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Switching perspectives: Physicians meet Engineers in a Novel Lab on Medical Device Development

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Abstract

Education nowadays often still lacks in seeing the big picture. While becoming an expert in a certain, narrow field is naturally desirable, switching disciplinary perspectives is mandatory for an overall understanding. Next to benefiting from the knowledge of other disciplines itself, the merging of two disciplines and their actors leads to a synergy effect through the exchange of their knowledge and experience. Therefore a mixed course structure consisting of theoretical and practical parts seems most feasible to guarantee varying degrees of didactic approaches including co-operative course designs. In this paper our already well established advanced lab on medical device development (part of the Bachelor's degree in Computer Science) and its enhancement towards an interdisciplinary lab and lecture with medical students is presented. Based on the existing lab, we analyze the prior knowledge of physicians and computer scientists and derive contents, structure and necessary competence goals for a four-week block course. The main objective of the lab is to enable the students of both disciplines to share a common language and a common understanding of the procedures, approaches and tools.

Keywords: *Advanced Lab; Digital Medical Devices; Digital Medicine; Interdisciplinarity; Computer Science, Physicians.*

1. Introduction

1.1. Motivation

Studying Medicine in Germany is strictly regulated and lacks of interdisciplinary courses, although an exchange with other disciplines would broaden the horizon of the soon to be physicians. The same applies for other fields such as engineering, which could profit from a closer collaboration with the respective users. Since the winter semester 2012/13, the University of Siegen offers a new major in Medical Informatics for the Bachelor's degree. It is tightly connected to the well-established curriculum of computer science and extends on that knowledge by incorporating the very basics of medicine and biology. Of course the students insights to those disciplines are limited because of the restricted amount of ECTS points which can be given on all modules together. One Part of the bachelor's program is a so-called in-depth lab-course which is mandatory for all majors in computer science. As there was no lab-course for the major in Medical Informatics at first, this new lab-course was developed in the summer semester 2014. The new lab enables the students to link their acquired knowledge and skills on computer science to the basics of medicine and biology they learned earlier. The nature of the lab is solely practical with the focus on practical problems from the study focus. The aim of the practical course "Medical Device Development" is to introduce the students of computer science (especially those with the major in medical computer science) to hardware development and to show them that using relatively simple techniques are enough to measure biomedical signals. One possible application in our lab is a self-made ECG to monitor the user’s heart activity. As it is in the nature of a lab, the course should consist of a large practical part and foster the students motivation and creativity. Due to the very successful runs in the previous years, we are now opening the lab to physicians to create interdisciplinary working groups. By implementing this we expect to generate a fruitful connection between developers and practitioners which will lead to an increased understanding on both sides.

The remainder of this paper is structured as follows: First, the learning objectives and the motivational factors of our already established advanced lab on medical device development will be described. This is followed by a description of the concept and the implementation of the advanced lab in section two. Here an evaluation of the previous runs is also given. In section three the course modification towards an interdisciplinary lab is outlined. Finally, a conclusion and outlook on future works is given in section four.

1.2. Learning: Objectives and Motivational Factors

Our advanced lab on medical device development has been development in consideration of educational objectives defined by Bloom (1956), Dave (1970) and Anderson (2001) as well as the intrinsic motivation described in Deci and Ryan (1985). Theoretic groundwork has been considered in form of embedded-system specific competence descriptions, too (e.g. Schaefer et. al., 2012). The overall goal is to address all three domains of educational learning (using the revised taxonomy of Bloom). For this, the lab is divided into three different parts (see sections 2). In the preparation phase, the students should bring up their prior knowledge and different topics regarding overall system architecture such as user interfacing, wireless transmission, sensors etc. have to be worked out. This covers the knowledge skills ‘remembering’ and ‘understanding’ in the cognitive domain. The practical phase consists of different exercises, which range from ‘applying’ to ‘creating’ in the cognitive domain. This is complemented with the advanced lab’s follow-up and feedback phase, which emphasizes the knowledge ‘analyzing’ and ‘evaluating’.

In the preparation phase the students are already separated into smaller groups of two to three students. In the affective domain this fosters the attitudes ‘receiving’ and ‘responding’, since as early as in the end of phase one a first group presentation has to be given by each group and discussed with the other students. In the course of the lab, especially in the practical phase, this is carried forward and supplemented with ‘valuing’ (Anderson, 2001).

