# Computer-supported collaborative learning

## Praxes in new cell-oriented configurable PC-classroom

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## INTRODUCTION

Collaborative learning (CL) is a learning approach where group of people work on a common task, solve a problem, or create a product. CL is based on a standard of activity in which learners are more efficient together as a group than they would be as separate individuals. Individual learning is, however, part of collaborative learning, but the learning processes of individuals are affected by the group and other group members. [1] Several studies indicate that collaborative learning can offer many benefits over traditional classroom, which can be categorized as social, psychological, and academic benefits [2-5]. The most notable academic benefits are critical thinking, problem solving skills, and active involvement of students into learning processes [5].

Currently, technology-enhanced learning environments seem to be a research hotspot in engineering education. Universities invest in modern environments equipped with the newest audiovisual hardware and web-technologies. Also, work desks and other furniture are laid out to promote teamwork. These environments support learner-centred model of education, which highlights active role of learners, learning-by-doing, and collaborative learner autonomy in a democratic atmosphere. Therefore, traditional teacher-led classrooms can be transformed into more diverse and more creative environments in which teachers and learners have relatively different roles compared with the traditional classroom. All these characteristics are well-suited into social-constructivist learning theory; however, technology has raised many new *supportive learning approaches* such as blended learning, flipped learning, and computer-supported collaborative learning (CSCL), which involve computer and/or other technology-mediated instruments in order to improve accessibility of learning media, and to offer flexibility in time and space.

Technology is also used to provide a native communication channel for the present-day students. For example, internet-based applications, such as Socrative, Padlet and AnswerGarden exist, which are used for student-teacher and student-student information exchange. Nowadays, many teachers use such software to make their contact teaching more interesting, and to encourage students to participate during the actual contact teaching. It is believed that technology, in its diverse forms, can bring teachers and learners together, and hence, ease the student-teacher communication. In this regard, the aforementioned *supportive learning approaches* pursue towards similar objectives as the traditional social-constructivist learning theory. However, now through a media-rich environment in which innumerable material and immaterial tools are available to meet the objectives. In order to create impactful technology-enabled learning episodes, teachers must be able to redesign teaching and learning relationships by rethinking the nature of activities occurring in the learning environment. In addition, mastery of communications technology and communication skills are essential. Otherwise, no solid ground to surmount traditional teacher-led classroom exists. Recent research promoting success of technology-mediated learning in university education can be found; for example, in [6-7]. We feel that TEAL (Technology-Enabled Active Learning) project initiated roughly 15 year ago in MIT (Massachusetts Institute of Technology) is also an interesting example [8].

Nevertheless, we adopt in this paper the concept of CSCL, which concerns how students can learn together with the help of computers [1]. Communication and collaboration between students are essential in CSCL framework; however, communication is not necessarily and not entirely executed through support from online communication medium. In such case, computer support may include, e.g. simulations of physical systems, whereas collaboration may involve construction of knowledge within a group using traditional face-to-face communication. Therefore, computer has diverse roles in CSCL, but it is in most cases secondary: computer and its software are designed to *support*, *not replace*, human group activities and processes [1].

In this paper, we discuss how CSCL has improved our automation science and control engineering education. We exemplify the implemented CSCL practices in our newly developed cell-oriented configurable PC-classroom. We would like to note that the new classroom allows grouping of students into their own cells, which are equipped with hardware allowing seamless communication between the groups. Technically, such operation model replicates a situation, where student groups could be located elsewhere from the classroom, but still able to do teamwork. Furthermore, cell-orientation also allows authentic hands-on, competitive, cyber-physical attack-defence practices to be conducted, which improve our automation security training. We also present an interesting case study conducted in the classroom; namely, *Mathematical Modelling and Control System Design of a Hard Disk Drive Servo System*. Finally, we shortly introduce how our classroom has opened new opportunities for university-business cooperation in terms of education and recruit.

