A Multi-, Inter-, and Trans-Disciplinary Approach to Teaching Wireless Sensor Networks

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Abstract

The field of wireless sensor networks has drastically advanced over the past several years, and is penetrating into all aspects of engineering, medicine, and management in particular, and the society as a whole. Consequently, a need has arisen to create a course which is accessible to students of engineering, medicine, and management, and other majors, as well. This paper presents one such effort, to create a course which is, in its three-credit version, suitable for electrical and computer engineering graduate students, in its two-credit version suitable also for graduate students of management and business administration, and in its one-credit version suitable for graduate students of medicine. The results from the experiment course show that levels of semantization, synergy, and symbiosis are significantly increased. Multi-disciplinary, inter-disciplinary, and trans-disciplinary effort helps create new scientific values, and students enjoy trans-disciplinarity.

Key words: Multidisciplinary course, interdisciplinary course, transdisciplinary course, wireless sensor network, health care

1. Introduction

This paper presents the results of a trial course carried out to examine issues related to multi-, inter-, and trans-disciplinarity. All tests of the trial course were developed to examine effects such as semantics, synergy, symbiosis, and satisfaction. Graduate students were collected from three different majors, put together into the same classroom, and exposed selectively to the same set of materials (as explained in the rest of the paper).

In order to maximize the value of the experiment, related approaches were also studied. The examples include the following courses: "Managing the New Product Development Process: Design Theory and Methods" at the University of California, Berkeley (Hey, et al. 2006), a post-professional diploma course in occupational health and safety at McMaster University in Canada (Verma, et al. 1988), and a course on embedded systems design at School of Engineering, James Cook University (Maskell and Grabau, 1998). These courses are based around project-based learning (Hey, et al. 2006) and problem-based approaches (Verma, et al. 1988). While these approaches represent a powerful learning paradigm, especially when multidisciplinarity and cooperation are one of the goals, they are not best suited for transferring a broad theoretical basis (for engineering students) on one hand, and providing a basic insight into a matter which is outside of the main scope of studies (management and medical students).

Therefore, this course was organized as a combination of traditional, didactic based course, aimed at establishing a solid foundation, followed by a large multidisciplinary project, aimed at deepening the understanding of the matter and developing interdisciplinary communication skills.

The students from three different fields are together introduced to a topic, with variations to fit specific needs and interests of each field. Finally, the course impacts go beyond product development, into providing a deeper insight into the technology to the users (medical students).

The course is intended as a graduate level course. From the engineering field, the course primarily targets computer engineering students with solid knowledge of programming and networking and basic understanding of electronics. The course aims to present them with sufficient knowledge and understanding of the theory and current market technology, from the perspective of industrial product development. Students of management and business administration should gain a basic knowledge of wireless sensor networks (WSN), in order to implement it in developing business and marketing strategies, with the aim to provide general acceptance of WSN technologies. Medical students are only given high level overview of the technology, in order to enable them to generate ideas and support the product development more effectively, as well as to prepare them for using this technology in practice.

The rest of the paper is organized as follows. Next section describes course structure. The following section presents results of a trial offer. Section four gives summary of major contributions, target audiences, and future plans, with lessons learned.

2. Course Structure

The course structure includes seven topics related to WSN. The specific coverage of the course is organized by weeks: two weeks per topic, where each topic is organized in credit-oriented layers - all three layers for the three-credit version of the course, the first two layers for two credits, and only the first layer for the one-credit version of the course. The course is, in its three-credit version, suitable for electrical and computer engineering graduate students, in its two-credit version suitable also for graduate students of management and business administration, and in its one-credit version suitable for graduate students of medicine. The structure of each topic is given in the following text.

2.1 Topic No1: WSN Basics and Applications

This topic introduces students to some of the basic terms related to WSN, including: sensors and sensor types, wireless sensor nodes and their functions, gateways and ad hoc networks in general, as well as the basic ideas lying behind the WSN, and issues related to networking. The first and the second layer introduce students to potential uses of WSN technologies in different aspects of everyday life (medicine, home automation, interactive surroundings, surveillance, automobile traffic, business management, industrial machine building, agricultural, and environmental applications) (Goldsmith and Wicker, 2002, Hu and Cao, 2010). The third layer additionally introduces students to the issues regarding MAC layer (Hu and Cao, 2010), and routing protocols (Akkaya and Younis, 2005) in WSN systems.

This part of the course is created to enable students to develop a basic understanding about the possibilities, potentials, and limitations of the WSN technology, and its applications, which could be expected to influence the future society.

