

Transition From Traditional to LMS Supported Examining: A Case Study in Computer Engineering

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ABSTRACT: Modern education is hard to imagine without the use of e-learning tools, but still the transition from traditional “paper-and-pencil” examining to electronic exams is to some extent cautious. Although course administration and exam evaluation are much easier with learning management systems, there are concerns among teaching staff, that electronic tests simplify examination process compared to paper tests and classic examining. At the University of Belgrade, School of Electrical Engineering, e-learning tools are used at several exams, mostly as a secondary tool to aid with laboratory exercises. In this paper, we show our experience with four courses from the computer engineering study program that are to various extent moved to Moodle LMS, and electronic examining. We mostly concentrate on certain aspects of transition from paper tests to electronic exams. We present 12 different transformations needed to conform to electronic examining and automated evaluation, and discuss benefits and drawbacks of such a transition. © 2016 Wiley Periodicals, Inc. *Comput Appl Eng Educ* 24:775–786, 2016; View this article online at wileyonlinelibrary.com/journal/cae; DOI 10.1002/cae.21750

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INTRODUCTION

Computer-aided learning and examining have become a widespread practice in recent years. University courses moved largely to the Internet, offering technical information, lectures, course materials, discussion boards, etc. E-learning tools have been gradually introduced to courses in order to demonstrate concepts taught and provide students with hands-on experience. On the other hand, examining has been moved to the cloud at much slower pace, as teachers tend to be more cautious with knowledge assessment, and evaluation.

In the last decade, learning management systems (LMS) have been often used in higher education to offer online courses, and distant learning, as well as a teaching aid for traditional courses. LMS offer much easier course administration, content management, evaluation, and reporting, which is why such tools easily

gained popularity in academic community. There are many positive reports [1,2] when it comes to the use of LMS in education, as teachers tend to ease the burden of handling massive exams. Also, several studies [3,4] showed that e-learning tools have positive effects if they are used appropriately.

At the University of Belgrade, School of Electrical Engineering (UB-SEE), all courses offered to students include practical work in the laboratory as an important part of the course. Many e-learning tools were introduced, both to cover the practical work in the laboratory and help teachers with course organization, and administration. Some of those tools were developed by the teaching staff from computer engineering department. None of them covered all aspects of course organization, but were rather specialized for use during lectures, in laboratory, for homework submission, etc. Most of those tools are from the computer architecture domain such as Refs. [5–9]. Some e-tools and simulators have been implemented for courses on algorithms and data structures [10], data security [11], and expert systems [12,13]. Automated test assembly for massive exams was covered in Ref. [14].

Over time, we realized the potential benefits of using LMS, especially for student assessment. We present our experience with

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transition of four different courses to Moodle LMS and electronic examining. Moodle LMS was first introduced to Computer Networks (CN) and Computing Fundamentals of the Internet (CFI) courses, and later it was used at Computer Security (CS) and Algorithms and Data Structures (ADS) courses. Courses descriptions are summarized in Table 1.

The paper is organized as follows. First, we present Moodle LMS, and the rationale behind the decision to use it in our courses. Experiences of others with transition to LMS, and some studies on user satisfaction are discussed. We conclude the Related Work section with e-learning tools that were developed at our university. In the following sections, we describe our courses and existing practices that were prevalent in course administration, and examination at our university before the introduction of LMS, and we specifically explain the transition from paper tests to electronic exams in Moodle. Our experience with the use of LMS is summarized and discussed in the Evaluation And Discussion section. A short conclusion and directives for future work are given in the Conclusion section.

RELATED WORK

LMSs are used at numerous universities around the world. There is a large number of LMS available for use, either free of charge, or as commercial tools. Some of general-purpose systems that are frequently used in higher education are: Blackboard [15], Moodle [16], Desire2Learn [17], and Canvas [18]. Experiences with use of LMS are mostly positive, but there are some critical reviews in the open literature.

Moodle LMS

All of the aforementioned systems have more than enough functionalities that are needed in computer engineering courses. We decided to use Moodle LMS in our courses, as Moodle platform has already been made available to us by the Academic Network of Serbia (AMRES) [19]. Moodle LMS is one of the most popular open-source learning management systems. It is used at various levels of primary, secondary and higher education by pupils, students, teachers, and professors. It is used in more than 230 countries, and Serbian Moodle community is growing with 295 registered sites [20].

The key advantages of Moodle platform are good course organization, easy management of course materials, simplified communication between teachers and students through forums and discussion boards, extendibility, and support for electronic student assessment. Also, it offers better access control to the course content, as students usually need to enroll to the course. Several studies, such as Refs. [21,22], show user satisfaction with Moodle comparing to commercial alternatives, or offer advices with course development [23].

Student Assessment in Moodle

There are many distance education programs and online courses [24,25] on various universities, which rely completely on the use of Moodle. However, this paper focuses on traditional computer engineering courses, which use Moodle to improve examination process and course organization, and administration.

The most important module for student assessment is Moodle quiz. The module is suitable for knowledge assessment in massive courses through automated evaluation and correction. Quizzes are assembled from questions in a question bank. Questions are organized in categories. Also, Moodle supports random quiz assembly. Students can be divided into groups and different quizzes can be visible to different groups, which is a good feature to avoid cheating.

There are several types of questions available in Moodle. Multiple-choice questions are the most frequently used ones, while true/false questions, free response questions, matching, numerical questions, and short answers are also available. Moodle offers several variants of parameterized questions. For example, calculated questions use predefined set of values which are randomly chosen when the test is taken, and the result is calculated using given formula. This way the pool of available questions could be diversified.