# 1 CONFIGURABLE PC-CLASSROOM

In 2014, our department fabricated a new flexible and configurable PC classroom. The construction of the new classroom was required to satisfy certain objectives. First, the layout and equipment of the classroom was supposed to promote flexibility, e.g. the learning environment should easily be configured as needed. Secondly, the classroom should natively support collaborative learning with computer support. Thirdly, authentic design tasks, in which students can be challenged with 'real-life' engineering problems, should be enabled by the classroom's hardware and software. Fourthly, audio-video infrastructure must wirelessly support BYOD (Bring Your Own Device, e.g. tablets, mobile phones and laptops) without limitation to particular operating system. Finally, it should be possible to simultaneously teach small groups even from different courses, and hence, permit an efficient use of the available room space.

Moreover, automation and information networks as well as information security are key courses of study in our department. Therefore, network architecture of the classroom is crucial in order to establish a professional environment for students, industry partners and for public-private-partnership (PPP) educational events. In addition to normal automation education, attack-defence exercises, as well as testing of security features of various industrial devices and software should naturally be enabled. To be more specific, the network architecture must allow the usage of standard university IT accounts and software, as well as usage of separated industrial automation network, which fulfil the industrial automation integration and security standards: ISA-95 and IEC-62443. The core network infrastructure should also enable secure use of long-lifecycle automation systems and software via virtualization. For example, unsecure hardware and software should be securely used in the classroom while keeping the risk for university network at minimum. The classroom should also be extendable to other parts of the university campus and even to the other universities through its network architecture and services.

In order to fulfil these demanding objectives, the classroom was fabricated as follows. The classroom was divided into four cells, which can be used either independently, or two or more cells can be compounded together. The cells can conveniently be separated by sound-proof retractable walls. Large movable LCD screens are deployed at the front of each cell. Furthermore, the audio-video solution allows all users to use any single, or any combination of these display devices. Therefore, students and teachers can easily share their work for the whole class, or for targeted parts of the classroom. The movable desktops and computers of the classroom are organized in a pairwise manner. However, they have been built such that the pairwise blocks can easily be transformed to support groups of four, or even larger groups, if necessary. The schematic layout of the classroom is depicted in *Fig. 1*, respectively.

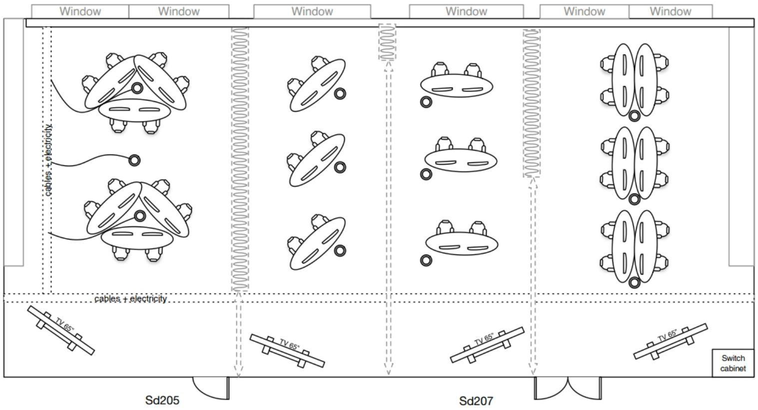

*Fig. 1.* Layout of cell-oriented configurable classroom.

From soft-skills point of view, our objectives were to strengthen students' commitment to learning, improve the motivation of the students, make learning more attractive in general, ease student-teacher and student-student interaction, and to provide a native, comfortable, technology-enhanced learning environment for students. We would like to note that all students have limitless access into the classroom, and students have used the classroom actively outside the office hours. In what follows, we present an interesting application of CSCL, which has been implemented in our new classroom.

## 2 MATHEMATICAL MODELING AND CONTROL SYSTEM DESIGN OF A HARD DISK DRIVE SERVO SYSTEM

Hard disk drive (HDD) is the most widely-used storage device of personal computers. HDD is an interesting apparatus by its fine-mechanical construction and by its operation principle. A HDD device and its primary components e.g. an R/W (read/write) head, data-flex cable, and VCM (voice-coil-motor) are depicted in *Fig. 2*, respectively.