2.2 Topic No2: Sensor node overview

This topic introduces the students to sensor nodes, as the basic building blocks of WSN. The first-layer provides an insight into purpose, typical size, weight, battery autonomy, and other issues important to end-users (Edgar and Callaway, 2003). It presents several sensor nodes, such as: MicaZ nodes, Shimmer nodes, and SunSPOT nodes.

The second layer gives an additional insight into the hardware and software costs of individual nodes, entire networks, complexity and costs related to operating and maintaining nodes and networks including costs of training individuals to use these systems (Brent, 2006). It discuses node metrics (Hill, 1993) related to flexibility and security.

The third layer gives an in-depth technical insight into the architecture and hardware issues related to WSN nodes, including generalized node architecture presentation (Cordeiro and Agrawal, 2006), with a discussion of individual subsystems and requirements. This layer discusses individual node metrics (Li, 2008) that were not covered in the second level (power, communication, computation, and time synchronization).

2.3 Topic No3: Medical Sensor Applications

This topic introduces the students to some of the basic vital parameters whose monitoring employs sensor technology and can efficiently be covered by WSN systems (electrocardiography, electroencephalography, electromyography, blood pressure, pulse oximetry, and glucose monitoring). Consequently, it gives an overview of current monitoring devices for these parameters. The first layer students (medical students) should already be acquainted with the subject, so this section of the course is designed to refresh knowledge and to add a new angle to the approach to these students.

The second layer introduces students to issues regarding healthcare costs and some wide-spread diseases (hypertension, heart attack, stroke, vertebral problems, and diabetes mellitus), whose treatment can be effected by the introduction of WSN systems, including economic aspects of treatments of these diseases. The third layer provides an insight into the technical details of vital parameter monitoring (Stankovic, 2009).

2.4 Topic No4: WSN Applications in Medical Prevention and Medicine

This topic introduces students to wireless sensor applications related to medical prevention and medicine as a new approach and a new concept of health management. The first layer introduces students to advantages of WSN systems in the health domain, such as: portability, unobtrusiveness, ease of deployment, scalability, real-time and always-on, and reconfiguration and self-organization (Virone, et al. 2006). It presents an overview of the current applications of WSN systems targeting healthcare and health monitoring (Khan, et al. 2009).

The second layer introduces students to the process of the new (technological) product acceptance by its users (Davis, 1986). It provides basic understanding of customer's purchase decision making and categories of product adopters (Mohr, et al. 2009), as of techniques for communicating functionalities and advantages of WSN in health domain to the potential users (Northouse and Northouse, 1997).

The third layer contains an in-depth examples of discussion on system architectures for WSN system related to health monitoring (Virone, et al. 2006, Otto, et al. 2006). It also revises the case studies from the first layer of the topic to a more technical perspective.

2.5. Topic No5: Advanced issues in WSN systems Related to the Medical Domain

This topic covers a number of issues that should be noted when designing and using WSN systems which directly interact with humans. The first layer provides an understanding of possible impacts when WSN is used with several different categories of people: (1) patients (home-care and hospitalized), as the most important category according to this course; (2) employees, as a very wide category, including the effects of WSN in working environments; (3) athletes, as a very specific category, including the possible effects on their training routines. This part of the course outlines some considerations regarding invasive health monitoring devices, related to preoperative, intraoperative, and postoperative complications. In this light, a part of the lesson is devoted to discussion of possible materials suitable for designing devices that interact with the human body, as of regulatory requirements that need to be met (Khan, et al. 2009) when designing, marketing and implanting these devices.

The second layer introduces students to basic criteria for segmentation and targeting potential users of WSN systems. The example shows the key characteristics of basic WSN users segments (patients, employees and athletes), as well as marketing and communication strategies for introducing WSN systems to these categories of people.

The third-layer consists of issues related to security in medically oriented WSN systems, because both, the collected data and the process of data collection, are vital for the success of WSN. It gives an overview of general security issues (Walters, et al. 2006) and solutions, as recommendations for complementary reading on cryptology and information security (Walters, et al. 2006). More emphasis is put on security in body area networks, with the specific challenges and discussion of several recently proposed solutions (Mana, et al. 2011; Saleem et al. 2009). Here students learn about the problems of localization in WSN systems (Mao, et al. 2007). Finally, the lessons provide discussions of strengths, weaknesses, and current limitations of different techniques.

2.6 Topic No6: Special Issues

This far, the course has followed a simple pattern: out of three layers, the first one was the most general and was intended for all medical, management, and engineering students; the second layer was intended for management and engineering students; the third layer was only for the engineers. Thus engineering students would have listened to all three layers. For most multidisciplinary subjects, this makes a very good structure. However, certain topics are of interest only to a single group of students. Therefore, this part of the course is held separately for each of the three groups.

