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Expert Competence in Remote Diagnostics- Industrial Interests, Educational Goals, Flipped Classroom & Laboratory Settings

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Abstract. The manufacturing industry are dependent of engineering expertise. Currently the ability to supply the industry with engineering graduates and staff that have an up-to-date and relevant competences might be considered as a challenge for the society. In this paper an education approach is presented where academia - industry - research institutes cooperate around the development and implementation of master level courses. The methods applied to reach the educational goals, concerning expert competence within remote diagnostics, have been on site and remote lectures given by engineering, medical and metrology experts. The pedagogical approach utilized has been flipped classroom. The main results show that academic courses developed in cooperation with industry requires flexibility, time and effort from the involved partners. The evaluation interviews indicate that student are satisfied with the courses and pedagogical approach but suggests more reconciliation meetings for course development. Labs early in the course was considered good, and division of labs at the system and the component level. However further long-term studies of evaluation of impact is necessary.

Keywords Engineering education, flipped classroom, smart home and health, diabetes, scientific literacy, engineering competence, academia - industry, expert competence, metrology, Internet-of-Things

1 Introduction

Engineering skills and competences that are desired from industry are important to integrate in the education system. This is to increase the employability of engineering graduates as well as to provide an education platform further education adequate also for engineers active in industry. In the end, this is expected to result in increased competitiveness, productivity and innovation rate within the industrial system. The importance of recruiting staff with suitable competences has been examined in several studies, for example in an EU study from 2010 [1].

In engineering, there is a gap between the skills developed at universities and the skills required by the industry [2]. Academia has an important role in bridging this gap. The strength in academia in combined with the competences in industry seems to be a given success for society. However, the “art” of creating academic courses at an expert level that are of relevance to industry is a challenge in itself.

According to Xia in [3], there are possibilities to link research and teaching for a win-win situation. Xia mentions that combining education, work experience, and knowledge generation in work-integrated learning provides students with opportunities for learning to be a professional by working and communicating with professionals.

Universities and companies are increasingly working together to define new degree and certificate programs. For example, Harris Corp. worked closely with the Florida Institute of Technology to develop a master of science program in systems engineering providing a M. Sc. Degree with complementary enterprise architecture certificate. Other examples are for instance the DARPA Grand/Urban Challenges and the Association for Unmanned Vehicle Systems International, Autonomous Underwater Vehicle Competition, where industry, government, and academia partners address real world problems. [4]

A common way to increase competences in industry is to procure courses from other educational or industrial partners. Today Internet provides both free online courses and courses providing higher education credits, see e.g. Study, MOOC-List and Future-Learn [5-7].

The MOOC-List provides a collection of Massive Open Online Courses offered by different providers. To facilitate learning and training activities e-learning provides a way that also meet today's demand on learning to be conducted anywhere and at any time. In [8] the phenomena of MOOCs are described, placing them in the wider context of open education, online learning and the changes that are currently taking place in higher education at a time of globalization of education and constrained budgets. Chang presents in [9] a high level review concerning e-learning and proposes the use of interactive learning as a recommended method for staff training in industry and academia.

In the [10] EU initiative ICo-op, Industrial cooperation and creative engineering education based on remote engineering and virtual instrumentation, interesting approaches within the focus of this ongoing project remote diagnostics is presented. With the logical frameworks, laboratory settings and similar set an example of possible approaches within academia-industry cooperation.

The intention with our approach to develop and implement master level courses in collaboration with industry and research institutes is to complement the existing approaches and to build novel types of collaboration to further extend the expert competences to increase the innovation capacity. In this paper we introduce an education project focusing on academia - industry - research institutes collaboration concerning the production of engineering courses in smart home and health applications directed towards expertise for innovation.

We describe, the principles applied, the pedagogical approach, the setup, the educational goals and the laboratory settings. Within the framework of this Knowledge Foundation (KKS) funded project, “Remote Diagnosis - online engineering, at master level” BTH students and in particular employees of the companies participating in the project

but also other professionals in the industry, were able to attend the newly designed distance learning courses in Measurement and Sensors [11]. KKS the research financier for universities with the task of strengthening Sweden's competitiveness and ability to create value [12].