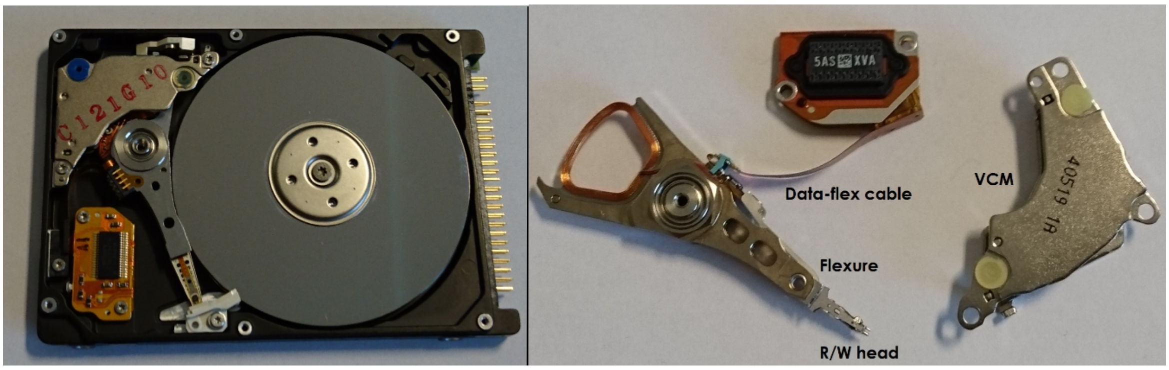

*Fig. 2.* HDD device and its essential components.

Data is read from, or written to, disk surface by the R/W head, which is connected to the tip of a metal arm via spring-like flexure. The data-flex cable is attached to the metal arm, which itself is connected to a rotating shaft of the VCM. The VCM is used to provide a high-precision rotary motion in order to move the R/W head on top of a desired data track to ensure reliable data transfer. Furthermore, the R/W head must be moved between data tracks as quickly as possible within subnanometer interstice using constrained control voltage. It should be noted that position control of R/W head is one of the most researched single-device control application at the highest level of scientific journals. As a result, many of the innovations developed for this application has found its way to other application areas as well. In this regard, HDD is also a highly motivational object for educational purposes.

In this case study, modelling and control of R/W head-arm-assembly of a commercial HDD is investigated. Modelling and control of HDD system is pedagogically instructive in terms of substance, because it includes mathematical modelling based on laws of physics, system identification, model analysis, controller design, and numerical simulations using comprehensive solver algorithms with stringent tolerance options. All aforementioned topics are central part of general education of a control engineer, and hence, it is advantageous to have them all included within an interesting but simple application. It is also easy to bring forth the meaning of mathematics and theory in a concrete way by such application.

Rotational motion and positioning mechanism are generally well-understood among engineering students. Also, position control is taught relatively early in control engineering curricula, and HDD, as a device, is familiar from everyday life. Therefore, students have some intuitive understanding as regards to dynamic behaviour of the whole system, which allow a constructive learning approach to be adopted for more comprehensive topics. Furthermore, real HDD devices are given to students, and hence, they can physically ‘feel the dynamics’ of the device and its components. According to research of embodied cognition, such tactile information strengthens the development of conceptual knowledge [9]. Finally, the case study prepares students to face facts-and-reality drawbacks, which, at the end, are converted to increased motivation towards more comprehensive courses. In what follows, we describe how the case study has been executed in our classroom.

First, a group of 16 students are divided into four groups; namely, to 1) process model analysis group, 2) control system design group, 3) friction model group, and to 4) data-flex cable modelling group. Each group consist of 4 students. A physical HDD device without top cover is given to each group. The friction model and data-flex cable modelling groups are also equipped with completely disassembled HDD devices, which allow more detailed investigation of the key components. Next, the groups are given their own work-desks, tasks, as well as an own cell from the classroom. We feel that a private cell not only provides a comfortable surrounding for the students to work and learn, but it also offers an intimate space for students to get familiar with each other. Finally, the teacher will introduce the roles of the groups, and initialize the tasks of each group before they are allowed to work independently. It should be noted that students are not required to do any prework, so all tasks are given on-site. Therefore, students are challenged with unknown and even with group-derived changing tasks, which is discussed later in this section.

The tasks of each group are shortly described below.

