Collaborative Multi, Inter, and Trans Disciplinary Courses: A Case Study based on Wireless Sensor Networks

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ABSTRACT

As with any new technology with a potentially wide impact, securing that the benefits are fully utilized and the take-up is facilitated requires effort from several disciplines. However, the skills for interdisciplinary cooperation and communication are often times lacking. This paper summarizes the findings of a trial course, which was created as an attempt to alleviate this issue. The course is focused around the use of Wireless Sensor Networks, a relative recent technology, in a set of medical applications, as well as an accompanying business models to make such products commercially viable. The course was designed to be given to students from three groups of majors: computer engineering, medicine, and business. The results show that after the proposed collaborative multidisciplinary course, the results of joint team efforts of the students increased, as well the individual level knowledge.

التعاون المُتَعدد والمُشترك في دورات التعليم والتدريب المُتَخَصِصة المَبنـية على الشبَكَات اللاسلكية

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المُستلخص

تهدف هذه الدراسة إلى الاستفادة القصوى من التقنيات المُستَحدَثة ذات التأثيرات الواسعة في دورات التعلم والتدريب عن بعد، وذلك بتوظيف مميزاتها المفضلة مع تسهيل استخداماتها في دورات التعليم والتدريب المشتركة بين التخصصات المتعددة. تأسست هذه الدراسة على تنظيم دورة تجريبية مبنية على التواصل باستخدام أجهزة تكنولوجيا حديثة وحساسة للشبكة اللاسلكية واعتمدت على تجميع سلسلة من دورات تعليم وتدريب عن بعد في عددٍ من المجالات العلمية المتخصصة والمتباينة. تم تصميم التجربة لعدد ثلاثة مجموعات في تخصصات هندسة الحاسوب Computer Engineering، العلوم الطبية Medical Sciences، والعلوم الإدارية Business Administrator، هذا وقد أوضحت نتائج الدراسة أفضلية مثل هكذا الدورات المشتركة لطلاب في تخصصات متباينة من حيث الفعالية واكتساب المعارف بالنسبة للطلاب المتدربين.

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الكلمات الدالة

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Introduction

Wireless Sensor Networks (WSN) is a novel and a rapidly developing technology that promises to revolutionise many aspects of the modern society. A Wireless Sensor Network is a system that consists of many - tens to possibly millions of small electronic devices. Each of these devices contains some number of sensors with which it can gather information, and can wirelessly communicate with devices in the network. As with any new technology with a potentially wide impact, securing that the benefits are fully utilized and the take-up is facilitated requires effort from several disciplines. Namely, what is needed is that: the technical expertise to build a product is present, use-cases and the requirements for the product are well defined, and that there is a clear marketing strategy. However, the skills for interdisciplinary cooperation and communication are often times lacking (Janis and Lynn, 2005).

This paper summarises the findings of a trial course, which was created as an attempt to alleviate the above mentioned issue. The here presented course was designed to teach topics related to Wireless Sensor Networks (WSN) to students from three groups of majors: computer engineering, medicine, and business. Goal set for the course was to educate the students to create marketable products based on the (WSN) technology, with the application related to the medical domain. The rationale for choosing computer engineering students is the most obvious of the three groups, as the (WSN) are essentially a computer-related technology. Business majors were included, as the product development cycle inevitably requires a marketing expertise. The medical application domain was selected for two reasons:

(a) Wireless Sensor Networks (WSN) indeed have a wide application potential in the medicine.

(b) Developing a medical product requires a large amount of expertise specific to medical experts, thus underlying the needs for a multidisciplinary approach.

Collaborative Multi, Inter, and Trans Disciplinary course is aimed at graduate level students. Perquisites for the computer-engineering students include a solid understanding of programming principles, and elementary knowledge of networking and electronics. For management and business administration the perquisite is familiarity with market analyses and product placement strategies. No specific perquisites are placed on the medical students. The aims of the course, regarding the development of the skill-sets, for each of the three groups are the following:

(a) For the engineering students the course gives a comprehensive training on the Wireless Sensor Networks (WSN) technology and development.

