Innovative and Efficient Teaching Methodology for Digital Communication Systems Using an e-Learning Platform

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Abstract —This paper studies the possibilities of employing an e-Learning platform for effective teaching and evaluation of a course on Digital Communication Systems. The platform not only provides high-impact pedagogical practices that deepen learning and foster student engagement, but is also an appropriate tool for efficient instructional methodology, accurate and transparent student evaluation, and easy implementation. The main motivation behind building the course material using the online e-Learning platform is twofold. First, to impart substantial knowledge and understanding to the students effectively; and second, to receive student performance statistics and feedback instantly at the completion of each module of the course. The adopted approach of imparting knowledge to the students utilizes an innovative and customizable platform for efficient learning outcomes. We employed the Finnish National Board of Education system to implement the course and its evaluation procedures. At the end of the course, the students felt this to be a convenient, understandable, and efficient approach for imparting knowledge and students felt they gained more, compared to the traditional approach.

Index Terms—Digital communication system; ViLLE platform; teaching methodology; evaluation of students; sustainable teaching approach

I. Introduction

With the advent of modern computer and communication technology, many computer-assisted educational tools have been developed and have proliferated excessively in recent years [1]. The goal of this development is to realize and implement the course curriculum effectively and efficiently and to strengthen current teaching and learning practices. In this work, we have created a course curriculum on Digital Communication Systems for undergraduate level students, and have analyzed and examined the outcomes by running this course during the autumn semester of 2015 at the Department of Information Technology (IT) at the University of Turku (UTU), Finland. The course materials, teaching methodology, exercise solving, and students' assessment and evaluation were carried out using an e-Learning platform developed by our department. The main aim of using this platform is not only to deliver high-quality education to the students but also to create a simple, transparent, and straightforward assessment methodology. This approach involves continuous assessment of the registered students, which means that, after each lecture, students must perform the given exercises within a certain time, and each of their performances will be evaluated automatically. Based on the students' performances, the e-Learning platform instantly produces an average statistical chart that includes various kinds of important information regarding the average understanding of the course module. This information will play a key role for the instructor running the course module by illustrating the understanding level of each student. With the help of the statistical feedback, the instructor may tweak his/her teaching strategy during the course.

E-Teaching, e-Content, e-Exam, and e-Learning are now becoming the new trends for technology-driven education systems. The current and next generation students are more likely to employ digital media in their education. At the Faculty of Humanities and Social Science, University of Zagreb, research [2] shows that the application of e-Learning at Croatian Universities has increased rapidly, and the use of an e-Learning tool called Omega has met student requirements satisfactorily in that the tool made their studying easier compared to traditional teaching methodology. The term 'traditional teaching methodology' is mentioned often in this paper. This term implies teaching methods without the use of any electronic media and employing traditional paper and pencil. The motivation for employing the new e-Learning approach and digital media in teaching and learning processes has increased considerably. This is due to the fact that students have variable levels of motivation toward making use of and benefiting from the media and technology components in the lecture classes [3], [4].

A study has been made of the recent literature regarding efficient teaching and learning methodologies for digital communication systems courses. In order to find related approaches to the research presented in this article, we studied the paper "Experiential Learning of Digital Communication Using LabVIEW" [5], where the authors discuss the design and implementation of laboratories and course projects using LabVIEW in an instrumentation course for undergraduate level students.

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In [6], Schubert et al. present some interesting research in "Simulation of the Effects of Companding on Quantization Noise in Digital Communication Systems." Presently, state-of-the-art research in the direction of developing new and innovative computer-based courses at undergraduate level is emerging very rapidly. The main purpose of this innovative e-Learning platform is to impart high-quality knowledge and understanding to the students in both the theoretical and the experimental domain. In [7], Linn et al. An Ultra Low-Cost Wireless Communications Laboratory of Education and Research have introduced an ultra-low-cost wireless communications laboratory based on a commercial off-the-shelf field programmable gate array (FPGA) development board. The total cost of the laboratory is less than 200 USD, including complete transmission, channel emulation, reception (coherent and noncoherent), and probing capabilities. In papers [8]-[11] respectively, approaches for forecasting student performance, innovative use of computers and computer networks in teaching, student feedback and systematic evaluation of teaching, and course development for Green ICT are described. In this work, rather than emphasizing one particular knowledge domain (i.e., simulation, theoretical knowledge, experimental knowledge), our aim is to provide an innovative and efficient teaching methodology that supports students in enhancing their overall knowledge and understanding in digital communication systems at the undergraduate level.