The different skills of the psychomotor domain are developed and trained in the advanced lab’s practical phase. While in the first exercises basic skills up to ‘guided response’ and ‘mechanism’ are touched upon, the last exercise addresses the student’s creativity. Skills acquired so far should lead into self-invented projects, that covers the complex behaviors ‘adaptation’ and ‘origination’ (Dave, 1970).

Next to considering the three domains of educational training, it is also important to satisfy three innate needs in order to lay the foundation of optimal learning conditions: competence, relatedness and autonomy (Deci and Ryan, 1985). In our advanced lab, basic exercises at the beginning of the practical phase ensure a sense of achievement and therefore competence. The learning setting including working in small groups and the presentation of results guarantee relatedness and the practical phase’s last exercise (self-invented project) allows autonomy.

More details on the concept and implementation of our advanced lab is given in the following section.

2. Advanced Lab Project

2.1. Concept and Implementation

Each Credit Point in Bachelor and Master studies corresponds to a workload of approximately 30 hours. This module of 5 CP therefore entails a workload of 150 hours (consisting of the lab and self-study). The total time is divided into the following three phases (see Table 1):

Table 1. Comparison of the advanced lab's phases corresponding to the workload

Phase	**Duration in weeks**	**Duration in hours**
Preparation Phase	1	35
Practical Phase	2	80
Follow-up and Feedback Phase	1	35
TOTAL	4	150

Preparation Phase: In order to provide students with an understanding of the course conditions, structures and procedures, an introductory event is organized before the practical phase. At first the reference to medicine and computer science is created. Afterwards the tutors present the hardware components which will be used. The course is divided into smaller groups of two to three students that also work together in the practical phase. Such an approach also makes sense because engineering work is usually carried out on a cooperative basis. The mind-map method is used to give all students a simple way to make the inherent comprehension of the devices internal mechanisms and their communication visible. The different groups present their results in a short presentation to the other students. Finally, a summary of all results is given on the whiteboard. In the remaining preparation phase, different topics are assigned to the groups to acquire a deeper knowledge and become an "expert" in their fields. At the beginning of the practical phase, the students should present their gained knowledge to the other groups in a short presentation.

Practical Phase: In the practical phase, the students first start to explore working with microcontrollers. This is achieved via four exercises. In order to prepare the students for the advanced lab, the basic knowledge of a simple microcontroller circuit, consisting of sensors and actuators, is imparted in the first exercise. Basic knowledge of diodes, various sensors, the microcontroller and C-programming must be acquired before the first meaningful source code can be tried out. The second exercise adds an LCD display to the entire system to visualize the read-out sensor values, and a Bluetooth module to transfer the data for visualization to a mobile device (see Figure 1. ECG-Hardware of the advanced lab and data visualization on a smart phone). In the next exercise basic knowledge of Java and Android programming is refreshed. The visualization of the sensor values is first done with the help of a text output. The sensor values have to be shown on the display with the help of a coordinate system/graph afterwards.

A special attention has to be paid to the fourth exercise. A conception and realization of a small project has to be carried out. The open task should promote the acquired skills and apply them to a self-invented project. This challenges the students to rethink their understanding of the previous lab exercises and apply all gained competences to deepen the examination of the subject matter.

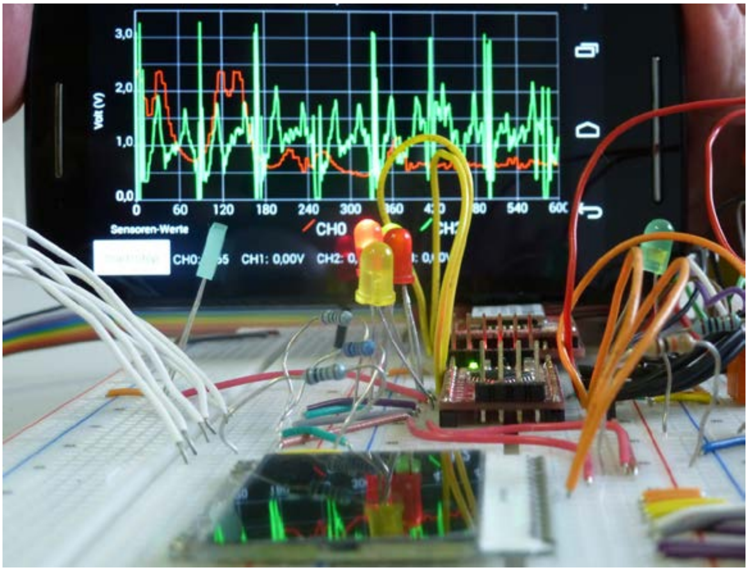

Figure 1. ECG-Hardware of the advanced lab and data visualization on a smart phone