In Ref. [26], authors compared computer-based assessment and paper-and-pencil testing in an undergraduate course of introductory computer programming, and claim that the programming abilities of the students are better evaluated using computer based assessment. Several studies, such as Refs. [27,28] report positive experiences with Moodle quizzes in mathematics courses for engineering degrees. The authors claim that Moodle quizzes are a consistent and reliable tool for electronic assessment, not

Table 1 Course Information

Category	Course			
	Computer networks	Computing fundamentals of the internet	Computer security	Algorithms and data structures
Study program	Undergraduate	Undergraduate/graduate	Undergraduate/graduate	Undergraduate
Semester	spring	autumn	spring	autumn
Year of study	II	III	IV	II
Number of hours per week during the semester (lectures+exercises+labs)	2 + 2 + 1	2 + 2 + 1	2 + 2 + 1	2 + 2 + 1
Theoretical part	90%	85%	85%	70%
Practical part	10%	15%	15%	30%
Laboratory using Moodle	■	■	■	■
Colloquia using Moodle	■	■	○	○
Final exam using Moodle	■	●	○	○
Percentage of LMS examination in final grade	100%	85%	15%	10%
Academic year of transition	2009/2010	2010/2011	2013/2014	2013/2014

■, completely; ●, largely; ○, not implemented.

only in the domain of mathematics, but in other disciplines, as well. There are numerous alternatives for student assessment in Moodle, especially in the computer engineering domain. Several Moodle extensions support automated scoring and assessment of programming assignments [29–31], or offer visualization of algorithms [32].

To the best of our knowledge, there are no comparable reports on research similar to ours in the open literature. The problem of transition from traditional to Moodle supported examining is mostly studied from the perspective of basic first year undergraduate courses, that is, programming courses. Our paper presents a comparative analysis of four different courses from senior study years in the computer engineering context.

Course Transition Experiences

Since e-learning tools are used mostly for managing a course, the method of use is similar regardless of the course that they are used at. However, depending on the type of activities that need to be done in a LMS, some differences may exist.

In Ref. [1], authors presented an undergraduate physics course that they implemented in the Moodle platform. They used LMS to provide course material, assign homework, discuss course topics through forums and chats, and assign quizzes. For quizzes they used true/false and multiple-choice questions.

Introduction of the Moodle platform in a first year medical physiology course was explained in Ref. [33]. The LMS was used for online communication via forums and chats, course material distribution, preparation of laboratory exercises, and quizzes. For quizzes they used multiple choice, true/false, matching, and filling in the blanks questions. Both studies claim several benefits of using LMS: easier course organization for teachers, more convenient communication between students and teachers, and better results at the exam for students who regularly used LMS during a semester.

User Satisfaction and Effects of LMS

Many studies examined the effects of LMS, and the satisfaction of teachers and students who use LMS. In Ref. [34], authors present a study based on a 2 years survey on use of a LMS. The conclusion is that both instructors and students agree that efficient communication enabled by a LMS is its largest benefit.

A critical examination of the effects of LMS on university teaching is presented in Ref. [35]. This study focused on educational issues regarding the use of a LMS. Some limitations of LMS are listed, like reliance on types of questions which can be automatically assessed. In Ref. [36], authors suggested a framework for introduction of LMS in a traditional course. They collected results of LMS usage for 3 years and claim that usage of LMS can improve the quality of learning for students.

E-Learning Tools From Our University

E-learning tools have been developed at the Department of Computer Engineering (DCE), UB-SEE for more than a decade. Since DCE offers massive courses, those tools have not been developed only for educational purposes, but also to ease course administration, student assessment, and grade reporting. Most of those tools were used in the domain of computer architecture. At first, only simulators were developed, but later more complex learning platforms were proposed in Refs. [5,6,8] to allow student

assessment, self-testing, and learning, and in Ref. [7], where authors proposed web-oriented system.

One of those systems, CASTLE [5], has been developed through several generations. It is mostly used during computer architecture laboratory exercises to test students at the beginning of the exercise. CASTLE test consists of multiple-choice questions, and it is time-limited. The system supports IP filtering and password protection of the tests. Students do not have to register to the system, as it enables LDAP authentication using student credentials from school information system.

COALA system [11] has been developed to teach cryptographic algorithms and it has been actively used together with Moodle LMS at CS course. A visual simulator with correction and assessment capabilities [10] has been implemented for ADS course. A student is able to play with various algorithms, and the simulator can track and evaluate his progress, and keep records. A visual interactive educational system for expert systems learning [12] is used at undergraduate and graduate courses. The system guides students through examples and step-by-step tasks related to topics presented during the lectures.

COURSE DESCRIPTIONS AND EXISTING PRACTICES

From 2003, most of the courses offered by DCE at UB-SEE have similar structure, as shown in Table 1 for CN, CFI, CS, and ADS courses. Course curricula are visible on the website of the UB-SEE, in the accreditation section, and all information are available in the school information system (SIS).

Lectures are given every week, and related course materials are posted at course website. Laboratory sessions are usually organized several times per semester, and usually last from 1 to 3 h, depending on the course. During laboratory sessions, students do various practical tasks guided by the teaching assistant or on their own. In some courses, they use simulators and write reports about observed behavior; in other courses they write code or use some tools. At the beginning, or during some laboratory sessions, students are assessed, either through paper tests, simple quizzes, or oral examination.

Course information are usually distributed using course websites and mailing lists. Most of the courses have their own websites, but no common infrastructure, or platform is provided. Instead, people use different, usually static HTML pages. Some teachers exclusively use mailing lists and their archives as repositories for course materials, information, etc.

Most of the course materials have open access to any visitor, but some teachers put materials in password-protected archives, and distribute passwords during the lectures, or using mailing lists. Course materials include, but are not limited to teaching slides and presentations, textbooks, scripts, e-books, homework assignments, examples of past exams, audio and video lectures. Websites contain different announcements, final grade reports, laboratory schedules, and similar information, usually not in a structured form.