This article is structured as follows. The following two sections provide descriptions about Course Outlines and Learning Outcomes and the E-Learning Platform, respectively. Underlying Teaching Approaches and Implementation Results are discussed in sections IV and V. Skills Development and Instructor Workload in the transition are described in Section VI. Sections VII and VIII present Course Statistics, Evaluation and Grading, and Conclusion and Future Works, respectively. Acknowledgments and References are the final sections of this article.

II. Course Outlines and Learning Outcomes

The course on digital communication systems allows the students to understand the underlying principles of the reliable transmission of information by focusing on the most basic ideas of digital communication. For an IT engineering student, knowledge of communication technology is absolutely vital as communication has been one of the compelling needs of the human being throughout recorded history. This course imparts the knowledge to understand, analyze, and design digital communication systems and their components. This course also allows the students to compare and analyze different telecommunication concepts and scenarios for their implementation. Today's emerging communication systems include radio and TV broadcasting, cellular telephony, satellite communication, computer networks, wireless sensor networks, cyber-physical systems, the Internet of things (IOT), communication in health, bio-medicine and neuroscience, location-based services and so on. The major design challenges for the students here are hardware design (precise components, low power, small, lightweight, inexpensive), system design (high data rates, robustness to noise and interference, trade-off between simplicity and bandwidth availability), network design (seamless connectivity, high speed, energy, and delay constraints). To cope with these design challenges and the learning interests of the students, there is a huge demand for an innovative and efficient teaching methodology using an e-Learning tool, which will help the students to acquire this knowledge successfully.

In the curriculum for a Bachelor's degree in Information and Communication Technology, 28 hours are allocated for the lecture course and 14 hours for demonstrations, tutorials, and simulation/experiments on the Digital Communication Systems course. These 28 lecture hour time slots have been divided into 12 'chapters'. Typically chapters are two hours in lecture duration. However, a few chapters such as the optimum receiver for binary data transmission and channel coding take four hours lecture duration. Chapter 1 begins with an introduction to digital communications, basic components, and application areas; the targeted learning outcomes are to understand electronic communication systems, historical evolution, emerging applications, and ViLLE as a learning environment tool. Chapter 2 is focused on information theory, probability theory, random variables, and random processes. The students will be able to understand the notion of information in the quantitative sense, information measurement, entropy, stochastic processes and their properties. Binary data transmission will be covered in chapter 3 with the objectives of understanding how to send and receive a single bit step by step in an ideal communication system, and to simulate single bit transmission using MATLAB. Here students will learn the process of analog to digital conversion, and become familiar with random process terminology and channel modeling concepts. Basic concepts like sampling theorem, quantization, inter-symbol interference and discrete memoryless channels will be the subjects of lectures in chapter 3. Chapters 4 and 5, respectively, present details of the optimum receiver for binary data transmission and baseband data transmission techniques. The targeted learning outcomes for these two chapters are to develop a foundation for the analysis, evaluation, and design of a wide spectrum of digital communication systems and to learn different baseband modulation methods, respectively. Using MATLAB code, the students will be able to analyze and compare the bit error probability for various baseband-signaling schemes. Chapters 6 and 7 are dedicated to passband modulation schemes and source coding, where students will be able to compare the performances of various passband modulation techniques, and learn the principle of fixed and variable length source coding,

