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Collaborative Learning in Mechatronics with Globally Distributed Teams*

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The subject of mechatronics has been taught at the Mechatronics Lab, Royal Institute of Technology (KTH) since 1984. The educational model is based on the four didactical questions: the questions of identity, legitimacy, selection and communication; and as a result there are strong intentions of communicating the subject of mechatronics in an interactive fashion, with an exemplifying selection. Due to the emerging issue of globalisation an attempt has been made to internationalise the education in mechatronics, and this article aims at investigating the possibilities of expanding the questions of selection and communication to also enrol the added aspects of international collaborative learning in mechatronics. Among the conclusions are, besides enhanced motivation for the students, signs of improved disciplinary learning, improved communicational skills and an education which better prepares students for future careers and work in a global area.

INTRODUCTION

THE SUBJECT OF MECHATRONICS has been taught at various universities over approximately 20 years, and has been thoroughly described and defined in earlier publications. In this article we continue on the definition of mechatronics outlined by Grimheden and Hanson [5, 6]. In this approach the subject of mechatronics is characterised in perspective of the four didactical questions [3]:

- legitimacy
- identity
- selection
- communication.

In a two-dimensional view where the questions of legitimacy and identity are illustrated by two dialectical opposing extremes, the two extremes of a formal legitimacy and a functional legitimacy as well as the extremes of a disciplinary identity and a thematic identity, the subject of mechatronics is placed in the quarter of a thematic identity and a functional legitimacy. As described by Grimheden and Hanson [5], this categorisation implies that the questions of selection and communication are answered by applying a vertical exemplification to the question of selection and an interactive perspective to the question of communication.

In this article we would like to expand the questions of selection and communication further by adding the issue of globalisation. To investigate this possibility a study has been made of an attempt to create an international field for collaborative education in mechatronics, a collaborative experiment where:

- Stanford University (ME310 Design Project Experience with Corporate Partners, Design Division, Department of Mechanical Engineering),
- and KTH (4F1161/62 Mechatronics Advanced Course II, Mechatronics Lab, Department of Machine Design),

jointly gave a problem-based and project-organised course in a distributed setting.

A thematic view of mechatronics

The choice of defining the identity of mechatronics as thematic (the theme is related to the concept of synergy) is in unison with the legitimacy of the subject. In a choice between a formal or a functional legitimacy mechatronics is mostly regarded from a functional point of view; the demands from the society and/or the industry is rarely formal but mostly functional, i.e. the demands from the industry is rather functional skills than formal knowledge, which is also reflected in the selection and communication of the subject [2, 10, 13].

The issue of globalisation

Why does somebody want to put up a globally distributed educational setting at all? According to earlier research and our empirical data presented below, we identify some potential educational goals, which motivate this kind of educational settings [4, 7]:

- to improve disciplinary learning/problem solving;
- to improve general skills;

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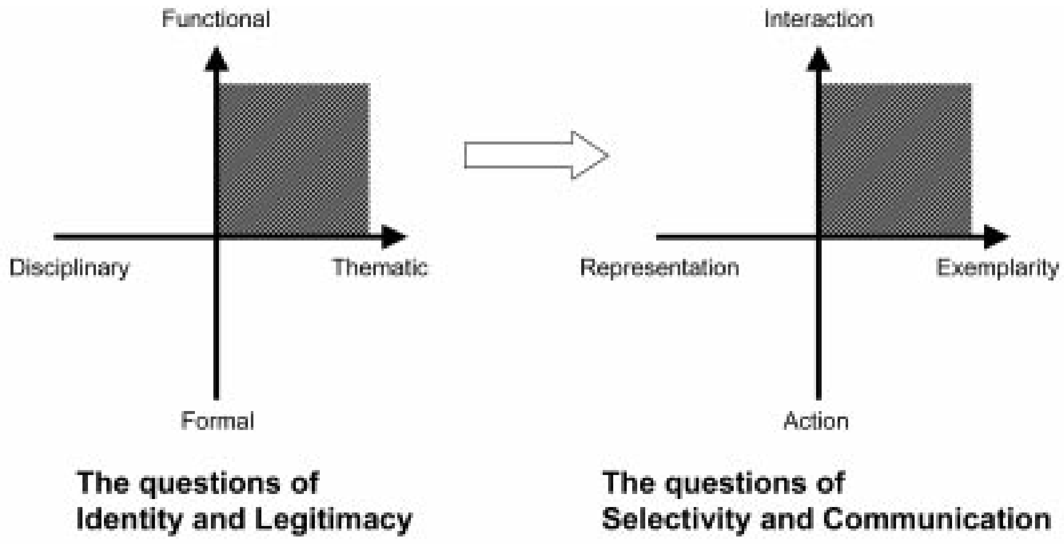