Final exams are typically conducted in pencil-and-paper written form. The quantity of questions and tasks vary from course to course, but most of them have some kind of “coarse grain” examining, having larger tasks, and more ample questions. Most of them have 3–5 tasks and questions, and some of them have 5–10 questions, and smaller tasks in form of a test. Questions and tasks are mostly with open answers, rarely in closed form. Depending on the course, a student should give an answer with excerpt from

theory, solve numerical problem, write a piece of code, draw, and explain a picture, etc. Few exams are conducted using a computer, mostly those related to web design, internet programming, and programming mobile devices. Final grades are ranged from 5 (did not pass) to 10 (excellent). To pass the exam, student should collect more than 50 out of 100 points. To achieve final grade 10, student should collect more than 90 points.

Course administration and student grade management is usually done in several steps. UB-SEE has implemented an excellent school information system [37], to track student records and for global course management, but it does not tackle individual courses, except final grade submission. Instead, teachers usually download XLS/CSV files (worksheets) with enrolled students, and manage those worksheets locally during the semester. Maintaining the worksheets includes a lot of paperwork, among other: publishing schedules, mid-term results, manipulating with paper reports, etc. At the end of the semester, the sheets are again converted to format needed by SIS to submit final grades.

All described practices were good indicators that we need to move from traditional course organization to some LMS. All three of the authors, independently decided to move the whole course or part of their courses to Moodle LMS. Courses are moved to Moodle to different extent, as CN and CFI courses are completely moved to Moodle, and their former websites were shut down, while Moodle is partly used at CS and ADS courses, mostly to help with student assessment during laboratory exercises. In the following sections, we describe the rationale behind such a transition and give more details on each of aforementioned courses.

Computer Networks and Computing Fundamentals of the Internet Courses

CN and CFI courses include broad topics in the domain of computer networks covering protocols and technologies of the TCP/IP model. Both courses are part of our department in present form for less than a decade, and they are taught by relatively young teaching stuff, open to changes, and new technologies.

All teaching materials, slides in PDF format, lectures, exercises, and audio files that were posted at courses websites were transferred to Moodle, and former websites were shut down. Teaching materials are organized and structured according to weeks they are presented to students. Communication with students is moved to Moodle, as it has integrated forums and announcement areas.

Before the introduction of LMS, both courses had exams in written form, which consisted of three or four longer theoretical questions, and one or two practical tasks. Students wrote their answers in exam workbook. That format of examination did not cover all topics presented at the course, and students could pass the exam by learning only selected topics. On the other hand, correcting and scoring of those exams was time consuming for the teachers, so we decided to move from paper to electronic exams in Moodle. The old format of exam with longer questions and open answers was abandoned in favor of Moodle tests, with shorter questions that require knowledge of higher levels of details. Exam is split in two parts, one consisting of shorter questions from theory and the other one containing a bigger practical task with several smaller tasks. This bigger practical task is often related to the topology of computer networks, which is large to display on the computer screen, and instead students get the task on paper, but they enter their answers in Moodle.

Laboratory work has been also redesigned to include Moodle. During a laboratory exercise, students work with different computer network topologies, draw them in Packet Tracer or Graphic Network simulator, and respond to questions related to the simulation in Moodle. This organization of laboratory work simplified evaluation and tracking of student records.

Computer Security Course

CS course covers cryptographic algorithms and mechanisms used in computer, and network security. Moodle was introduced to CS course, as an aid during laboratory exercises. At the laboratory exercises, students follow the execution of cryptography algorithms and answer questions about them in a form of a report.

Introduction of Moodle platform required some changes to be done in examination process during laboratory exercises. Before Moodle was introduced to the course, students wrote their report on paper. The report itself consisted of answers to the questions related to the execution of specific algorithm. The questions and tasks required students to write down a specific value during the execution, fill in a table with observed values, draw and explain a picture, give an answer to a theoretical question about the algorithm, and write down some conclusions. Students' reports were later examined, and based on their answers, they earned points that were included in the final grade. The transformation of questions and tasks to electronic form supported by LMS was a challenging task.

Algorithms and Data Structures Course

ADS course covers important topics like linear and non-linear data structures (arrays, linked lists, trees, graphs, etc.), and corresponding algorithms. The course consists of written exam and practical work in laboratory. During the laboratory work, students present and defend their programming solutions from homework assignments. Each laboratory class was preceded by entry test done on paper, which consisted of simple theoretical questions covering knowledge necessary to solve homework assignments.

Moodle was introduced in the course to replace paper testing and improve examination process. Other course materials have been partially moved to Moodle. Those are mostly lecture notes, homework assignments, and announcements related to the course. We decided not to move all course materials, but opted only to add new, revised ones. ADS course has been taught for a long time, so there is significant "backlog" of obsolete materials. We have seen the transition to Moodle as a fresh start, and an opportunity to revise all course materials which is a process that needs time.

We used most of the time during the transition to Moodle to introduce electronic tests at the beginning of laboratory classes. Multiple-choice questions were prevalent in paper tests, but substantial part consisted of computational questions, free response questions, matching questions, questions that required drawing as a response, writing small portions of code, etc. All those questions required some degree of change in order to be incorporated in Moodle.

MOVING FROM PAPER TESTS TO ELECTRONIC EXAMS

In this section, we describe our experience with the transition from paper tests to Moodle quizzes. As described in previous section, all

four courses needed a transition to new type of examining. It was a challenging task, since we wanted to keep the balance of our tests and use existing question database, as much as possible, but on the other hand, we needed to change the way of examining to conform to Moodle. In CN and CFI courses, both exams and laboratory exercises were transferred to Moodle, while in CS and ADS courses only laboratory exercises were transferred, as shown in Table 1.