respectively. The students will also learn to analyze the power spectral density (PSD) function of different passband modulation schemes. Chapters 8, 9, and 10 are on Channel Coding, Encryption and Decryption, and Synchronization, respectively. The purpose of these three chapters is to understand how fast and how accurate and reliable communication takes place over an unreliable/noisy channel, to understand cryptography and its role in digital communication systems, and to learn various synchronization techniques to establish a successful communication system. After completing the encryption and decryption module, the students will be able to describe the use of ciphers, the role of randomness in encryption, and the development of RSA encryption. Chapter 11 introduces advanced concepts and practical standards, where students will learn about important modulation paradigms such as CDMA, and the OFDM and WLAN technologies. Lastly, a summary chapter is dedicated to present overall design and simulation problems/cases in order to understand how different topics are inter-related. As textbooks and reference books for the course, we chose "Digital Communications" [12] by John G. Proakis and Masoud Salehi, and "A First Course in Digital Communications" [13] by Ha Nguyen and Ed Shwedyk, respectively. The combination of these two books offers students extensive theoretical and mathematical concepts and understanding regarding digital communications.

III. E-LEARNING PLATFORM

We utilized the ViLLE collaborative educational tool for the e-Learning platform. Student-centered learning [14] and problem-based learning [15] are the key features of the ViLLE e-Learning tool. This tool enables instructors to create virtual courses and automatically/manually graded assessed exercises of different types without any difficulty. In addition, all of the created courses, exercises, tutorials, and the teaching resources can be utilized, commented on, and evaluated by other teachers.

Moreover, the platform automatically gathers data about students' learning behavior and results while they are using the system. This creates new research possibilities, as a huge amount of quantitative and qualitative data becomes available. This platform is a versatile and ongoing e-Learning project to support an effective, efficient, and environmentally friendly education system. Some of the features of the platform include course rounds management, student registration facility, assignment management, adding and removing exercises, automatic and manual grading system, student performance monitoring, and course statistics. The features of this platform are described briefly in the subsequent paragraphs. This e-Learning platform is fundamentally based on exercises submitted by the students, and this makes it distinct from other learning environments such as Moodle or Moodle 2. Most of the exercises are automatically assessed, and they provide immediate feedback when submitted. The same exercises can be used in lectures, homework, and exams in a randomized fashion; however, in the exam mode, the feedback is disabled by default. The exercises are divided into three main categories: coding and computer science exercises, mathematical exercises, and general exercises. All exercises created by the editors are automatically shared with all other teachers registered in the system. Private materials can also be attached to courses, rounds, and assignments. In addition to automatically assessed exercises, it supports a variety of manually graded assignments and automated tasks, such as attendance, demonstrations, file submission, study journals, and course assignments. Assignments assessed by the teacher (such as essays and course projects) can also be peer-reviewed by other students or colleagues. The details of this newly developed e-Learning platform are available online at www.villeteam.fi/en [16].

IV. UNDERLYING TEACHING APPROACHES

The course outlines are described in section II. The course materials for all these chapters were taught during the lectures as several rounds, as shown in Fig. 1. For each lecture, various multiple choice, true-false type, numerical problems, simulation-based examples, and short answer type questions were created. Students had to solve these problems using the e-Learning platform within a specified time frame.

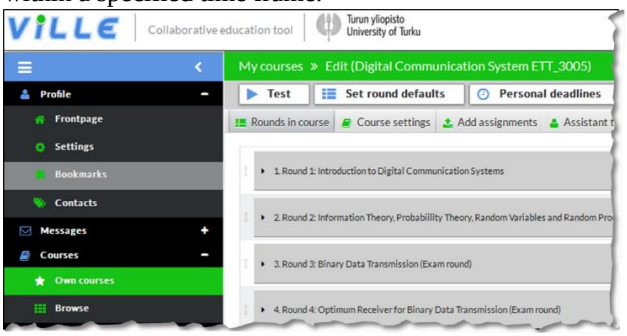

Fig. 1. Graphical user interface for DCS course on ViLLE

Before the beginning of the next lecture, the instructor is able to perceive student performance by looking at the number of submissions, average submissions per student, and average submission score. The instructor is also able to observe the total time spent, average time used per student, average time used per assignment, and best assignment of the average of all submissions. This instant feedback option for each lecture statistic would be very clumsy and difficult in traditional teaching methodology. This could be one of the emerging scopes of ViLLE-based learning techniques. As mentioned previously, the teaching methods utilize a continuous assessment approach. Therefore, for each lecture, students must solve a certain number of problems to sharpen their understanding toward the course materials. In this teaching method, students need to spend at least some