The project is divided into three categories (a, b and c) based on the following areas: a) Electric power transmission, b) Mechanical power transmission and c) Smart home and health applications. Furthermore, the design of three courses within in the area of smart home and health applications will be described in section 2.

Online Engineering can be described as methods to control and monitor physical equipment, but also smart home and people, remotely over the Internet. In section 3 the experimental setups in the remotely controlled laboratories and the design of the instructions for the experimental work in the remote laboratory will be described.

Furthermore, the pedagogical design, Flipped Classroom, implemented in the courses will be discussed in section 4. Flipped Classroom is a form of blended learning which encompasses any use of Internet technology to leverage the learning in a classroom, providing teachers with more time to spend on interacting with students instead of lecturing. This is commonly implemented with e.g. the aid of teacher-created videos that students may study outside their scheduled time for lectures. [13, 14]

Finally, in section 5 the result of a questionnaire answered by students enrolled in the courses will be presented.

This study aims to answer two questions;

- How can academia make engineering courses of relevance to industry?
- How can we make use of resources in academia such as laboratory resources, and flipped classroom as pedagogical approach to reach the educational goals?

2 Outline of the courses in smart home and health applications

The courses are divided into two blocks, one block that covers methods for diagnosis and one block concerning technology for remote diagnosis. The courses in the block concerning methods for diagnosis are based on each other while the courses in the block which covers technology can be studied independent of each other. Each course with green frame in the block diagram shown in Fig. 1 results in 3 European Credit Transfer and Accumulation System credits (ECTS-credits), except for the Ethics and Architecture's lecture series. One academic year corresponds to 60 ECTS-credits.

The course block that concerns methods for diagnosis is divided into three specializations; Mechanical systems, electrical systems and Smart homes and health applications. Each course consists of six lecture sessions (2 x 45 minutes), six exercises (1 x 45 minutes) and one laboratory session (3 x 45 minutes). Each course is given during a period of eight weeks. Each course is given as a distance course and includes experimental work on remotely controlled experimental setups. Thus, the lab assignments in the courses are carried out remotely. Adjustments to the course schedule were made based on interest from the companies involved. The courses include application modules and these can be adjusted according to the participants' interests.

Furthermore, the first time a course was given within the project only employees from the companies participating in the project attended the course. The second time a course was given both students from academia and industry may attend the course.

The pedagogical approach utilized was Flipped classroom, in essence, the students were provided with course material before each lecture, and the lecture focused on deeper discussions and analysis concerning the course subject. In some of the courses an inquiry was compulsory for the students to fill in before each lecture. The enquiry was used as a tool to identify if the students had read and understood the lecture material.

Fig. 1. Block diagram of the courses developed in the project and how different courses and areas of expertise support a remote diagnostic system. Real equipment, with control, calculations and automation inside blue frames and courses inside green frames.

In essence the considered courses within Smart home and health applications were as follows:

2.1 Course 1: Technical metrology

The technical metrology course was held in cooperation with the SP Technical Research Institute of Sweden. SP works close in cooperation with industry and academia, and evaluate technologies, material, products, and process and provide an effective link between research and commercialization [15]. Metrology is a special niche for SP, it is Sweden's national metrology institute.

In the course 11 students participated, company representatives. The course was divided into three courses corresponding to the subject division in the project with electrical, mechanical and smart home & health applications.

The whole series of lectures in this course followed the well-known quality-assurance loop (originally formulated by Deming) [16]. Lecture 1 - A general lecture with common concepts were held, furthermore specifics related to the different focus areas were presented. Lecture 2 - Metrology with human, Lecture 3 - Temperature, fall and moisture, Lecture 4- Introduction to measurement uncertainty, Lecture 5- Decision-making and Lecture 6- Decision-making: Human cases.