1) **process model analysis group**: Perform mathematical analysis and model-based frequency domain simulations to investigate the dynamics of a given VCM arm-assembly model. Identify the most challenging dynamic phenomena occurring in the assembly. Discover the effects of uncertainty in the flexure. Propose methods to mitigate uncertainties.
2) **control system design group**: Use knowledge from the course core content to find a suitable control structure for controlling the displacement of the R/W head. Tune the selected structure such that predefined design requirements can be satisfied, which actually are the same as in a real HDD system. However, the control system model is incomplete, because it only describes the rigid-body dynamics of the arm-assembly. Initial servo control laws are usually designed using a model, which only captures dominating dynamics of the system, which in this case is, the rigid-body model.
3) **friction model group**: Build a Simulink model from the given static and dynamic bearing friction models of an actual HDD system. Test and verify the obtained friction models. Describe in words how friction affects to R/W head’s movement on top of the disk surface. Is it possible to reduce bearing friction? How?
4) **data-flex cable modelling group**: Identify a mathematical model, which resemble nonlinear mechanical force generated by the flexible data cable. Build a corresponding block diagram within Simulink. Exploit the disassembled cable to verify the identified curvature of the force. Simulate the nonlinear force generated by the cable, and propose a method to overcome the cable nonlinearity. Note that the nonlinear cable force behaves as a displacement dependent constant when the R/W head has reached the desired data track, and therefore, its influence can be observed from the measured output.

The duration of the work is 8 hours, which is split into four separate 2 hour sessions along the course time frame. In this way, we can build knowledge through the whole course in a constructive manner, which evolve hand-in-hand with the course content and substance. During the sessions, the groups can conveniently collaborate through the technology-mediated environment provided. In principle, each result of all groups interest other groups and more or less affects to their tasks as well. For example, the outcome of the process model analysis group, as regards to model uncertainty, interest control system design group, because the outcome affects to their own primary task, i.e. the controller design. Also, the results from the friction model group interest the process model analysis group as well as the control system design group. Therefore, the tasks are subject to many changes along the sessions, which introduce reality of work-life to students. We feel that ability to tolerate changing environment is advantageous education. Furthermore, the groups are required to deliver the outcome and possible changes to one another using classroom's hardware and software. In this way, students also need to consider how such information is enunciated to their peers.

We have used a common Padlet-wall, where groups can post their results using Matlab figures and files, pdf-documents, text, etc. The content of the wall is accessible by all groups, and hence, quick information exchange is obtained in a representative way. For example, groups can ask questions from one another, and teacher can attach descriptive comments to supplement their inquiries using, e.g. a mobile phone, despite in which cell the teacher currently is. In this way, creative activities and collaboration is continuously in operation, which allow teacher to take an active role of a facilitator and adviser. We would like to note that communication through the wall is not always pleasant, because some things are easier to say than post. However, we feel that students benefit, when they are exposed and trained to tolerate such inconvenience.

Nevertheless, at the end of each session, all groups *verbally* present their outcome to the whole class. Hence, students can improve their verbal presentation skills in a familiar and comfortable environment. They can also illustrate their results using simulation software and equipment of the classroom. Once again, the teacher actively facilitates the discussion and delivers supplementary knowledge to strengthen students' understanding, which, to our experience, greatly improves the effectiveness of contact teaching. Finally, the content of the Padlet-wall is converted into pdf, and it is shared to students immediately after each session.

During the last session, the outcomes of all groups are collected into a single Simulink model, which can be run by all groups as well as by individual students. However, the results from the groups 3) and 4) significantly influence to the outcome of the groups 1) and 2), and as a result, the original design specifications cannot strictly be satisfied. Furthermore, publications considering the same HDD device from the highest level of journals are handed out to students. In this way, they can reflect and compare their own work with the ones found in open publications. At this point, students also realise that their design is no match for the state-of-the-art designs from the top of the world. Despite the negative connotation imposed by such information, students seem to appreciate that the facts are displayed to them as they are. Furthermore, those facts seem, together with teacher-led guidance, translate to increased motivation towards more comprehensive courses and more difficult topics offered by our curriculum.