The medical students listen only the first layer, where they should get introduction to the fundamentals of telemedicine, including different types of programs and services provided to patients and good practices regarding remote healthcare (Esser and Goossens, 2009; Wootton, et al. 1999).

The management students listen to the second layer only, where they get introduction to the fundamentals of multidisciplinary (WSN-related) business plan (Rogoff, 2003; Barringer, 2008). The first part is indented to refresh knowledge of the structure, content and the form of the business plan as a tool for making a good business credible, understandable, and attractive to someone who is unfamiliar with the business (Barringer, 2008). The second part is oriented towards the areas of business plan applications, with an emphasis on the plans whose goals are related to investing in research, development and sales improvement of WSN products (Barringer, 2008).

The engineering students listen only to the third layer, where they learn about fundamentals of software design for WSN. This layer presents an overview of key characteristics and classification framework for WSN operating systems platforms (Reddy, et al.2003). It outlines and compares several wide-spread platforms, including TinyOS, Contiki, Sensor Operating System (SOS), and SunSPOT Squawk VM. The part of the course related to TinyOS includes introduction to TinyOS component-based structure (modules and interfaces), execution model (tasks, concurrency, and allocation), wiring (configurations parameterized and generic configurations), and good programming practices and pitfalls (Crnjin, 2009). Regarding the SunSPOT nodes, as most of the programming takes place in Java (students are expected to be acquainted with it), the part of the course related to programming SunSPOT nodes includes the examples of design cycle of a relatively simple application.

2.7 Topic No7: Internet of Things

The final topic is devoted to the Internet of Things (sometimes referred to as the Future Internet) (Wang, et al. 2008). This WSN based technology is expected to influence society perhaps as much as the introduction of the original Internet. Having a sense of how the future Internet will look and function should give the students a look-ahead, useful in professional as well as private domains.

The first layer provides an overview of what the Internet of Things will look like, its capabilities and its impacts on society. The second layer acquaints students to an additional insight into the general architecture of the currently proposed solutions for the Internet of Things. This insight should be sufficient to generate ideas regarding services and business models related to this technology. The third layer of the course starts with an explanation of the basic concepts related to WSN middleware. Four major components should be defined: programming abstractions, system services, runtime support, and quality of services mechanisms (Hadim and Mohamed, 2006), including an overview of the existing middleware approaches (presented as case studies): modular programming (Impala), and message oriented middleware (Mirel). It introduces students to WSN interoperability frameworks, several types of integration frameworks, through examples including Server client architectures: SenseWeb (Chatzigiannakis, et al. 2005), IrisNet (Shneidman, et al. 2004) and Peer-to-Peer: HourGlass (Spieß, 2005), Cobis (Chatzigiannakis, et al. 2007).

3. Lessons Learned from the Experimental Offering of the Course

3.1. Testing

One of the major challenges, evaluating multidisciplinary courses with collaborative components, is how to appropriately asses the course effects on individual and group level (Strijbos and Fischer, 2007). Approach used was based on separating the two measuring perspectives, qualitative, focused on collaboration in practice and quantitative, based on statistical testing (Arvaja, et al. 2007). To this end, several tests were conducted with students. One set of questions was given at the beginning of the course and another one at the end.

Four groups of questions were presented to test semantization (the individual level of knowledge), synergy (group level knowledge), symbiosis (measure of how prepared a student is for working with people from other professions), and satisfaction (student's personal perspective on the structure and organization of the course).

The testing was conducted with over 40 from a total of 218 graduate students (pending an extended experiment with 100 trainees). 16 students were females, and 24 males. The course was attended by approximately 30% of students in each area.

Taking into regard the ratio of the number of students in the sample and the total number of students, the ratio of the number of females and males in the sample, as representation of students from all three areas, the sample can be considered representative.

3.1.1. Semantization

Semantization level testing was done in a form of a number of multiple-choice questions, related to all three aspects of the course (medical, management, and engineering). These questions were designed to evaluate the advancement in knowledge and understanding, both in the students' native field, as well as in the fields native to the other groups of students. The results of the enclosed table indicate that students had little a priori knowledge about each other's majors, but were able to learn fast (Table 1).