The lectures in general were structured as follows, in Flipped classroom.

Lecture 1, for example:

- Introduction to metrology - basic concepts
- E-tivity: Introductory Metrology. E-tivity is a term coined by Professor Gilly Salmon to describe a framework for facilitating active learning in an online environment [17]. An E-tivity involves learners interacting with one another and with the course tutor in an online communication environment, e.g Adobe Connect, in order to complete a particular task.
- Spark: Pre-recorded lecture, video on group work, video presenting whole course
- Learning objectives: – Why measure? – How to measure? – What decisions are based on measurements?
- Task: – Study the material on the LMS Itslearning, pre-lecture, videos – This lecture – Complete assignment 1 and submit it by Itslearning
- Learning resources: – Videos, pre-lecture, this lecture,
- Respond to others: Group work, video presenting the whole course

2.2 Course 2: Analysis and modeling 1

Participants were both students and company employees, and in the curriculum to the course “Analysis and modeling of smart home and health applications” the learning goals were described. Thus after completing the course the student should have acquired the following knowledge and understanding:

- demonstrate an understanding of the use of systematic methods for modeling of technical systems in the application of smart home and health systems
- understand the principles of modeling of sensors, actuators and modeling of smart homes and health systems
- understand the general characteristics of dynamic technical systems
- understand the use of simulation as a method to analyze the technical system characteristics
- understand the system properties that include measurements on people

The activities in the course were structured accordingly. Furthermore, as a part of the pedagogical approach, i.e. flipped classroom, the students had access to a prere-

corded metrology lecture with specialist and students' comments focusing on measurements with persons, measurements on humans and humans as measurements instruments.

Demands for skills and competences for engineering students. Given this, the practice to perform real world engineering laboratory experiments as an important part to provide engineering skills need a focus of its own. Today, many academic institutions offer a variety of web-based experimentation environments, so called remote laboratories (RL), that support remotely operated physical experiments. These are new tools enabling universities to provide students with free experimentation resources without a substantial increase in cost per student.

At the end of 2006, the Department of Applied Signal Processing at BTH started a project known as Virtual Instrument Systems in Reality (VISIR) together with National Instruments in USA and Axiom EduTech in Sweden to disseminate the online workbench concept created at BTH using open source technologies in collaboration with other universities and organizations[18, 19]. Apart from BTH, five universities in Europe have set up VISIR online laboratories for electrical experiments, 1) University of Deusto, Bilbao, Spain, 2) The National University of Distance Education, Madrid, Spain, 3) Carinthia University of Applied Sciences, Austria, 4) FH Campus WIEN, Wien, Austria and 5) Instituto Politécnico do Porto, Portugal [20-22].

Lecture 1 Introduction

The course was introduced and the curriculum and course layout were presented. Flipped classroom as pedagogical approach were presented, as were the course structure with lectures, experimental work, literature, schedule, grading and expectations on the students. In all the lectures the course leader holding Ph.D. in computer science were present, thus holding an engineering perspective throughout the course.

Lecture 2 Smart home systems

This lecture was focusing on systems level of smart home and health systems. This to provide an overview of the challenges of smart home systems and the specifics of an expert working with state of the art in technology and implementation aspects. A strategic selection of a technical manager from industry working part time both in a small size and a large size company with smart home technologies was made. His competence and up to date skills on system and application level were put into action while assembling and adding/removing sensors to smart home system IRL during the lecture. After the lecture discussions with a student concerning specific technical implementation details were performed. Giving the student answers and indications towards further competence and development.

Lecture 3 Patient personalization

A student on a technical study program having diabetes type 1 discussed engineering support solutions for visualizations of information and measurements and automation of inserting data and information. He spoke from the need perspective, how he func-

tions and his interests and requirements from a personalization perspective. Engineering of application and web were presented and discussed from requirement engineering perspective, and implementation perspective. Different functions and ways of displaying of measurements were discussed. Brief focus upon the social sharing of data were also part of the lecture. Interesting discussions between student-lecturer and between students were initiated based on diabetes, course literature and the personalized competence perspective. Several questions revolved around measurements and when to take them optimally, and which factors that impacts blood sugar.