Three different types of transition, based on the type of paper tests and exams, were made:

- (1) Final exam—"coarse grain" theoretical questions and assignments—CN and CFI courses,
- (2) Test at the laboratory exercises—paper tests at the beginning of an exercise—ADS course,
- (3) Report at the laboratory exercises—questions about the exercise in the laboratory—CN, CFI, and CS courses.

Table 2 summarizes the transformations that were made in order to complete the three described transitions. In the column "traditional question type" a description of the type of question in paper test is given. For each traditional question type, one or more types of questions from Moodle, which were used for transformation, are represented in column "Moodle question type" in the table. The remaining columns denote if a transformation is applied for specific course.

Writing values from the simulator question (1) was used to make students write specific values while following the simulation at the laboratory exercise. This type of question was replaced directly with Short Answer type of question in Moodle.

Question that required drawing as an answer (2) was used to make students draw algorithm or algorithm iteration structure for an algorithm whose execution they were following. This type of question was replaced with one or more multiple choice type of question in Moodle. For example, the question "Draw the structure of DES algorithm for encryption," for which the answer was a drawing shown in Figure 1, was replaced with two multiple-choice questions presented in Figure 2. Another way to transform this type of question is to offer several diagrams in a multiple-choice question. In ADS course, questions related to insertion of a key with specific value in binary search tree were transformed this way. Instead of drawing a new picture with inserted key, four possible trees were offered as a response.

Question that required table as an answer (3) was used for two purposes. First, it was used to make students deduct permutation tables used in the algorithm from the simulator.

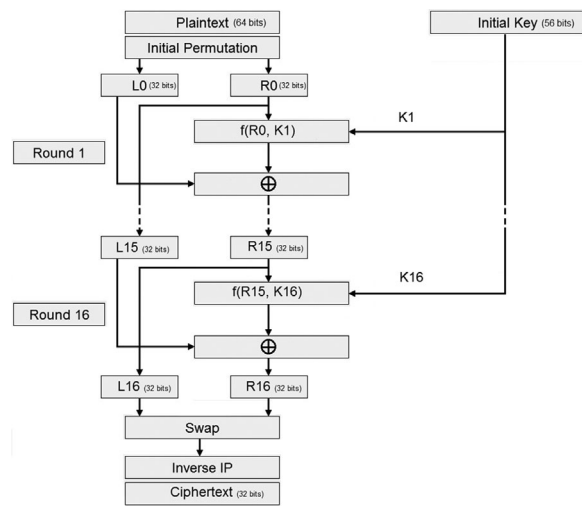


Figure 1 Answer to the question "Draw the structure of DES algorithm for encryption." before Moodle was used.

Second, it was used to make students note iteration keys and values after each iteration of the algorithm. This type of question was replaced with a true/false question for the first purpose. Students now see a table and they are asked whether or not it is the right table for some operation in the algorithm. For the second purpose the question is replaced by matching question, where they have to select appropriate value for iteration keys for all iterations in the algorithm.

Paper-test question type (3) was replaced either by true/false or multiple-choice questions. Usually when there is a conclusion to be drawn they are now offered with a statement, and need to say whether or not it is correct. For situations where they have to reproduce some knowledge from lectures they are offered a multiple-choice question.

Theoretical questions with free response (4) were transformed either as true/false or multiple-choice questions. In the first case, the statement related to the question was given and students should decide if it is true or false. For example, paper question: "What is the balance criteria of an AVL tree?" is transformed to statement: "In an AVL tree, the heights of the two child sub-trees of any node differ by at most one." The other way to transform theoretical question was to decompose it to several statements in multiple choice question with one or more correct answers.

Table 2 Transformations from Traditional to Moodle Question Types

Traditional question type	Moodle question type	CN	CFI	CS	ADS
(1) Writing values from the simulator	Short answer	+	+	+	
(2) Drawing as an answer	Multiple choice	+	+	+	+
(3) Table as an answer	True/false, Matching	+	+	+	+
(4) Theoretical with free response	True/false, Multiple choice	+	+	+	+
(5) Multiple choice	Multiple choice	+	+		+
(6) Piece of code as an answer	Multiple choice				+
(7) Fill-in the missing word	Multiple choice, True/false, Short answer				+
(8) Numerical result	Numerical, Calculated	+	+		+
(9) True/false	True/false	+	+		+
(10) Knowledge of terms/concepts	Matching	+		+	+
(11) Task without explanation	Short answer, Multiple choice, Matching, Numerical	+	+		
(12) Task with detailed explanation	Short answer, Multiple choice, Matching + Essay (with manual grading)		+		

Values of the following DES algorithm parameters are:

Choose one answer:

- ☐ a. Block size: 64 bits, Key size: 56 bits, Number of Iterations: 10.
- ☐ b. Block size: 56 bits, Key size: 56 bits, Number of Iterations: 16.
- ☐ c. Block size: 64 bits, Key size: 56 bits, Number of Iterations: 16.
- ☐ d. Block size: 64 bits, Key size: 64 bits, Number of Iterations: 16.

The following expression describes a DES algorithm iteration:

Choose one answer:

- ☐ a. $L_i = R_{i-1}; R_i = L_{i-1} \text{ xor } F(R_{i-1}, K_i).$
- ☐ b. $R_i = R_{i-1}; L_i = L_{i-1} \text{ xor } F(R_{i-1}, K_i).$
- ☐ c. $L_i = R_{i-1}; R_i = L_{i-1} \text{ xor } F(L_{i-1}, K_i).$
- ☐ d. $L_i = R_{i-1}; L_i = R_{i-1} \text{ xor } F(L_{i-1}, K_i).$

Figure 2 An example of transition from traditional question (type 2) to Moodle. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Depending on the importance of the concept in the question, one of those approaches was taken.