Table 1. Results of Semantization Level Testing Before the Trial Course

Questions (% out of 100%)	Before / after the course			
	Average score	Eng	Mng	Med
Engineering students	25/85	80/90	20/95	10/75
Medical students	20/75	5/55	10/80	80/90
Management students	10/75	5/60	10/70	80/90

Legend: Eng: questions related primarily to the engineering matter in the course. Mng: questions related primarily to the management matter in the course. Med: questions related primarily to the medical matter in the course

3.1.2 Synergy

These questions were designed to test how students from the three groups can work together to solve problems. For this part of the test, students were divided into 10 groups of 4 students, each group containing at least one student from each of the three profiles. Each group was given a complex problem to solve, including a medical issue to be addressed, engineering behind the solution, and business strategy.

Due to time constraints of 35 minutes (Zikic and Radenkovic, 1997), only the basic concepts of the solution were expected. In order to ensure the validity of the tests, students were paired differently before and after the course. The results were not affected by the fact that in some groups were more members from a particular area (Table 2)

Table 2. Results of Synergy Level Testing

Project score (1-10)	Average score	Eng	Mng	Med
Before the course	5	5	5	5
After the course	8	9	7	8

Legend: Eng: project score from the engineering standpoint. Mng: project score from the management standpoint. Med: project score from the medical standpoint.

3.1.3. Symbiosis

These questions were designed to evaluate students' ability to gain appropriate feedback from the students of other profiles. A short scenario was presented to the students. Students were than expected to come up with three questions for specialists from the other fields. A multidisciplinary committee assessed these questions for clarity, precision and value of the information included. (Table 3)

Table 3. Results of symbiosis level testing

Project score (1-10)	Average score	Eng	Mng	Med
Before the course	1.3	2	1	1
After the course	3.6	5	4	2

Legend: Eng: project score from the engineering standpoint. Mng: project score from the management standpoint. Med: project score from the medical standpoint

3.1.4. Satisfaction

These questions were compiled to assess satisfaction with teaching (e.g. quality of teaching, gained knowledge and skills, etc.), and satisfaction with the structure of objects and other non-teaching factors (e.g., multi-disciplinary structure of the students) (Table 4).

4. Conclusion

This paper describes the essence of a new course, which brings together students of three different majors, and tries to teach them in a way which maximizes the effects like: semantics, synergy, symbiosis, and satisfaction. The paper also presents the mechanisms used to evaluate the success of the educational mission.

It was reconfirmed that multi-disciplinary, inter-disciplinary, and trans-disciplinary effort helps create new scientific values (some good research ideas were created), and it was also reconfirmed that students enjoy trans-disciplinarity (when algorithms, procedures, and thinking philosophies were ported from one field to the other).

According to Tables 1 to 3 relative increases of test results can be calculated. Semantization level increased by 388,3 percent. Synergy level increased by 60 percent. Symbiosis level increased by 176,9 percent. Therefore, it can be noted that the course had a greater impact on the student's level of knowledge from the personal perspective, than form the group perspective. Interestingly, these results are not in accordance with the student's subjective assessment (given through the satisfaction level testing), where the multidisciplinary nature and impacts of the course were given a higher mark than the filed-specific knowledge gained from the course.

This experiment is of interest for those interested in multi-disciplinary, inter-disciplinary, and

Table 4. Results of satisfaction with course content

Statements \ marks	1	2	3	4	5
Concepts I learned from this course will be useful to me later on.	2	4	13	12	9
Experience of working with people from other specialties during this course will be useful to me later on, if and when I work on WSN in healthcare.	2	5	11	14	8
Experience of working with people from other specialties during this course will be useful to me later on if and when I find myself working in any multidisciplinary field.	3	4	16	10	7
Multidisciplinary nature of the course had a positive impact on my learning	0	5	14	10	11
Multidisciplinary nature of the student group had a positive impact on my learning	1	4	9	10	16
Introduction of aspects regarding technology applications in a broader sense had a positive impact on my learning	3	6	15	9	7
I understand basic principles of WSN and how they may be of use to me	0	6	16	12	6
I am capable to participate in development of WSN technology for healthcare	5	10	13	9	3
I am capable to participate in marketing, deployment and use of WSN technology for healthcare	4	12	11	8	5
I have an insight into principles of WSN in healthcare, so that I may use them in other areas as well	3	5	15	10	7

Legend: Numbers in the table represent the number of students that have given the according mark trans-disciplinary education, and for those interested in methods to maximize the effects of semantization, synergy, symbiosis, and satisfaction among students of various majors.

Note

The entire environment and all processes related to this course have been defined using CMMI, and if the EIC and/or reviewers find it appropriate, CMMI definition can be added to the paper, as an appendix (at the end of the paper, or on the web).

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