Lecture 4 Sensor system (engineer and entrepreneur component level)

This lecture was given in the lab environment in a small company. The lecturer was an industry development manager having the skills as an entrepreneur on a large company now having his own smaller company taught on component level. App and sensor engineering were discussed in detail from an application perspective in the research front. Specific laws, rules and regulations, street smart perspectives as well as attitudes and ethical acceptance models were discussed. Furthermore, engineering solutions that were less successful and domain and staff related changes were presented. The students were engaged in the discussions, and participated fully and expressed positive words as signs of insights made from the lecture and the discussions. Specific engineering descriptions about how the sensor were engineered and user interface discussions were made. Presentations of personalized unidentified data with discussions about personalization, histogram and individual bio-rhythmic were made, see Fig. 2.

Fig. 2. Sensor based bio-rhythms of individual anonymized personal data with time on the x axis and number of events on y axis.

Some discussions on personal bio-rhythms and personal patterns in behavior were made. Also prediction and change of behavior models were presented from a perspective of personalization. Predictions are a prioritized area for innovation in EU context. Reliability in measurements and complexity in interpretation of data, how to read and understand statistics and histogram corresponding to the learning goals of 'general

characteristics of dynamic technical systems' and 'system properties that include measurements on people.

A clear innovation perspective was put and the lectures out on the company in the company lab were productive and appreciated. However small tech obstacles were to be handled during the process.

Lecture 5 Medical doctor and researcher expert on diabetes

A medical doctor, specialist and also a researcher in diabetes gave a lecture on the basics of diabetes and more advanced aspects of diabetes. A strong discussion concerning what is technical possible today and what is desired as functions from a medical perspective were performed.

2.3 Course 3 - Analysis and modeling 2

This course was only given to company employees in cooperation with industry and were iteratively evaluated, i.e. suggestions for topics, lectures and after the lectures comment for improvements were given. The lectures contained input from a PhD thesis with focus on gesture recognition technologies, awarded the Chester Carlsson the Swedish Engineering price. The labs were to apply to the participants own industry and based on the smart home IoT lab at BTH. Methods for diagnose within healthcare were presented. Within the lectures the essence within smart home architectures, measurements uncertainty - metrology, system architecture, IoT, open systems, technology for measurements of movements of motion for example accelerometer, skin cancer, diabetes and the flipped classroom approach were presented.

3 Lab settings and design of lab exercises

3.1 Smart Home lab architecture and settings

Laboratory exercises represent an ideal scenario for engineering students to comprehend through the application in actual situations of fundamental concepts and to analyze, synthesize, and make judgments based on evidence.

The smart home lab is situated at BTH in Karlskrona. The physical lab structure is similar to an ordinary furnished flat. A basic one room apartment with entrance, hall, one living room with a bed, toilet and kitchen, see Fig. 3. Hygiene facilities is however excluded i.e. shower or bathtub and a washing machine. Standard sensors available on the market are used. They were selected on requirements given by the functions and to be less as well i.e. multiple sensors to have as few sensors/actuators as possible. They are ubiquitous and merged into the environment i.e. engineered to blend in. Thus a person may in principle pass through the whole apartment without observing the sensors/actuators.

The lab setting has been engineered in cooperation with industry, thus it is an industrial platform with on the market sensors and software solution in use in everyday smart

Fig. 3. The architecture of the smart home lab. X11– sensor Fibaro: light, temperature and motion, 10- sensor VISION: toilet door, open – close, 9- sensor, Fibaro, living room, door, open – close, 7- motion detector, SP814-1

home applications more specifically in care homes or in elderly and/or disabled persons home/s. The system includes remote control and functions enabled via a smart phone.