Multiple-choice (5) and true/false (9) questions are more or less straightforwardly transferred to Moodle. Multiple-choice questions usually consist of 4–6 answers. In some cases, one question from paper tests was transformed to two or three questions with the same topic, but different answers. For example, in one question, one of the available answers would contain a correct statement, but in other question, that statement would be negated to be incorrect. If multiple-choice questions have more than one correct answer, we penalized incorrect answers with 20% of total points for that question to avoid randomly chosen answers by the students.

Since we mainly wanted to avoid manual evaluation of responses, we needed to transform questions that required piece of code (6) as an answer to multiple-choice questions. We took two approaches. The first approach was taken if the answer consisted of few lines of code. For those questions, we prepared and offered four slightly different pieces of code. If the request code was longer, we usually gave the skeleton of the code to the student, and asked to fill-in the missing part from one of the offered answers.

Questions that required to fill-in the missing word (7) were replaced with multiple-choice, true/false questions, and short answers. For example, the question: “Write down the time complexity of unsuccessful search in an unordered array” was replaced with multiple-choice question with six answers: “(1) $O(n)$, (2) $O(n/2)$, (3) $\log(N)$, (4) $O(n \log n)$, (5) $O(n^2)$, (6) $O(1)$.”

Questions with numerical results (8) were mostly used in ADS course to test knowledge on various numerical characteristics of arrays, trees, and graphs like order of the tree, degree of a specific vertex in a graph, etc. Those questions were directly replaced with numerical questions in Moodle. Usually a picture of example tree or graph is used, and students should calculate the asked value: “For the given tree, calculate the number of external leafs.” Some of those questions were even expanded in Moodle with parameterized, calculated questions. Row- or column-wise linearization of a matrix is a good example, as questions with fixed

values were parameterized with a set of values: “Given row-wise linearized matrix $M[3 \times 5]$ stored in memory from address {adr}, calculate the address of element $M[\{x\}, \{y\}]$. One element is stored in one memory word and row and column indices start from 0.” In this type of question, {adr}, {x}, {y} are randomly replaced with values from a predefined dataset consisting of several combinations, and the result is calculated based on address function for a given matrix:

$$\text{address} = \{\text{adr}\} + \{x\} * 5 + \{y\}.$$

Paper-test questions type (10) refers to the knowledge of the basic concepts and terms in some field. For example, the theoretical paper-test question “Define protocols for each of the seven levels of the OSI (Open Systems Interconnection) model” is transformed to the matching question, as shown in Figure 3, where a specific protocol should be linked to the OSI level to which it belongs, or vice versa.

The tasks on paper exams, in courses CN and CFI, were supposed to be adapted to the new format of electronic colloquium, and exam. Task without explanation (11) is divided into several shorter questions of different Moodle formats: short answer, single/multiple choice, numerical, and matching. Figure 4 shows the task with the Spanning Tree Protocol given on the paper exam, namely partitioning of network address space and/or routing protocols. Students had to write gradually every step while solving the task, to explain them, and to draw final path on the figure.

Similarly, task with detailed explanation (12) can be transformed. The only difference is that the teacher can ask students about textual explanation, similar to discussion of a solution in paper workbooks on paper exams. For this purpose, the teacher can use an essay as the type of question in Moodle LMS. Since students can give various solutions, it is necessary to review, and grade this question manually.

Testing these specific tasks (11 and 12) in Moodle LMS required the use of several different types of questions. Several examples of paper-exam questions transformations for these types of questions are shown in Table 3.

Pair the following terms:

UDP	Transport (Layer 4) ▼
IP	Network (Layer 3) ▼
Ethernet	Choose... ▼
Internet Explorer	Choose... ▼
Optical Fiber	Choose... ▼
IEEE 802.3/802.2	Choose... ▼

Choose... ▼

- Data link (Layer 2)
- Transport (Layer 4)
- Physical (Layer 1)
- Network (Layer 3)
- Application (Layer 7)

Figure 3 Example: pairing concepts in CN replaced the paper test question that required the description of levels in the OSI model. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

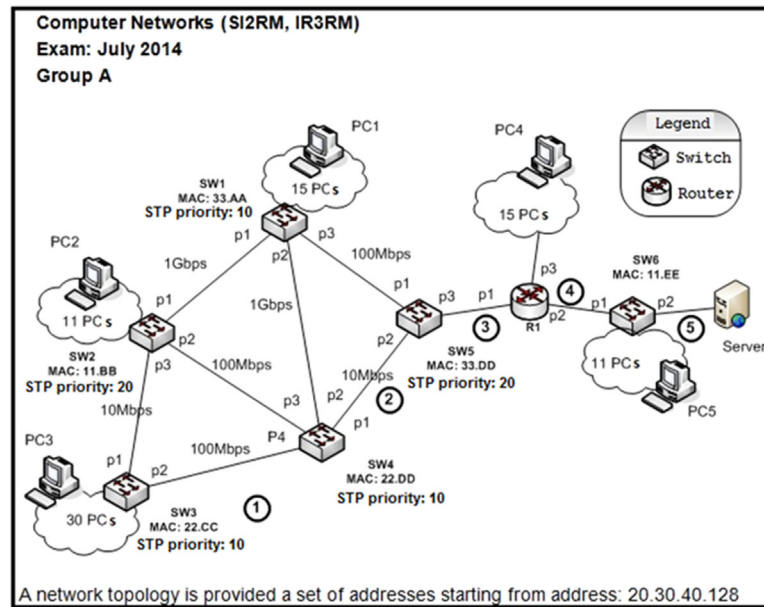


Figure 4 The traditional task for the CN course that became the task with short questions. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

EVALUATION AND DISCUSSION

This section presents course statistics before and after introduction of Moodle. Our goal was to demonstrate that the introduction of Moodle did not impair the previous course statistics, since during the transition to electronic exams we focused on maintenance of examination quality. In the end, we discuss benefits and drawbacks of transition to electronic exams that we observed.