time solving the problems and submitting them to the electronic submission system within a prescribed time to pass the course. Likewise, the students need to perform actively/diligently for all the lectures and submit the assignments in due time to receive the minimum score specified by the instructor. Finally, students need to take a final exam, which accounts for 50% of the total score.

Several pedagogical approaches [17] such as the scaffolding approach, collaborative learning, and student-centered learning were explored regarding implementation during the lesson. The student-centered learning approach was found to be highly appropriate for the course ETT-3005. This is because the ViLLE platform supports individual performance evaluation and student assessment. For collaborative learning, the students were given a couple of tutorial problems during the demonstration lecture hour, where students had the possibility of sharing their thoughts in a team on the coding approach, design methods, and the performance an performance analysis. Four to six hours were spent on collaborative learning during the course, and the students had the right to form their group (not more than 2-3 persons per group) independently depending on the attendance during the tutorials. per group) independently depending on the attendance during the tutorial lectures. For coding as a learning outcome, students are given the facility to use a licensed version of MATLAB through the ViLLE system. Earlier, we utilized a few other e-learning tools, such as Moodle and Moodle 2. The features of the current e-Learning platform are also compared to the earlier tool, see Table I, Table II, and Table III.

The teaching approach using the e-Learning platform is innovative in the sense that it is capable of providing instant feedback to the teacher about the average performance of the students. The results of the student's performance give an opportunity for the teacher to revise topics where the students fail to answer successfully. As an example, we have illustrated the round statistics in Table I. The information contained in Table I appears to the teacher once the students have submitted the specified assignment sets. At the end of the course, overall course statistics are also created by the e-learning platform.

TABLE I: INSTANT FEEDBACK

Round open	09/01/2015 12:00 AM
Round closes	09/09/2015 09:00 AM
Number of assignments	4
Average Submission per Student	3.57
Average submission score	5.7
Total time used	12:43:43
Average time used per student	00:16:14
Average time used in assignment	00:04:32
Best Assignment	True False Type
Most time used in assignment	Multiple Choice Type

TABLE II: COMPARISON OF STUDENTS' PERFORMANCE

Year	2013	2014	2015
Students Registration	29	34	47
Number of Assignments Submitted	2	3	22
Number of Problems Solved	12	12	180
Number of Intermediate Rounds	3	3	10
Av. Number of Problems in Each Round	4	4	18
Number of Problems in Final Exam	7	12	30
Students Passed in First Final Exam	15	5	29
Average Grade in Final Exam (5)	2.6	3.6	3.96

TABLE III. COMPARISON OF VILLE PLATFORM AND MOODLE

Features	ViLLE Platform	Moodle
Automatically Assessed Exercise	✓	
Collaborations between students and teachers	✓	
Electronic Exam	✓	
Manually Graded Assignments	✓	✓
Tutorials	✓	✓
Device Compatibility such as Mobile Phone, Tablet, iPads	✓	