Fig. 1. The four didactical questions applied to the subject of mechatronics.

- to create awareness of and benefit from cultural differences;
- to increase variation in approaching an assignment;
- enhancing motivation;
- comparison of different educational systems;
- preparing students for future careers.

The issues of selection and communication in a transnational setting

According to the potential goals for a globally distributed setting the importance of international collaboration partners has been noted since the first courses in 1984. Returning to the didactical approach to the subject of mechatronics first the question of selection will be placed in a global perspective [11].

To choose a vertical exemplarity in favour of a horizontal representation can be a matter of choosing relevant and representative aspects and projects for the subject of mechatronics. Since the situation where the graduated mechatronics students in most cases will be active is an international market de facto, an international educational setting is a more representative exemplification than a non-international.

The difference between an international educational setting and a local setting is that the aspect of communication, mainly if seen in an interactive perspective, radically changes due to the increasing number of nodes in the system and also to the fact that these nodes represent different backgrounds, knowledge and cultures. In reflection of the two extremes of the question of communication, the extreme of action respective interaction, with the issue of internationalisation, or globalisation, the most advantageous position are deemed to be the interactive perspective because this focuses on the importance of the nodes instead of the top-to-down educational setting.

PROBLEM-BASED AND PROJECT-ORGANISED EDUCATION IN MECHATRONICS WITH A TRANSNATIONAL EDUCATIONAL SETTING

KTH has given courses in mechatronics since 1984. Today the Mechatronics Lab completes a full Master of Science program with a major in mechatronics. According to the research on education in mechatronics the aim is to teach mechatronics with a vertical exemplarity and an interactive communication [8, 12].

The data used for this research are gathered from two years of field-studies of education in mechatronics at the Mechatronics Lab, during October 1999 until June 2001. The Mechatronics Lab gives an annual course in advanced mechatronics which runs from October to June, and for these years about 35 students each year participated. During this course the students work in a project-based organisation with a problem-oriented view on the learning process. During the first week the students are divided into three teams with eleven to twelve students each, and introduced to a corporate sponsor with an industrial project at hand.

Since the start of these courses, in 1984, there has been an intention of the faculty to keep these projects in an international framework due to the reasons described above. This international framework can be generalised into two different settings, either the corporate sponsor has been based abroad, or the student-team has been divided over two or more universities. The setting of these field-studies is the latter, and in both cases the student teams have been divided between KTH and Stanford University. In these cases the KTH students have taken the advanced course in mechatronics at KTH and the Stanford students a similar course at Stanford. Of importance to this paper is therefore the fact that the students have been taking similar but different courses, with different curricula and different faculty.

In the two case-studies presented twelve students were located at KTH and four at Stanford University. In both cases the corporate sponsor has been located in Sweden, in the first case in the form of the research and development department of a major international company, and in the other case in the form of a small company based in Stockholm.

Data collection

The material used in this field-study has been gathered in the following way:

- Interviews with the students. Every student was interviewed twice, during Phase Zero and Phase Two.
- Interviews with the professors responsible for the courses.
- Questionnaires. All KTH students completed questionnaires after each phase.
- Written project reports made by the students after each phase.
- Local and distributed meetings. Most meetings were documented by video camera or by notes.

The projects

The two distributed teams are formed in the late fall. At Stanford University the students choose groups of four, and each team chooses from a number of projects. Typically the list of projects contains several with an international collaborating partner. On the Swedish side the students are formed into teams with twelve students in each.