Course Statistics

Table 4 shows several statistical parameters that were measured before the introduction of Moodle (BMI), and after the introduction of Moodle (AMI) at all four courses. In the first row the number of students (NoS) and the pass rate (PR) for the academic year BMI are given. NoS at our courses is between 69 and 107, and PR is between 68.47% and 79.31% in this case. The second row shows NoS and PR for the academic year, AMI for CS and ADS courses, and average NoS and PR for academic years AMI (since there are more than one). NoS at our courses is between 58 and 162, and PR is between 65.43% and 84.3 % in this case. By comparing these two rows we can see that the NoS at our courses in both cases is not negligible. Second observation is that

PR basically remained on the same level as before (in three cases it got slightly higher and in one case slightly lower). This is consistent with our initial hypothesis that the introduction of Moodle would not impair previous statistics. The remaining two rows in Table 4 show Spearman's rank correlation between the points won on laboratory exercises and the final grade for the academic year BMI, and the academic year AMI, respectively. Since CS and ADS are partly moved to Moodle, we analyzed this correlation in order to observe the significance of the activities that were transitioned to electronic examination. The results from Table 4 show that the association between those two variables could be considered statistically significant. It can be observed that the introduction of electronic examination did not change correlation of points won on laboratory exercises, and final grade. Before introduction of Moodle, CN and CFI courses had optional, demonstrative laboratory exercise, and that is the reason why we could not conduct rank correlation analysis for that period.

Since CN and CFI courses are completely moved to Moodle, first we discuss the success rate and observations related to those courses. Table 5 shows the difference in the duration of colloquia and exams in the last school year, when the exam was done on paper and in the last school year, when the exam was organized using LMS, as in the previous 5 years. The duration of the exam

Table 3 Transformations From Paper Exam Task to Moodle Question Types

Part of paper exam task	Moodle type of questions
[STP—choose root bridge] Which switch will become the root bridge at STP, in the shown network topology?	Single choice question
[STP—branches] Which branches belong to STP tree?	Multiple choice question
[STP—interfaces] Indicate status of individual ports: (a) SW4.p1; (b) SW4.p2; (c) SW4.p3; (d) SW4.p4;	Matching question
[STP—choose path] Which path is transmitted frame from PC1 to PC3? Which path will be transmitted frame, if the connection between SW3 and SW4 disconnect?	Short answer
[Network layer] What is the last assigned network address in the network with PC5?	Short answer
[Network layer] How many host IP address is available in this network?	Numerical
[Routing] How many broadcast domains has this network?	Numerical
[Routing] Which router port or ports appear as the next-hop for the LAN-x network in the routing table Router Rn?	Multiple choice question or short answer

Table 4 Course Statistics

Category	Course			
	Computer networks	Computing fundamentals of the internet	Computer security	Algorithms and data structures
Number of students/pass rate [*]	104/79.31%	107/72.89%	69/78.26%	92/68.47%
Number of students/pass rate ^{**}	112 (avg)/84.3%	97 (avg)/78.56%	58/79.31%	162/65.43%
Spearman R/two-tailed p [*]	N/A	N/A	0.56542/4.14e ⁻⁰⁷	0.76276/3.73e ⁻¹³
Spearman R/two-tailed p ^{**}	0.43405/0.00031	0.63385/1.44e ⁻⁰⁸	0.61441/2.89e ⁻⁰⁷	0.78668/4.90e ⁻²²

^{*}For academic year before the introduction of Moodle.

^{**}For academic year(s) after the introduction of Moodle.

was reduced by a third. Prior to introducing the Moodle platform, the course CN included one laboratory exercise, which had a demonstrative character and did not carry points, as shown in Table 6. Students have often avoided optional exercises. With the introduction of Moodle in course CN, the course included two laboratory exercises in which students can achieve points. Three laboratory exercises were introduced at the CFI course, since the 2010/2011 school year. Each laboratory exercise carries a maximum of 5 points, that is, total of 10 or 15 points in the final grade, depending on courses. The remaining points are distributed on two colloquia and final exam. The structure of points on these courses and relations between the theoretical part, assignments and laboratory exercises, through school years (one BMI and three AMI), are given in the Table 6.

At the CN course, a student can win 90 points through two colloquia during the semester and final exam, and 10 points through laboratory exercises. In 2008/2009 school year, 62% of students in the group took part in demonstrative laboratory exercise. The change in the course increased the motivation of students and their attendance of laboratory exercises (in the last 5 years in the range of 91–95.8%), and the final results are unimpaired, as shown in Table 6. Similar blended learning approach is presented in Ref. [38]. The authors claim that e-learning resources are very useful in the learning process for course in the field of computer networks and protocols.

At the CS course a total of 15 points for the exam can be achieved at the laboratory exercises, as shown in the Table 1, and it cannot be compensated at the exam. This was the same BMI and AMI.

Figure 5 shows the percentage of students who scored 15, 14, 13, 12, 11, and 10 points out of 15 at the laboratory exercises at CS course in 2 consecutive school years: 2012/2013 and 2013/2014, BMI and AMI, respectively. Only students who have not completed all laboratory exercises scored lower than 10 points, and the percentage of these students dropped from 10.4% to 8.3% AMI. This figure shows that the percentage of students who score maximum number of points have risen from 36.2% to 43.75% AMI.