(b) Management and business administration should gain a basic understanding of (WSNs), in order required for developing business and marketing strategies

(c) Medical students are presented with only a high-level overview of the (WSN) technology that is needed to create ideas for potential applications, support the development of (WSN) products, as well as to prepare them for applying this technology in practice.

These aims may be met through organization of three separate courses (one for each group of majors), following a traditional didactic methodology perhaps adapted to a modern environment, as described in (Richardson 2008). However, an additional, overall aim for all of the students is to prepare them for cooperation within multidisciplinary teams. Typically, such goals are addressed through organization of project-oriented courses, created around a project implemented in a group of several students. Examples of such courses are presented in (Hall and Weaver, 2001; Hey, Van Pelt, and Agogino, 2006; Pinto, 1990).Alternatively, multidisciplinary courses have also been organized, in the similar, but slightly different problem-based courses. Here students are given a series of smaller problems to solve, rather than one, larger, integrative project. Examples are given in (Verma, Shannon, Muir, Nieboer, and Haines, 1988).

The distinctive differences between these courses, and the one presented in this paper are in the diversity of the disciplines that constitute the multidisciplinary nature of the students. Specifically, those course target students from the same field, but different specialties (e.g. electronic and communication engineers, or medical doctors specialising in different diseases, ...*etc*.). Therefore, along with the differences in expertise, there is also a significant overlap in the prior knowledge. On the other hand, our course brings together very diverse individuals, with often no overlap in prior knowledge. Creating a common ground, thus, required a non-trivial amount of traditional didactic lectures.

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 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.

Material and Methods

(1) Course Structure

The course is structured into seven segments, each devoted to a particular topic related to Wireless Sensor Networks and their applications. Material in each of the segments is devised so that it may be covered in two weeks, thus the full duration of the course amounts to fourteen weeks. Weekly workload is, however, varied depending on the major field a student comes from. The engineering students are given the full-winded version of the course, which requires roughly six hours of effort. The management and business administration students are given a lighter version, without some of the technical and implementation details presented to the engineering students. Medical students are given the lightest form of the course, which requires a weekly effort of two hours, and only presents a basic introduction to each of the topics. We refer to the three versions of the course as consisting of layers: the first layer including only the two weekly hours material, second layer the additional material covered in the four hour version, and the third layer containing the engineering details only given in the full six hour version of the course. In terms of the European Credit Transfer and Accumulation System (ECTS) these layers are worth two, for and six (ECTS) points. The workloads have been confirmed through the post-course surveys taken from students.

(1.1) Topic No. 1

Wireless Sensor Networks (WSN) Basics and Applications

First two weeks of the course give an introductory overview of some of the basic terms related to Wireless Sensor Networks (WSN), like: sensors and sensor types, wireless sensor nodes and their functions, gateways and ad hoc networks in general, as well as a historical perspective in the development of (WSNs) and their applications. First to layers of the course 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). The third layer additionally introduces students to the issues regarding MAC layer, 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 Wireless Sensor Networks (WSN) technology, and its applications, which could be expected to influence the future society. The major objective of this topic is to enable the student to create a realistic vision of the application of (WSN) systems, given the current, and the recently expected technology.

Table 1: Summary of the Course Contents for the three Layers for Topic No. 1

Content	Layer (I)	Layer (II)	Layer (III)
Historical overview	X	X	X
Example applications	X	X	X
Technological bases of (WSN)			X

(Layer (I): *All students*/ Layer (II): *Business and Engineering Students* / Layer (III): *Engineering Students*)

(1.2) Topic No. 2

Sensor and Overview

The second topic of the course focuses on an individual sensor node, as the basic building block of a Wireless Sensor Network (WSN). The medical students are given an insight into purpose, typical size, weight, battery autonomy, and other issues important to end-users. Several real implementations of sensor nodes are shown, such as: Mica Z nodes, Shimmer nodes, and Sun SPOT nodes.

The management and business administration students are given an additional insight into the hardware and software costs of individual nodes, and the complexities and costs related to operating and maintaining nodes and Wireless Sensors Networks (WSN), including costs of training individuals to use these systems (Hill, 2003); (Brent, 2006) .