Follow-up and Feedback Phase: At the end of the advanced lab, students have to write a coherent text of 5-10 pages to summarize and evaluate their work. In order to help the students in structuring, questions have been worked out in detail beforehand. In addition, the students should give the tutors a general feedback on the advanced lab. An open and appreciative feedback can achieve a significant effect, because it enables the chance for further development and change of the lab course.

2.2. Evaluation

In general, the lab was rated as very educational by 25 students. They quickly have had their first positive experiences even without large prior knowledge, which has increased their motivation. The order in which the exercises were arranged have been rated useful, because the requirements were increasing and the exercises were based on one another. The group size of two to three persons has gained positive feedback as well as the daily working hours in the laboratory. Furthermore, the third exercise has been evaluated as too long and more support should be given in form of predefined parts. Especially the fourth exercise was evaluated highly positive. The range of different components for the open task was welcomed and used by some groups in exciting projects. However, more time was required for processing this exercise, which can be achieved by optimizing and shorting the third exercise.

The relationship between electrical engineering, computer science, and medicine has been evaluated as unequal, because less medical knowledge has been needed, in order to work on the experiments successfully. More medical aspects, sensors and topics could be added in the practical course.

3. Interdisciplinary course modification

As we read the reviews of our students on the traditional lab, we realized that we could strive for an even more practical approach by not only allowing computer science students but students of medicine to participate on the practical course, too. The benefits of incorporating developers with users into a lab are shown in Table 2.

Table 2. Benefits of interdisciplinary work

Medical students	Computer-Science students	Together
– Knowing the limits and possibilities of hardware/ software products – Understanding the complexity of hardware/software interactions – Experiencing common mistakes and their possible disastrous outcomes	– Given feedback on the practicability of their designs and solutions in terms of applicability in real life scenarios – Better understanding of the modes of action on biological processes as the basic foundation of sensor development	– Working on a common language to address tasks and challenges – Understanding different perspectives (medical and technical) on the same product

As appealing as these opportunities for a common understanding of two very complex disciplines are one has to make sure that all students share at least a basic knowledge of medicine and electrical engineering. The latter is not a problem in our situation because our computer science curriculum fosters various competences ranging from programming skills and hardware design to electrical engineering and even fundamentals of anatomy. More problematic on the other hand is the basic education of medical students in regards of computer science and digitalization skills - commonly missing in German physician curricula. We designed an introductory course which fits nicely in our flexible lab structure described earlier in order to meet this problem (see figure 2). The course conveys theoretical knowledge in the morning and the according practical skills in the afternoon. We have chosen this approach in order to make the transfer of theoretical and practical knowledge as easy as possible for the students.