3.2 Laborations 1 & 2 platform.

The platform in the lab were based on standard solutions on the market, but specially compiled to suit the experimental work in the course. The wireless protocol used is Z-wave, which is used to transmit the sensor events to the gateway, where all sensor data is collected [23]. The gateway translates the sensor events into MQTT events, a widespread publish/subscribe protocol, commonly used for IoT applications, which makes it easier to integrate the solution with other systems. Several services use the MQTT protocol to monitor what is going on in the experiment apartment. One of these is saving all events to a database and can be queried from there by a simple web interface. In Fig. 4 the graphical representation of the smart home sensors including the integration of the smartphone fall detection application and geographical position to inform where the fall has taken place are visualized.

As a proof of concept for simulating an elderly person falling down in their home, a set of automation rules were written, to keep track of where in the apartment the person was and to automatically notify when and where a person had fallen.

As MQTT is used by many different companies in IoT, it was interesting to see if it could be integrated with other solutions. The basic protocol is always the same, but the structure and naming of the events differ slightly between operators. The IBM IoT platform was one case study where it was shown that commands on their MQTT broker could be translated and sent to and from the smart home gateway, making it possible for solutions running in the IBM cloud to interoperate with the smart home system.

The reason for selecting z-wave are from an academic - industrial perspective, and in one of the lectures in the smart home & health applications course a detailed presentation and discussion about other industrial standards, advantages and disadvantages were presented. A bridge to IBM open system on GitHub has been engineered.

Fig. 4. Smart home lab environment, sensor/actuator logg.

3.3 Design of lab exercises 1

The first laboratory experiment concerned in essence interpretation of activities in the home based on the real time updates of the log of the sensors/actuators. The students were given the architecture of the room and the functions of the sensors and how they were placed.

A fundamental part of a smart home environment is to manage the sensors / actuators. These can be represented using different visualizations or interfaces. In this lab, we have developed various types of sensors and representations of the sensors when they are activated. The lab is to you to try to identify what is happening in the smart home based on what the sensors detect.

Learning Outcomes: To be able to interpret events, understand the complexity of events from the sensor / actuator data and try to understand how the sensor data is visualized, how often data is sent, the format in which, depending on the measure / register / identify.

Describe the events on the basis of what you think goes on in the lab.

Review and discuss which events really carried out in the lab.

Is it a reasonable visualization, logging of events linked to what they measure?

Can it be done better?

Discuss issues such as thresholds, timestamp, updating of sensor data, the sensor is activated, visualization, interface, representation etc. Use literature and other relevant literature.

3.4 Design of lab exercises 2

Learning Outcomes: To understand and manage large amounts of data to manage data files and visualization.

There are large amounts of data that can be used in the home appliance and health applications [24]. Some are open, others are locked in the example. Various companies and public bodies. To access, manage, visualize and understand this type of data is a desirable qualification in the home appliance and health applications. Use the resources available within the application, Diabetes, to develop a research question and visualize data and services related to this application.

In the smartphone application in the Fig. 5 the accelerometer was presented. The students downloaded the app themselves and then used it remotely and got access to the logg and could follow the lecture on threshold values.

Furthermore, we used two large companies' standard solutions on IoT and measurements and metrology for the lab.

4 Flipped classroom outline

Initially, it is important to prepare students what the pedagogical method Flipped Classroom is. The teacher in a course starts with an introduction and explain what education method flipped classroom implies to the students. This part is very important to get active students in the online lectures.

In the course Analysis and modeling of smart home and health applications, in a learning management system Its Learning, a student finds materials to read at least one week before each session. The materials contain compulsory quiz to be answered.

Fig. 5. Visualization of accelerometer x, y, z positions in smart phone app. This application of accelerometer data is measuring the accelerometer movements in fall. Discussing how service personnel can be empowered by the functions of knowing if a person is standing up or falling, enabled by remote diagnostics. Accelerometer attached to body in smart phone or on smart clock and safely alarm on wrist.

The teacher can document which material the students had shown interest in before lesson, but it was not possible to see if it really was read by students or just downloaded. To find out if the documents was read, not just downloaded, a quiz were sent out to the students. The quiz to be completed by the students contained information that must be solved by the students. The number of correct answers could then give an indication to if the students had read the article or the material before the lesson.