Finally, the engineering students are given an in-depth technical insight into the architecture and hardware issues related to WSN nodes, including generalized node architecture presentation (Cordeiro and Agrawal, 2011), with a discussion of individual subsystems and requirements. Individual node metrics (Li, 2008) that were not covered in the second level (power, communication, computation, and time synchronization) are discussed.

Table 2: Summary of the Course Contents for the three Layers for Topic No. 2

Content	Layer (I)	Layer (II)	Layer (III)
Concept of a (WSN) Node	X	X	X
Basic architecture and capabilities	X	X	X
Typical unit cost; unit cost breakdown; cost of running a (WSN) network		X	X
Detailed architectures of selected (WSN) nodes; How to design a (WSN) node?			X

(Layer (I): *All students*/ Layer (II): *Business and Engineering Students* / Layer (III): *Engineering Students*)

(1.3) Topic No. 3

Medical Sensor Applications

This topic introduces the students to some of the basic vital parameters that can be efficiently monitored using sensor that can be adapted to Wireless Sensor Networks (WSN) (electrocardiography, electroencephalography, electromyography, blood pressure, pulse oximetry, and glucose monitoring). Consequently, it gives an overview of current monitoring devices for these parameters. Medical students will likely 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 of this topic 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 Wireless Sensor Networks (WSN) systems, including economic aspects of treatments of these diseases. The engineering students are also given an insight into the technical details of vital parameter monitoring (Stankovic, 2009).

Table 3: Summary of the Course Contents for the three Layers for Topic No. 3

Content	Layer (I)	Layer (II)	Layer (III)
ECG, EEG, EMG, PO, Glucose test, BP: What they mean and how they are measured	X	X	X
Overview of health hazards, and their economic impact on the society; How (WSNs) can reduce the burden?		X	X
ECG, EEG, EMG, PO, Glucose test, BP: Physical characteristic of the signals and the measurement devices			X

(Layer (I): *All students*/ Layer (II): *Business and Engineering Students* / Layer (III): *Engineering Students*)

(1.4) Topic No. 4

Wireless Sensor Networks (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 Wireless Sensor Networks (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 (Saleem *et al.,* 2009).

The second layer introduces students to the process of the new (technological) product acceptance by its users (Davis, 1985). It provides basic understanding of customer's purchase decision making and categories of product adopters (Mohr, Sengupta, and Slater, 2009), as of techniques for communicating functionalities and advantages of Wireless Sensor Networks (WSN**)** in health domain to the potential users (Northouse and Northouse, 1998).

Table 4: Summary of the Course Contents for the three Layers for Topic No. 4

Content	Layer (I)	Layer (II)	Layer (III)
Telemedicine Services	X		
Telemedicine Delivery Mechanisms	X		
Business plans as decision-making tools		X	
Goals of business plan creation, means of its realization and necessary human and material resources		X	
Fundamentals of software design for (WSN)			X
Tiny OS + nes C			X
Java for Sun SPOT devices			X

(Layer (I): *Medical students*/ Layer (II): *Business Students* / Layer (III): *Engineering Students*)

The third layer contains an in-depth examples of discussion on system architectures for WSN system related to health monitoring (Otto, *et al.,*2005); (Virone, *et al.,* 2006). It also revises the case studies from the first layer of the topic to a more technical perspective.

(1.5) Topic No. 5

Advanced Issues in Wireless Sensor Networks (WSN) Systems Related to the Medical Domain

Topic five of the course focuses on issues and considerations related to developing and deploying technology that directly interacts with humans, on the physical level, with an emphasis on Wireless Sensor Networks (WSN). Special attention is placed on several likely (WSN) applications, namely:

(i) Patients (home-care and hospitalized), as the most important category according to this course.

(ii) Employees, as a very wide category, including the effects of (WSN) in working environments.

(iii) Athletes, as a very specific category, including the possible effects on their training routines.

This part of the course also outlines some considerations regarding invasive health monitoring devices, related to preoperative, intraoperative, and postoperative complications. A set of regulatory requirements that need to be met (Shahnaz Saleem *et al.,* 2009) when designing, marketing and implanting these devices is discussed. In addition, an overview of general security issues (John Paul Walters, 2007); (Shahnaz Saleem, *et al.,* 2009) is presented to the engineering students.

