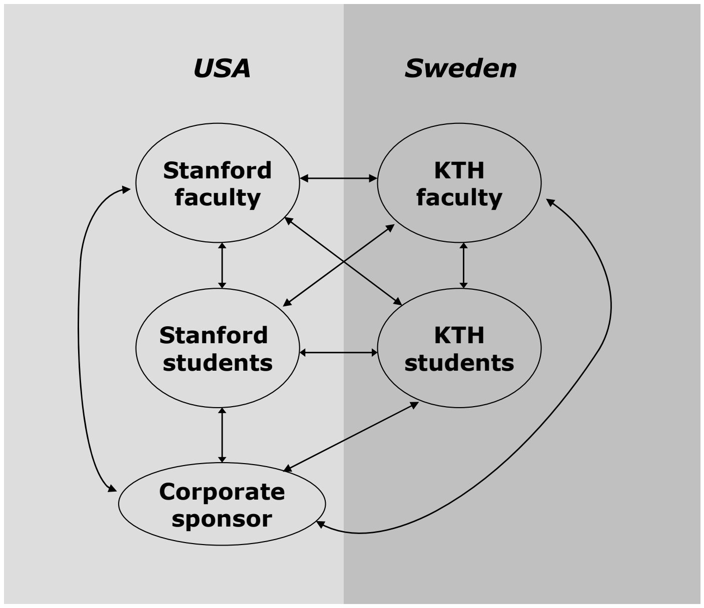

Figure 1. The setup and the communicational channels in the international collaborative educational project

In the example provided above, with the cow milking robot, the advantages of international collaboration soon became evident to the students. In this case, the corporate sponsor was located in Sweden, outside Stockholm, and a team of four students from Stanford joined the KTH student team of twelve persons. The Stanford student team provided access to competence at Stanford University and local experts in robotics were engaged. The respective skills of the Stanford student team and the KTH student team also proved complimentary; where the KTH students lacked in mechanical engineering and design skills was made up for by the Stanford team, equally the KTH students provided necessary skills in microcontrollers and digital signal processors.

The disadvantages related to the complexity of the collaborative setup mainly relates to differences in educational culture and traditions. In the cow milking project these differences manifested themselves in that the two student teams experienced different coaching and expectancies from the two universities and the two courses. Basically the two student teams tried to perform their best toward the industrial sponsor, meaning designing a good product, but were of different constraints from the two faculties. The two courses were not synchronized, something that would prove to be impossible since other teams in the two courses collaborated with other universities, which implied that the two teams each had to produce deliverables according to the respective faculty. These differences meant that one team could be working on delivering a functional prototype of one part of the machine while the other team worked on a state-of-the-art report.

In a real-life setting these requirements could be managed by a project coordinator making sure that the distributed teams were aware of the common goals, but in the educational project the educational goals were prioritized and these were not shared between the universities; the ultimate goal of each student team were to get high grades at the local faculty, and since the faculties were not synchronized this sometimes seemed to create conflicts between the teams and between team and industrial sponsor which affected the collaboration negatively.

Problem solving in a local team with an international industrial sponsor

To solve the issues with imbalance between the two universities another setup has been tried. This setup involves one student team at KTH and one industrial sponsor located abroad. This setting has been described and analyzed in previous publications[4]. The idea is to mainly keep the existing capstone course structure but exchange the typical local corporate sponsor for an international. This setting does not provide the local KTH-students with collaborative partners as in the earlier described setting, but instead creates a setting where the Swedish students work together with an international corporate liaison. This setting also resembles a real-life setting since the setting enables the students to gain experience from a sharp industrial development project.

One example of this setting was performed in unison between KTH, Boston University and Harvard medical School where a research team associated with Boston University, Harvard Medical School and a local Boston company acted industrial sponsor. The Boston group was organized as a team with two project managers, of which one acted as project coordinator for the KTH student team. The Boston research group is involved in research of the human balance, and the task assigned to the KTH student team was to design a balance prosthesis device based on the research performed by the Boston team.

In contrast to the setting described in the earlier case, the Boston setup proved to be considerably less complex and more manageable from the faculty's point of view. Only three nodes were active, which meant only two communicational channels per node. The student team only had to maintain communication with the KTH faculty and with the industrial sponsor in Boston.

However, from a global point of view, the Boston setup did not expose the KTH students to as much international thinking and acting as in the Stanford case. Where the Stanford related project had the students engage in daily contacts and collaboration with the international team the Boston case only had a few students interact with the international partners every now and then.

Spin off effects

To complete the picture of the two setups earlier described, it is of importance to look at spin off effects as well. These effects have mainly manifested themselves with the Boston node which is important in the comparison. At Stanford a select few of the participating students elect to continue studying at Stanford University or in the vicinity immediately after the project. Typically one to three students after each collaborative project decide to stay in the area. In most cases, these students perform their master thesis project at Stanford University, with an associated research group, or at a company in the vicinity. In all cases the students have kept a relation with Stanford, usually to follow a course or to provide coaching in new international collaborative projects. So far, however, during the last five years all students choose to return to Sweden after graduation.

In Boston the spin offs have been slightly different. During the last five years approximately the same number of students has remained as in the Stanford case, but in these cases most students have continued to either study with the research group, to work for the research group after graduation or even to join related companies started as spin off companies of the research team.

The main difference has been that the Boston collaboration has been seen as a long term commitment by both KTH and the Boston research team that has been fully integrated in the research activities at both universities. In the Stanford case the student projects were always associated with external companies, and in the Boston case those were instead associated with the research performed by the group which proved to be advantageous too all parties.

Other individual international experience

Beside the two settings presented above a number of collaborative nodes around the globe provide opportunities for KTH students to gain international experience by spending between six to twelve months and performing a master of thesis project. In most cases the international nodes consists of research teams at universities. While students performing master thesis projects locally in Sweden mainly collaborate with a local company in the international case this is difficult to organize since most students would require working permits etc.

Existing collaboration programs exists with universities in Tokyo and Australia, as well as the universities previously mentioned, and these usually accepts two students each every year. The agreements consist of mutual agreements and no funding is transferred; the students are expected to perform research for the respective teams and be financed by these.

Advantages of international collaboration in mechatronics education

Derived from the above, international collaboration in capstone courses has been found to promote:

- Improved disciplinary learning and other skills. International collaboration provides access to more resources and fosters new and different perspectives to problems. Collaboration also promotes general skills such as teamwork, team management and presentation techniques.

- Awareness of cultural differences and different educational systems, an important competence for a future career in a global company.

- Enhanced motivation. International collaboration is often perceived by students as an interesting challenge in itself.

The functional legitimacy implies the need for global competence to be incorporated into an education in mechatronics. One way of doing this is to expand a capstone course to include international collaboration as either collaboration with a foreign corporate sponsor or collaboration with one or more international student teams.

Conclusions

International collaboration has two main categories of benefits. The first is that of providing experience of working in a global setting in order to prepare students for future work in a multinational company. For this category, the setup described with the Boston example is the most beneficial: Problem solving in a local team with an international industrial sponsor.

The second category is more directly related to the special identity of the subject of mechatronics. As discussed earlier, mechatronics benefits from being taught in an international setting, and a mechatronics engineer needs more cross-disciplinary communication skill than does a traditional engineer. Thus the setting shown with the Stanford example (Problem solving in globally distributed teams) is likely to be useful for mechatronics education since the primary benefit is to promote transnational collaboration between students. The experience of working with global, diverse teams is valuable preparation for a future career in a global market, and differences between universities, students, and cultures are seen not as disadvantages but as a learning tool.

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