The projects have been divided into four phases. Each phase ends with a presentation where the results are presented in the form of a written report and in the form of a seminar for all people related to the project. In the end of the final phase a prototype is typically delivered to the corporate sponsor.

Phase Zero—defining the problem and conceiving the product

In the first phase, Phase Zero, the faculty focuses on teambuilding and conceptual understanding of the projects. The twelve students in each team are divided into sub-teams with different responsibilities and tasks. Examples of these are:

1. Project management and organisation.
2. Problem formulation and product definition.
3. Pre-study. Defining needs of competence, etc.
4. Resources and facilities. Workshop, economy etc.

During the first year of this study the KTH team and the Stanford team initiated the collaboration during this first phase by forming a joint team for Stanford University's paper bike race-competition. A team composed of two KTH students and four Stanford students built a bicycle jointly. During these two weeks the students established contact via telephone and videoconference equipment, and via daily communication the students designed the bike and produced the necessary parts. At the end of the two weeks KTH students travelled to Stanford University, with their manufactured parts, assembled the bike together with the Stanford students and participated in the competition.

During the second year of this study the international collaboration during the first phase consisted mainly of team-building and trust-building activities at a distance [9].

Phase One—designing the product

This next phase focuses on the design of the project. In the end of Phase Zero the product is defined, and the project where this product will be designed and implemented is established. Based on the results of this definition new sub-teams are formed. In this phase typically a matrix-like organisation is used where each student, KTH and Stanford students alike, are given a particular responsibility of either product-related or project-related areas.

During the first year of this study the KTH team and the Stanford team were given responsibilities where the Stanford team formed one sub-team with the responsibility of designing a module of the product, and as a result the communication between the two teams at this point came to focus mainly on interfaces and necessary common details. During the second year the two teams were divided differently which gave a different form of collaboration. At this point the project was divided into several sub-teams where four sub-teams consisted of students from Sweden and Stanford.

The actual product to be designed during the first year consisted of a control system for a robot-like device used for milking cows. The student's task was to design a control system for use in an existing product where pneumatically driven actuators should control a manipulator in three dimensions. At this point the project was expanded to also involve the design of active sensing teat-cups, and the students decided to divide the project into these two modules; the control system and the active sensing teat-cups, and the two modules were assigned to the two distributed teams.

In the second year the product to be designed was a collection of communicating art pieces with computer-controlled mechanical parts. Besides designing the control system the students also designed the mechanical parts, as well as the actuators and sensors.

Phase Two—implementing the product

This third phase focuses on the implementation of the product. As in earlier phases the team is divided into new sub-teams, and each student is given a particular responsibility.

During both years of this study the communication between the two distant teams intensified during this phase. The modules designed locally should now be integrated. During this period the two teams had daily contact via videoconferences, telephone conferences and e-mail. In a comparison between the two years of this study the educational aspects turned out to be of different natures. During the first year when the students designed two different modules to be part of the same control system the discussions during this phase tended to be of a 'business' nature where the students had to agree over certain aspects like which protocol to use, how the modules should communicate etc, and the decisions tended to be either an advantage for one team or the other.

The second year an agreement was made that the two teams should design two similar products. The corporate sponsor expressed the need for several prototypes, and the decision was made that two prototypes with similar functionality should be designed. As mentioned earlier this gave a more favourable setting where the sub-teams could be distributed as well. The two teams now worked on the same problems, and at a certain deadline could choose the more advantageous of the two.

Phase Three—operating the product

The last phase is a brief period of time where basically the product, or prototype, is delivered to the corporate sponsor. During this phase all material is gathered and condensed into deliverable documentation [1].

SUMMARISING THE COMMUNICATIONAL ASPECTS

In the figure presented below the communication between the different nodes in the project are summarised, a summary which is equal for the two years studied.

As shown in the figure the total amount of communication between the nodes vary. The most intense channels were between the student teams and between the respective faculty and team. Due to the location of the corporate sponsor, which in both studies where located within an hour's distance of the KTH campus, the communication between the KTH students and the corporate sponsor in both studies was as intense as between the faculty and the students. Of importance is also the fact that there was rare feedback from the Stanford faculty to the KTH students.