The major objective of this topic is to demonstrate different safety and security requirements for the Wireless Sensor Networks (WSN) systems that are designed to be used and worn by humans. This topic is mostly important for the engineering students, as it is aimed to develop a sense of various hazards that need to be properly addressed in the design. For the medical students, the aim is to draw their attention to point that need to be addressed, so that they may raise the appropriate questions, and understand the possible solutions. Management and Business Administration students are expected to gain sufficient knowledge to identify risks and liabilities related to human-worn (WSN) products.

Table 5: Summary of the Course Contents for the three Layers for Topic No. 5

Content	Layer (I)	Layer (II)	Layer (III)
Health-related (WSN) Applications with Sensor Placement: overview, ideas and targets.	X	X	X
Health-related (WSN) Applications with Sensor Placement: costs, possible business models, required logistic infrastructure		X	X
Health-related (WSN) Applications with Sensor Placement: engineering behind the solutions			X

(Layer (I): *All students*/ Layer (II): *Business and Engineering Students* / Layer (III): *Engineering Students*)

(1.6) Topic No. 6

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 (Craig and Patterson, 2005; Esser and Goossens, 2009).

The management students listen to the second layer only, where they get introduction to the fundamentals of multidisciplinary (Wireless Sensor Networks (WSN) -related) business plan (Barringer, 2008; Thompson, 2006). 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 Wireless Sensor Networks (WSN). This layer presents an overview of key characteristics and classification framework for (WSN) operating systems platforms (Farooq and Kunz, 2011). It outlines and compares several wide-spread platforms, including Tiny OS, Contiki, Sensor Operating System (SOS), and Sun SPOT Squawk VM. The part of the course related to Tiny OS includes introduction to Tiny OS 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 Sun SPOT 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 Sun SPOT nodes includes the examples of design cycle of a relatively simple application.

Table 6: Summary of the Course Contents for the three Layers for Topic No. 6

Content	Layer (I)	Layer (II)	Layer (III)
Impacts of (WSN) Systems on Humans	X	X	X
Preoperative influences and Potential Intraoperative and Postoperative Complications	X	X	X
Physical Fragility of (WSN) devices; Limited Resources in a System			X

(Layer (I): *All students*/ Layer (II): *Business and Engineering Students* / Layer (III): *Engineering Students*)

(1.7) Topic No. 7

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 Wireless Sensor Networks (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: Sense Web, Iris Net (Chatzigiannakis*, et al.,* 2007) and Peer-to-Peer: Hour Glass (Spiess, 2005), Cobis (Chatzigiannakis*, et al.,* 2007).

Table 7: Summary of the Course Contents for the three Layers for Topic No. 7

Content	Layer (I)	Layer (II)	Layer (III)
Internet of Thing: The Vision	X	X	X
Internet of Things: Actors and Stakeholders; Opportunities and pitfalls		X	X
Internet of Thing: The Vision: The Engineering details			X

(Layer (I): *All students*/ Layer (II): *Business and Engineering Students* / Layer (III): *Engineering Students*)

Results and Discussion

Lessons Learned from the Experimental Offer of the Course

(1) Testing Methodology

Courses that are aimed at multidisciplinary audiences, and aim to build on the collaboration among students need to be assessed for effectiveness on two levels: the individual and the group level, as indicated in (Strijbos and Fischer, 2007).The rationale behind this is that the objective of the course is both to educate individuals and prepare them for working within multidisciplinary teams. Another important point is that when a course with a novel approach is evaluated, both quantitative measures (e.g. student's performance on test scores) as well as qualitative ones (e.g. student's satisfaction and perception) should be assessed.

Taking the above into account four variables was specified:

(i) Semantization, as a quantitative measure of the course effectiveness on the individual level;

(ii) Synergy, as a quantitative measure of the course effectiveness on the group level;

(iii) Symbiosis, as a qualitative measure of the course effectiveness on the group level; and

(iv) Satisfactionas a qualitative measure of the course effectiveness on the individual level;

(Specific explanations of the four variables will be given shortly).