V. IMPLEMENTATION RESULTS

The authors have several years of teaching experience of the Digital Communication Systems (ETT_3005) course over the last few decades. This investigation was carried out by utilizing the newly developed e-Learning tool in our department during 2015. The students were notified before registration that this course would be carried out using an electronic platform. The data show that the highest number of registrations during the past three years occurred in the fall semester of 2015. The larger number of students registering shows that students prefer electronic media to the traditional paper-pencil teaching method. The percentage increase in student registrations for the ViLLE-based digital communication systems course compared to the traditional teaching in 2013 and 2014 was approximately 62% and 38%, respectively. During the fall semesters of 2013 and 2014 this course was taught, including 2 to 3 sets of student assignments in total, where the number of problems encountered was about 12. In 2015, using this platform, the students came across 22 assignment sets altogether and solved more than 180 problems before the final exam. This is a huge increase (approximately 14 times) in the number of problems that students solved independently. These problems must have a huge impact on the students in gaining diversified knowledge to enhance their learning of the digital communication concepts and problems taught in rounds 1-12. The overall goal was to enhance the students' understanding level for each of the chapters, compared to the traditional teaching methodology. The number of students who passed in the first final exam is illustrated in Fig. 2, which indicates that the students seemed to be more active and enthusiastic about taking the electronic exam using the ViLLE platform. Not only did they sit the exam, but they also performed very well in the final exam. Over the last four years, the author's personal experience regarding the final examination is that more than 30% of the students left the exam hall after just 30 minutes (which is the mandatory time to sit in the exam hall; students are not able to leave the exam hall before 30 minutes after the exam has begun). Using the ViLLE-based electronic examination system, no such cases were noticed,

although students were entitled to sit the exam a second or third time. During the experiment, a survey was carried out as to whether the lectures were found interesting and useful. The outcomes of the survey revealed that 74% of the students said that the lectures were useful; they learned something new during the lectures. However, 17% of the students expressed the opinion that the initial few lectures were not useful and they knew the content already. This claim for those 17% students was evaluated by their performance in the given assignments, and finally, it revealed that the majority of those 17% students had performed well. A few of the students, about 9%, said that they had faced heavy mathematical expressions in lectures 3, 4, and onwards. Thus the overall implementation results illustrate that teaching using the e-Learning tool for the Digital Communication Systems course not only helps the students to understand more but also supports teachers in recognizing the students' individual performance and difficulties efficiently.

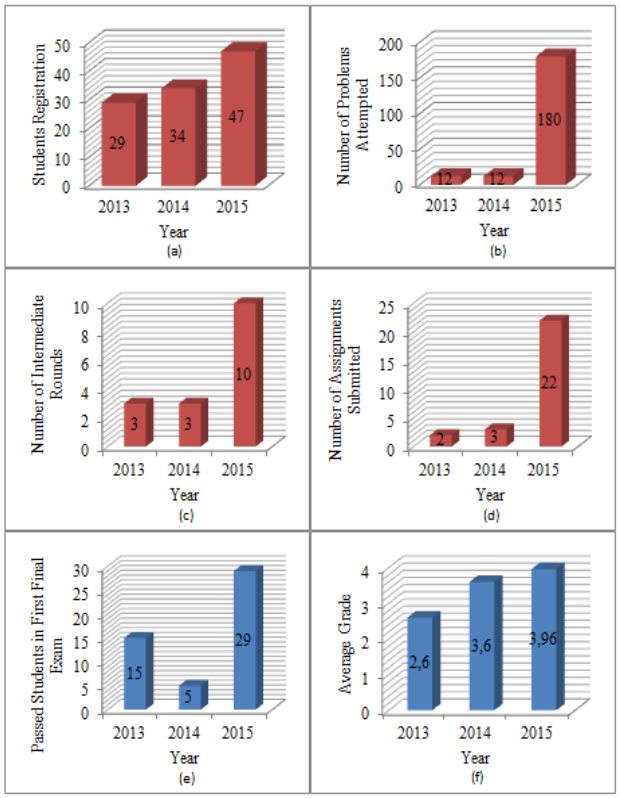

Fig 2. ViLLE Platform Implementation Results (a) Students Registrations in the years 2013, 2014 and 2015 (b) Number of Problems Attempted (c) Number of Intermediate Rounds of Assignments before the final Exam (d) Number of assignments solved by the students (e) Number of Passed students in first final exam (f) Average Grade obtained by the students