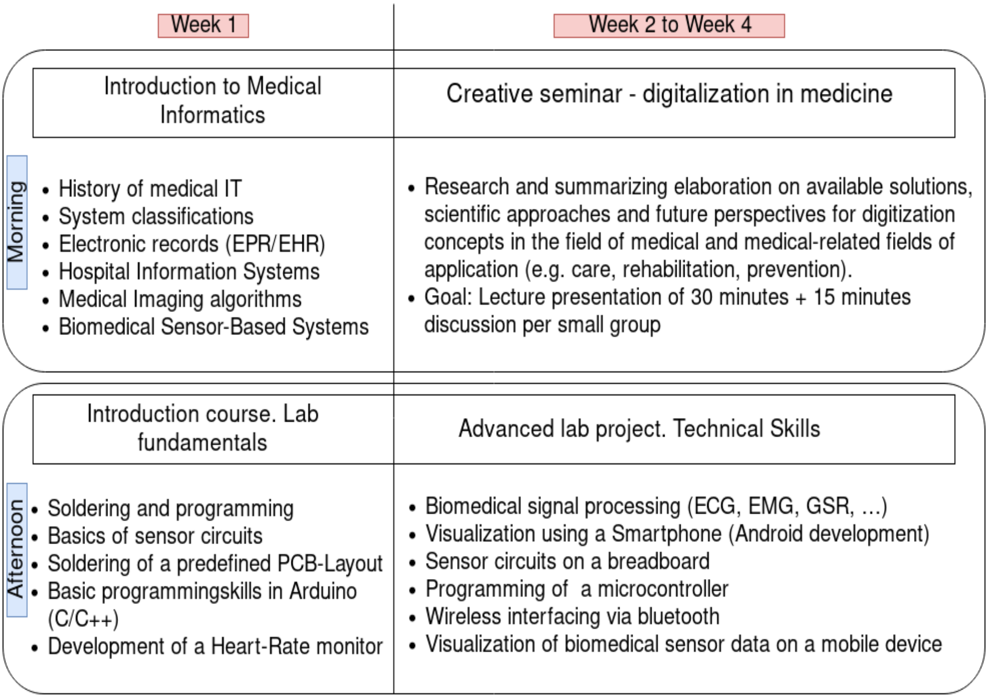

Figure 2. Preliminary course modification for the interdisciplinary lab

The course takes place in this structure for four weeks as a block event and incorporates a creative seminar as well as an advanced lab project after the fundamentals of theory and practice have been thought in week one. The lecture “Introduction to Medical Informatics” builds up the theoretical foundation of digitization in medicine and the history and milestones of computer science as the major discipline to foster this process. The students have their first practical introduction to soldering, basic of electronics, and sensor-circuits in the afternoons of week one. This part of our course uses the didactic concept of deconstruction which fosters competencies by giving the students an already build and finished solution (a sensor circuit in our case) first and lets them then deconstruct the whole product into its major building blocks (Magenheim, 2001). This methodology gives students a functional aim to strive for when they build up the system from the ground, as well as constantly raising questions about the need for the several system parts and the constrains which have to be met to incorporate them into the finished device they already saw at the beginning of the lab. We chose to use a rather easy entry to programming languages and corresponding development environments by using the Arduino toolkit which is widely known for its easy entry to the world of micro-controller and embedded device programming.

This interdisciplinary lab seems to be the one which benefits the most from heterogeneous groups consisting of computer scientists and physicians as well. While the latter are up to tasks like functional and non-functional constraint definitions, sensor selection and overall evaluation, computer scientists have to meet those requirements by choosing a suitable system-architecture and implementing the needed interfaces. However, medicine and computer science students alike should be able to discuss and comment on the ideas and drafts of each other. In the author's opinion, the most important competence to be fostered in the lab is to share a common language and a common understanding of the procedures, approaches and tools between medicine and computer science.

4. Conclusion & Future work

In this paper an advanced lab on medical device development and its modification towards an interdisciplinary lab has been presented. The highly positive feedback on our advanced lab brought us to the idea to open the course to physicians. In order to obtain the best benefits from this, a four-week mixed course structure consisting of theoretical and practical parts has been developed. Special attention has been paid on dealing with the heterogeneous prior knowledge of the students and to foster the communication and exchange between the two disciplines medicine and computer science. The evaluation of the interdisciplinary lab will be performed in near future. Using our approach as a blueprint, an extension towards other disciplines than medicine will also be pursued.

References

Anderson, L.W., & Krathwohl, D.R. (eds.). (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of educational objectives*. New York: Longman.

Bloom, B. S. (1956). *Taxonomy of Educational Objectives*. New York: David McKay.

Dave, R. H. (1970). Psychomotor levels. R. J. Armstrong (Ed.), *Developing and writing behavioral objectives* (pp. 33-34). Tucson, AZ: Educational Innovators Press.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior.* New York: Plenum.

Magenheim, J. S. (2001). Deconstruction of Socio-Technical Information Systems with Virtual Exploration Environments as a Method of Teaching Informatics. C. Montgomerie & J. Viteli (Eds.), *Proceedings of EdMedia + Innovate Learning 2001* (pp. 1199-1204). Waynesville, NC: Association for the Advancement of Computing in Education (AACE).

Schaefer et. al, (2012). Competence model for embedded micro- and nanosystems. *Global Engineering Education Conference (EDUCON) 2012* (pp. 1-6). IEEE.