Table 7 shows some statistical parameters about CS course laboratory exercises in 2 consecutive school years: 2012/2013 and 2013/2014, BMI and AMI, respectively. We can see from the table that the average number of points won at the laboratory exercises is as good as before and even slightly better AMI, which shows that students adapted to the new way of examination with no trouble at all. The obvious improvement after the introduction of Moodle is the duration of laboratory exercises. Before Moodle was introduced into the course, all students had up to 135 min to complete the exercise, and most of them used the entire session. Moodle enabled teachers to track time needed to complete the exercise for each student individually, so we could observe the duration of a laboratory exercise more precisely. After introduction of Moodle, the test was limited to 120 min, but all students completed the test in less time, as it can be seen in the table. Therefore, the introduction of Moodle fulfilled its goal.

The primary motivation to introduce Moodle to ADS course was to improve student assessment at the beginning of laboratory exercises, and ease the burden of manual evaluation and scoring for teachers. There are three laboratory exercises at ADS course and students can take up to 10% of the final grade by taking the entry tests. Before introduction of Moodle, about 70% of enrolled students took the tests, as they considered them “non-beneficial” for their final grade success. Due to complex formula for calculation of the final grade, students could “bypass” those tests, as they participated in the final grade less than 5%. We changed the formula to more straightforward one in 2013/2014 school year, so those tests account 10% of the final grade. After the adoption of electronic examining and a change in formula, that percentage raised to 81% as students found electronic assessment much more interesting and challenging. Total time for both paper and electronic examining remained 20 min, but students suggested that they had more time to think and answer the questions in Moodle quizzes than in paper tests.

Figure 6 shows distribution of points for students at entry tests in 2 consecutive school years at ADS course, before and after the introduction of Moodle, and electronic examining. As it can be seen, the percentage of students who won less than 50 points

Table 5 Duration of Pre-Examination and Examination Commitments for Courses CN and CFI

School year	CN 2008/2009 (paper exam)	CFI 2009/2010 (paper exam)	CN 2014/2015 (Moodle LMS)	CFI 2014/2015 (Moodle LMS)
Duration of colloquium 1	60 min	60 min	45 min	45 min
Duration of colloquium 2	60 min	60 min	45 min	45 min
Duration of final exam	120 min	150 min	90 min	120 min
Number of lab. exercises	1 demo. lab	No labs	1 demo. lab + 2 labs for points	3 labs for points

Table 6 Statistics for Courses Computer Networks and Computing Fundamentals of the Internet

Category	Course	School year			
		CN: 2008/2009 CFI: 2009/2010 (paper exam)	2012/2013 (Moodle LMS)	2013/2014 (Moodle LMS)	2014/2015 (Moodle LMS)
Num of students	CN	104	102	104	131
	CFI	107	84	105	109
Avg points on lab (max 5 points)	CN	/	4.62	4.71	4.82
	CFI	/	3.98	3.94	4.13
Avg points on final exam (including labs, max 100 points)	CN	70.81	70.39	74.91	74.44
	CFI	71.64	72.61	70.92	75.50
Structure of exam (shown in points or range of points)	CN	TQ: 60–70	TQ: 60	TQ: 60	TQ: 60
		PA: 30–40	PA: 30	PA: 30	PA: 30
		L: /	L: 10	L: 10	L: 10
	CFI	TQ: 60–80	TQ: 60	TQ: 55	TQ: 55
		PA: 20–40	PA: 25	PA: 30	PA: 30
		L: /	L: 15	L: 15	L: 15
Exam pass rate	CN	79.31%	82.4%	94.2%	87.8%
	CFI	72.89%	82.14%	81.91%	88.99%

TQ,theoretical questions; PA,practical assignments; L,laboratory exercises.

significantly dropped, while points are more or less uniformly distributed between 50 and 90 points. Table 8 shows that the average number of points has risen around 20%.

We think that students adopted the new platform seamlessly, and that overall success is higher than before, although we used more or less similar question database. In the new pool of questions, we were able to include about two thirds of old questions, and we had to create about one third of completely new ones. From the teaching perspective, Moodle offered us flexibility to create parameterized questions which diversified our pool of questions and decreased the possibility of cheating. Also, Moodle significantly reduced the time for test evaluation, and result management. Similar approach to ours in ADS course was taken in Ref. [24], but we managed to use much broader set of question types, rather than multiple-choice question, short text, and similar.

Benefits and Drawbacks

We can see that the introduction of Moodle to our courses brought several benefits for both students and teachers. Teachers benefited by easier course administration and scoring of laboratory exercises

and exams, but had an initial overhead for transition process. Students benefited by more efficient way of doing laboratory exercises (e.g., no writing on paper, obtaining the results instantaneously, etc.), while their results at the laboratory exercises and exams were unimpaired. After the introduction of Moodle, less time is needed for all students to complete a laboratory exercise. This means that students have more time to pay attention to the material and use less time for answering the questions.

We have noticed that students were enthusiastic about the laboratory exercises after the introduction of Moodle. This observation is consistent with the findings in the literature [28,33]. As we stated earlier, the percentage of students who completed all exercises is higher than before. In the official course survey, which is conducted among students at the end of each semester for each course, there were many positive comments about the new way of examining using Moodle. For CS course a separate survey regarding students' satisfaction with the laboratory exercises was conducted [11]. Before Moodle was used, students complained that they do not have enough time to complete the exercise and that they use too much time to write down their answers. The overall satisfaction with the laboratory exercises received average score