CONCLUSIONS—EDUCATIONAL POSSIBILITIES OF THE TRANSNATIONAL SETTING

Improving disciplinary learning and other skills

- To improve disciplinary learning/problem solving by creating access to resources, equipment, professors, information, technology, consultation.
- To improve general skills.

Due to the fact that the students from KTH and from Stanford had different backgrounds regarding earlier courses and experiences the combined competence improved the designs of the products greatly during both years. This was particularly visible during the second year when the Stanford student's knowledge in mechanical design greatly improved the KTH student's design, and also during the first year when the KTH student's

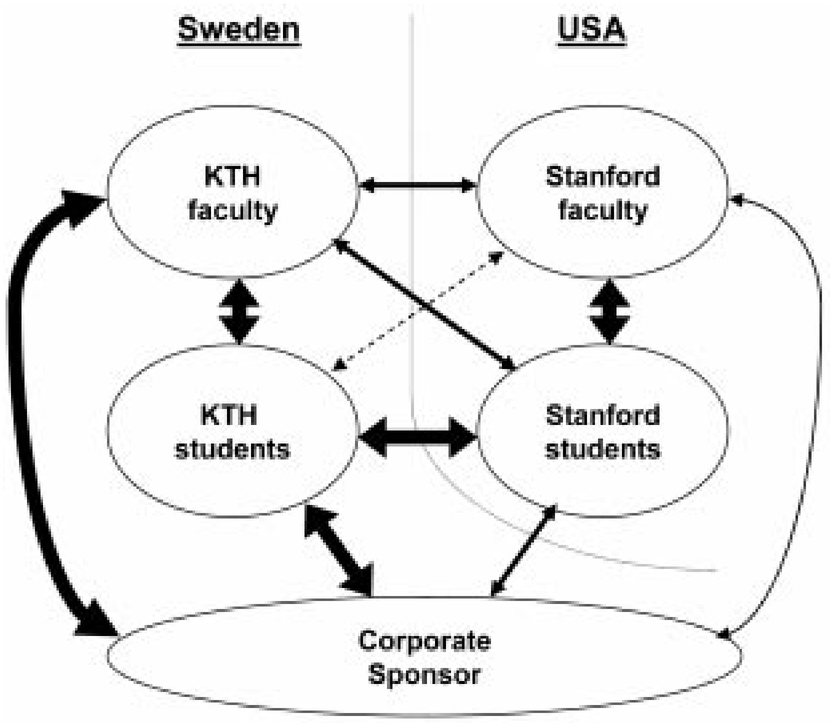

Fig. 2. Summarising the communicational aspects.

knowledge in embedded systems was used as input into the design of the active sensing teat-cup.

On several occasions the students used the video-link to describe and negotiate technical specifications, often by using the web-cameras to send video of actual prototypes, or of a technical solution of some kind. The fact that the technical quality of the conferences was not good, the implications on the demand of the student's ability to give good technical specifications and explanations, and for the KTH team in a language different from their native, became very high. However, most of the KTH students agreed that their abilities to communicate a technical subject in English had increased greatly. The fact that the student's abilities to communicate, and negotiate, mechatronic designs had greatly improved can be seen as signs of improved disciplinary knowledge in the area of mechatronics.

Regarding other skills of a more general nature, like presentation and report-writing these are more obvious due to the fact that in the case of the international collaboration these aspects were seen by the students as essential for the project.

Creating awareness of cultural differences and different educational systems

- To increase variation in approaching an assignment given by faculty or a cooperate sponsor.
- To create awareness of and benefit from cultural differences.
- Comparison of different educational systems, quality, level.

All KTH students were asked to compare their education to the education given at Stanford University. In all of the interviews the common view of the KTH students was that they had gained a higher confidence in their own education.

Regarding cultural differences the main focus was on the differences in language. From a Swedish point of view the advantages of this was major since this created the need for all communication and documentation to be made in English.

Enhancing motivation

- Work in an international group, competition between teams.

All KTH students stated in interviews that they preferred the international project in favour of local projects.

In the second year of this study, there were some aspects of competition between the distributed teams since they worked on solutions to the same problems. When asked about this matter the KTH students confirmed that there was a question of prestige involved, which helped motivation.

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