Interestingly, the number of students in our curricula have increased during the last two years. Therefore, it seems that students are drawn to institutes which are able to offer interesting and instructive learning episodes in which students are continuously activated with teacher-facilitated meaningful activities. In addition to raised interest, students generally perform better in mid-terms and final exams than before. Better grades easily translate to better satisfaction and they boost motivation. Students have also put significantly more effort towards our project works, which play significant role in our assessment.

We feel that improved success is resulting from several aspects. Firstly, learning episodes using learning-by-doing and collaboration helps mastering the core content, because it is ‘delivered’ in learner-centred and hands-on way. Secondly, according to student feedback, students are generally willing to spent more time in learning activities, which itself results from increased motivation. Thirdly, the role of teacher is different as opposed to traditional classroom. Now, teachers work in close cooperation with students, which permit students to feel equality with respect to teachers. Teachers are also able to give on-site guidance and feedback in order to assist students’ learning processes. Fourthly, many have expressed that the atmosphere is inspiring and supportive, which have motivated to perform better. Nevertheless, new pedagogical perspective has allowed us to increase the amount of content and substance within our courses, and typically, without negative student feedback. We feel that technology has allowed not only more rapid information exchange, but it has also allowed the usage of diverse and high-quality learning media to be delivered to students. All-in-all, we feel that pedagogically intelligent and carefully premeditated learning episodes as well as technological utilities are key to successfully conduct impactful university education. Finally, we shortly present an act of opening as regards to university-business-oriented education and PPP-events held in our classroom.

## 3 CSST TRAINING AND CODENOMICON HACK FEST

Our new classroom is part of ASECyberLab [10], which is a cyber-physical training and research environment targeted for automation information and communications technology. To be more specific, ASECyberLab is an industry-scale automation system, where information security can be taught in a multifaceted and technology-supported way. The classroom is technically a ‘situation and control room’, which replicates a real cyber-security room as well as a control room by its hardware. The only difference being that it is also a classroom used for educational purposes. In what follows, we introduce two university-business cooperation-based events, which also invite students for active participation. We begin the discussion with Control Systems Security Training (CSST) course [11].

CSST course gathers many participants from industry, academia, as well as students from our curricula. CSST is used to provide hands-on experience and implications of poorly-implemented information security in automation. The target audience is everyone working with, or work in close relation to automation systems, e.g. managers, developers, subcontractors, IT support, automation engineers, and most importantly, students. The required skill level is a “normal office user”, despite that relative high-level information security is discussed, and comprehensive hacking tools are used. CSST is fully implemented in the situation room, where participants can securely conduct controlled cyber-attacks into a real automation system. The audiovisual solution allows the room to replicate a fully functional cyber-security center. Therefore, the participants can be exposed to real life thrills, which was the original idea behind CSST. We would like to note that CSST is also available as co-operation with ASE-CyberLab partner KPMG [12]. Since the initiation of ASECyberLab, 194 participants from business world and 150 students have completed the course. The course has offered a successful meeting place for students and industry personnel.

ASECyberLab also hosted a day-long hack fest organized in cooperation with Finnish company called Codenomicon. The fest attracted 40 participants from several automation-related companies as well as students. Codenomicon provided their expensive security tools *free of charge* to all participants. We would like to note that license of those tools cost tens of thousands of euros per year. The tools were used to evaluate and benchmark attending companies’ real automation products, e.g. online-connected devices and software inside ASECyberLab. Students were allowed to hack real automation equipment using commercial software, which, on the other hand, offered opportunities to make demonstration-of-skills to the participants from business. Therefore, the hack fest also functioned as a recruitment event in a win-win-situation manner, and in fact, free of charge for all participants.

We feel that these impactful events are crucial in order to link university education and business world. They also open new opportunities for students to market themselves as potential thesis workers to companies. University, its personnel, and professional facilities are key to connect business world and students in a successful way. It should be noted, however, that significant timely investment is required to establish these multifaceted high-quality learning episodes and events. Most often, teachers sacrifice their own free time in order to improve service level for all stakeholders. Nevertheless, we hope that in future, university-business cooperation produces better chances for students to get employed; perhaps, even more rapidly than before.

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