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.

The research methodology, which was followed when assessing Semantization, Synergy, and Symbiosis was a quasi-experiment with a single group and pre-test and post-test design. Therefore, a test was conducted before the course for a reference, and repeated afterwards. The period of fourteen weeks before the initial test and the repeated test was considered sufficient to negate any effects of the pre-test on the post-test performance. Satisfaction was assessed using a simpler quasi-experiment with pre-test only design. This choice was due to the nature of the Satisfaction variable (described in section 2.1.4), measuring which before the course would not make sense.

(2) Semantization

Measuring the Semantization was done through 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 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 8).All of the results are statistically significant at the (5%) level, tested by a paired t-test, using the R statistical language.

Table 8: Results Of Semantization Level Before the Trial Course

Questions	Before / after the course			
Students	Average Score	Engineering	Management	Medicine
Engineering Students	35/85 (p-val = <10-7)	80/90 (p-val = 0.007)	20/95 (p-val = <10-15)	10/75 (p-val = <10-8)
Medical Students	35/65 (p-val = 0.0005)	15/55 (p-val = <10-4)	10/50 (p-val = <10-5)	80/90 (p-val = 0.007)
Management Students	30/65 (p-val = 0.0005)	15/60 (p-val = <10-5)	60/80 (p-val = 0.005)	10/55 (p-val = <10-4)

(*Legend: Engineering: project score from the engineering standpoint. Management: project score from the management standpoint. Medicine: project score from the medical standpoint*).

(3) Synergy

As stated above, by Synergy we denote the ability of the three groups of students to work together. To test this we divided the students into ten groups, each of four students, so that each group contained at least one student from each of the groups. Each of the groups was presented with a complex problem to solve, which included a medical issue to be addressed, engineering behind the solution, and development of a business strategy. Since the test was timed, and a relatively short time frame was given, only the basic concepts were expected, in a form of a written report. Short timing of the test, which was (35) minutes, as proposed by (Zikic, 1997), served to stress efficacy of the communication within the team. The report was than assessed by an engineering, a medical, and a marketing expert.

Table 9 shows the results of the Synergy testing. It can be seen that the scores improved, more so than the scores for the Semnantization level testing, thus an improvement was achieved beyond that coming from the individual gain in knowledge. These results must, however, be taken with a certain caution, since the post-test was conducted after students had taken the course together, and in the pre-test phase they only had a short time to get acquainted. To alleviate this effect, the students were paired differently before and after the course. To fully address this issue, a different experimental design would be needed, one including several parallel groups of the course, and a randomized pairing of the students from different groups. Such an approach was beyond the resources available at the time of the course offering. All of the results are statistically significant at the 5% level, tested by a paired t-test, using the R statistical language.

Table 9: Results of Synergy Level Testing

Project Score (1-10)	Average Score	Engineering	Management	Medicine
Before the Course	05	05	05	05
After the Course	08	09	07	08
Improvement %	60%	80%	40%	60%
p-value	0.001	0.0013	0.034	0.05

(*Legend: Engineering: project score from the engineering standpoint. Management: project score from the management standpoint. Medicine: project score from the medical standpoint*).

(4) Symbiosis

The Symbiosis testing was created to test the students' ability to gain appropriate feedback from the students of other profiles. The students were presented with short scenarios, including a set of specific information they would need to get from other specialties. The basic idea behind this test was to see if taking a joint course allowed students from different fields to better understand each other's patterns of thinking, the professional terminology, and the extent of the others understanding of their own fields. A multidisciplinary committee assessed these questions for clarity, precision and value of the information included, on the scale 1-10 (1-bad, 10-excelent).

What can be seen from the results is that there is a clear improvement in the scores. In all of the categories, the improvements are higher than that for the Semantization level testing. In other words, there is an improvement above that which can be explained by the knowledge acquired in the non-native field during the course. All of the results are statistically significant at the 5% level, tested by a paired t-test, using the R statistical language.

Whether this improvement can be attributed to the interpersonal communication or other factors cannot be entirely concluded from the given experimental design. To fully test this hypothesis, a control course with the three groups thought separately would be needed, which was beyond the available resources.