Furthermore, the students can provide feedback on whether the material needed to be updated or adapted to their situation or wishes of content.

5 Results

After the sessions a questionnaire was passed to the students to acquire their opinion about the courses. The questionnaire had 5 open ended questions. In total 17 students responded to the questionnaire. The questionnaire in its full form and the answers to it are presented below.

Questionnaire.

1. Did you find the course had relevance to the industry your working in?
2. If, what kind of job do you have, for example, business, academia, self-employed?
3. Has this course given you the opportunity to combine work with studies, if so, how?
4. What did you think about getting articles and study questions before you entered the lecture? (Pedagogical approach Flipped classroom)
5. What is your opinion about the lab exercises 1 and 2?

The open ended questions answer from students were;

1. Yes (8), No (8), I do not work (1).
Comments from 7 students: The course has clearly been relevant! The course was built on the "flipped classroom" and been so open has suited me very well. Personally, I appreciated the openness and formlessness (that's the best word I am going on right now) the issues very much, because by its nature given me a "nudge in the right direction," while they were big enough (not to be "lookup issues "), and made room for me and my way of working. I definitely think that through my work with the course got a good overview of smart home and its applications for health and feel far better equipped to possibly one day working in the fields. IoT. I can develop in my work, but most interested in self-interest. Not linking right now but work with similar tools and I will hopefully get use of the education in future.
2. Automotive Industry (5), Calibration Technician (1), IT industry (3), Electrical Engineer (3), Health Centre (1), Science Center (1) Manufacturing (1) and Production (1).
3. Very good because assignments deadline was at the end of the course and it was up to each individual to plan their work. Did thesis at the same time and was thus outside and worked during daytime. I spent 1-2 hours a week on the studies associated with the course. Had no time for the course. Did not read the course at all because I did not have time.
4. The pedagogical design Flipped Classroom suits me very well.
5. Very good! I liked that the first lab was early and with the layout. It gave me the inspiration to think about smart home opportunities and span, present and future situation, etc. Thought about other lab because I had to go a little deeper in a quite specific application, and work on the sensor level. The laboratory then supplemented each other very well (a general laboratory system-level, application-specific laboratory component level) and inspired at least me (again, thanks to data transparency and formlessness) to think freely and to take it beyond the assignments.

6 Conclusion

Academia usually educates students, in this approach a novel way to educate regular students and industry staff has been performed. Furthermore, for increased competence as a level of expertise for innovation for the already employed in engineering industry.

Conclusively, the answers to the two questions are as follows;

How can academia make engineering courses of relevance to industry?

- Hard to find students holding the requirements
- Hard to find students having the time being a student and performing work in parallel
- The production line of the companies needs to be taken into consideration (that is holding a product deadline are main priority for the companies)
- Trust
- Business awareness
- Measuring innovation - over time - how
- Education platform - how to reach students - how to measure their process

The questionnaire reveals that equal number of persons had found the course of interest to the industry they worked in as not of interest. In the second question of how we can make use of academic resources of flipped classroom as pedagogical approach to reach the education goals, one challenge has been to encourage the students to go through the preparatory material in advance. The tools used by the teachers for measurement in the learning platform show if the student downloaded the literature, but not if the student has read and understood the literature, it has been complemented with a survey. A survey holding questions that potentially can be answered correct if the given literature has been read.

Meanwhile, flipped classroom technology lead to greater effectiveness through a more active learning. Some specific goals, the most active learning way, was that:

- Encourage students to more rules-bound prepare for each lesson
- Helping teachers to better identify students' difficulties in good time to adjust the learning
- Helping students to develop a stronger "need to know"
- Establish an interactive environment in the 'classroom'

Further work and approaches towards evaluating education approaches of relevance to industry are of interest and much needed from several countries as one approach in bridging the gap of persons holding competence of relevance for industry.

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