VI. Skills Development and Instructor's Workload

The practical skills and learning outcomes for this course are predefined in the curriculum. We have followed the course curriculum thoroughly and imparted knowledge on theoretical, conceptual, numerical, and realistic phenomena within the domain of this course. For the Department of Information Technology at the University of Turku, this course is held for bachelor degree level students during the third year of their study. Although students already have a basic mathematical understanding at this stage, they seemed to struggle more with the heavy mathematical expressions encountered during the lectures, such as geometric representations of binary signals, the Gram-Schmidt procedure, and error performance in baseband signaling. This course includes numerous analytical mathematical expressions, which are needed in order to understand the theoretical concepts. The block diagram indicates that there is only one universal block diagram that describes all analog and digital communication systems. It is rare for the system designer to have control over the channel and even rarer to have it over the source. Therefore, design and analysis are focused on transmitter and receiver blocks. However, the design must take the source and channel characteristics into consideration. The second important aspect we emphasize in terms of student skill development is the use of MATLAB (or a similar tool) in simulating the communication processes and techniques taught during the lectures. On the ViLLE platform, it is easier to formulate several types of exercises such as classification exercises, fill-in exercises, matching text and image pairs, short answer type exercises, randomized numerical parameter problems, multiple choice exercises, and problems using a simulation tool. These varieties of problems force the students absorb not only the theoretical concepts of digital communication systems but it also broadens their knowledge and skills toward the analysis and design of processes and techniques. The workload of the teacher was considerably reduced compared to the traditional teaching and evaluation processes. Multiple Excel files for students' overall performances are created automatically. The ViLLE platform does all the manual operations and time-consuming calculations required to obtain the students' final grade.

VII. Course Statistics, Evaluation and Grading

In this course, the grades are awarded as per student performance in continuous assignments and final examinations. The course policy is such that continuous assignments and the final examination each carry 50% of the total weight, although regular attendance at the lectures earns bonus points to a certain extent. For each round, lecture statistics such as the average score for tasks, number of submissions and average time spent on tasks are graphically visualized for the instructor. This supports a tremendous area of improvement and feedback for the teachers in the next round of lectures. For example, the sixth lecture round was on the subject of passband modulation. The course statistics generated by the proposed e-Learning platform illustrate the average statistical number of submissions, scores, and time spent by the students. These average statistics could be utilized

for further improvement, precision, and fine-tuning for the next lecture and assignment. The final examination was carried out in the assigned pre-determined lecture hall, where students were allowed to use their own devices (laptops, tablet, or even mobile phone). The students needed to make sure themselves that the ViLLE tool was running satisfactorily on the device they used in the examination. The evaluation of the students was performed automatically based on correct answers in the multiple-choice questions, true-false type questions, numerical problems, short answer type questions, and MATLAB simulation and coding skills using the e-Learning tool. All these question patterns apart from the short answer type questions are automatically graded within the system, whereas the short answer type problems need to be graded manually.

VIII. Conclusion and Future Works

Our research work makes several important contributions.

Two key conclusions from this study are:

- An innovative and efficient teaching methodology using the ViLLE learning platform for a course on Digital Communication Systems has been proposed, which supports the provision of high impact pedagogical practices, accurate and transparent student evaluation, and easy implementation.
- The chosen approach is green, environment-friendly and highly aligned with the roadmap of reducing and eliminating paper consumption [18] in academic institutions.

There are many avenues for further research. The first important future goal is to develop an exam registration system and step-by-step validation system for student assignments. There are several gaps in the ViLLE platform such as an interface for entering mathematical equations and expressions, and adding a facility to insert symbols, equations, and drawings into short answer type assignments. Another imperative topic for future work is to consider more randomization in the examination and a screen locking facility during the electronic exam. We are currently working on these issues.

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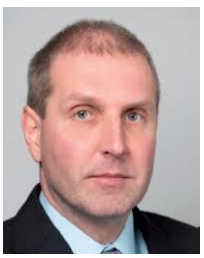

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