We did, however, include a question in the Satisfaction testing questionnaire, regarding the students' personal opinion whether or not the communications during join course, along with the new non-native knowledge, helped them better understand the professionals from the other fields. The majority of students replied positively. Therefore, conclusions which can be drawn are two folds:

(i) there is an increase in the Symbiosis level scores, beyond those that can be explained by the knowledge acquired in the non-native field during the course;

(ii) the students feel that the multidisciplinary nature of the course audience contributed to this score. Due to the fact that we here rely on the student's opinions, rather than number from a conclusive experimental design, we consider this result to be qualitative in its nature.

Table 10: Results of Symbiosis Level Testing

Project Score (1-10)	Average Score	Engi-neering	Manage-ment	Medi-cine
Before the Course	1.3	02	01	01
After the Course	3.6	05	04	02
Improve-ment %	176%	150%	300%	100%
p-value	$<10^{-5}$	$<10^{-5}$	$<10^{-4}$	$<10^{-4}$

(*Legend: Engineering: project score from the engineering standpoint. Management: project score from the management standpoint. Medicine: project score from the medical standpoint*).

(5) 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 11). The results were tested for significance against an expected mean of 3, which may be expected in the case of a random population sample (regardless of whether the students took the course), in order to assess the impact the course may have had. The tests were conducted with a single-sample t-test in the R statistical language. Out of the ten questions, seven questions showed statistically significant difference from the expected mean. The three questions that did not show a statistical significance were related to the student's perception of the level of preparation for a real word task in the domain. This result is somewhat expected, as it is fairly difficult for a single course to affect this issue, which is typically addressed by much larger segment of ones education.

Table 11: Results of Satisfaction with Course Content

Statements \ Marks	(1)	(2)	(3)	(4)	(5)	Mean	p-value
Concepts I learned from this course will be useful to me later on.	02	04	13	12	09	3.5	0.005
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.	02	05	11	14	08	3.47	0.008
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.	03	04	16	10	07	3.3	0.009
Multidisciplinary nature of the course had a positive impact on my learning	00	05	14	10	11	3.62	0.0003
Multidisciplinary nature of the student group had a positive impact on my learning	01	04	09	10	16	3.9	$<10^{-4}$
Introduction of aspects regarding technology applications in a broader sense had a positive impact on my learning	03	06	15	09	07	3.2	0.14
I understand basic principles of (WSN) and how they may be of use to me	00	06	16	12	06	3.45	0.004
I am capable to participate in development of (WSN) technology for healthcare	05	10	13	09	03	2.875	0.49
I am capable to participate in marketing, deployment and use of (WSN) technology for healthcare	04	12	11	08	05	03	01
I have an insight into principles of (WSN) in healthcare, so that I may use them in other areas as well	03	05	15	10	07	3.3	0.049

(*Legend: Numbers in the table represent the number of students that have given the according mark*).

Conclusion

This paper describes a new approach to creating multidisciplinary courses, based on a mix of didactic and project-driven course organizations. The design is intended to exploit communication and cooperation between students, in addition to the exposure to novel material. Furthermore, the paper presents the mechanisms used to evaluate the success of the educational mission.

The results confirm that after the proposed collaborative multidisciplinary course, the results of joint team efforts of the students increased, as well as the individual level knowledge. Moreover, the results confirm that the students enjoy working in such multidisciplinary teams.

Examining the tables 8-10, the changes in the test scores can be summarized. Scores on the individual quantitative level (denoted as "Semantization", the individual multiple choice tests) increased overall by (115%). All of the students scored the highest on the material from their native fields, which was expected. Collaborative, quantitative scores (denoted as "Synergy", the score on a multidisciplinary group project) increased by (60%). Collaborative qualitative scores (dented as "Symbiosis", the ability to formulate questions and request understandable and meaningful to other major groups) level increased by (176%). Therefore, it is evident that the course had a somewhat greater impact on the student's level of knowledge from the personal perspective, than from the group perspective. However, the greatest benefit of the course was seen in the ability to formulate questions and request understandable and meaningful to other major groups.

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