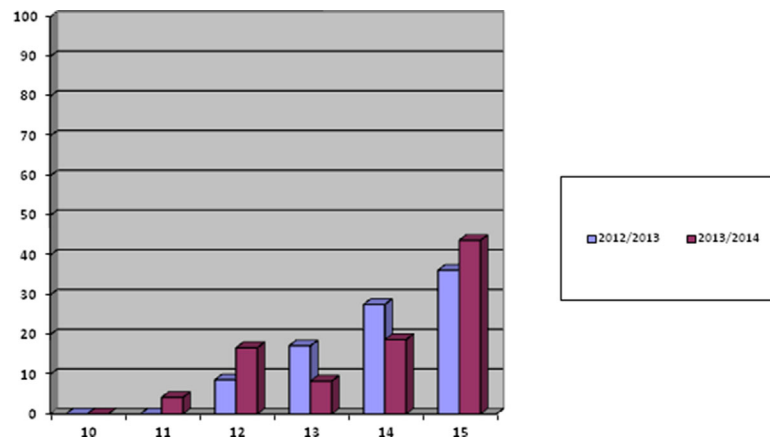


Figure 5 Success of students at the laboratory exercises at CS course in 2 consecutive years. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Table 7 Laboratory Exercises at CS Course Statistics

School year	2012/2013	2013/2014
Number of students at the laboratory exercises	58	48
Average number of points won	13.37	13.46
Duration of exercise 1	135 min	92 min
Duration of exercise 2	135 min	98 min
Duration of exercise 3	135 min	72 min

3.7 out of 5. After the introduction of Moodle, there were no complaints about the examination process and the overall satisfaction with the laboratory exercises average score increased to 4.67 out of 5.

During the transition process, we had some concerns regarding quality of examination. Designing questions for electronic exams is challenging, especially when creating non-objective questions and questions to measure students' in-depth understanding [39], or creativity. Initially, teachers need to put significant effort to move to electronic examining, but in the following years they can spend more time improving the quality of the questions. Moodle offers various quiz statistics to help with this task. In our courses, the results at the laboratory exercises and exams are unimpaired, so we think that we preserved the quality of examination. Creativity is preserved in CS and ADS courses through other forms of examination (homework assignments, written final exams), since they are not completely moved to Moodle. In CN and CFI courses, free response questions with manual grading are used as a part of the exam to assess creative thinking. For example, to assess student knowledge on collaboration of different routing protocols, free response questions in CFI course comprise 15% of the grade.

Our experience with Moodle was mostly positive, but we also encountered some difficulties during its exploitation. Those were mostly related to security and reliability of the system. In our own practice, we found that these drawbacks severely hamper usability of the system. Similar opinion is observed in Ref. [40]. System downfalls and problems with enrollment affects teacher's time in a negative way. Instead of concentrating on quality issues (course materials, examining), teacher spends time on course administration. Similarly, security issues such as possible intrusions undermine the credibility of examination process.

Table 8 ADS Course Statistics After Introduction of Moodle

School year	2012/2013	2013/2014
Number of students that took the tests	65	132
Average number of points won	44.26	55.98
Average grade	8.03	8.18

During CFI exam, we encountered an intrusion to the system. Although we used IP filtering to restrict the access to the test only from certain subset of IP addresses, one of the students managed to tunnel to one of our servers and login to the system from outside. He tried to take the exam, but teaching staff noticed that number of students in the laboratory did not match the number of students who took the exam, and blocked the assault. Teachers identified the student and the method of attack, by inspection of Moodle and server logs. On several occasions, we had technical difficulties with massive simultaneous access to Moodle server, which caused its downfall, and subsequently we could not carry on with the activities. Some of those reliability problems were related to hardware faults, but others were related to Moodle itself. In one of those cases, more than 400 students from various departments were active in the system.

We had some issues with students' registration and enrollment to the course in Moodle. Students should enroll to the course by themselves, and there is no simple way to create new users and enroll them to the course by the course administrators. We needed a way to import information about students enrolled to the course from our SIS, and control the enrollment. Although LDAP authentication is possible, it is not easy to set up, which is why, we asked the students to enroll to the course manually with a passphrase distributed through the course mailing lists. As a security measure, students had to register to Moodle with their student e-mail address. We approved every subscription manually, which was the process that consumed significant amount of time.

CONCLUSION

In this paper, we have presented our experience with Moodle LMS at four different courses in computer engineering domain. We described the existing practices at our courses and most courses at

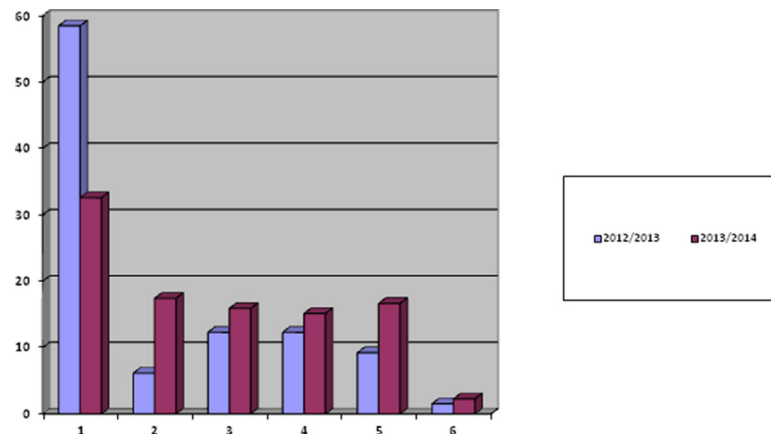


Figure 6 Success of students at the laboratory exercises at the ADS course in 2 consecutive years (1, less than 50 points; 2, between 50 and 60 points; 3, between 60 and 70 points; 4, between 70 and 80 points; 5, between 80 and 90 points; 6, more than 90 points). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

DCE, UB-SEE, and explained the motivation behind LMS introduction. Then, we have analyzed the experiences of others, published in the open literature, with use of LMS at university courses. Moodle LMS was selected, as it is flexible, open-source solution, widely available, and easy to use.

Our courses were moved to Moodle to different extent, and we spent most of the time on transition from paper tests to Moodle quizzes. It was not an easy task, as we needed to transform different types of questions and tasks to types of questions available in Moodle. In the paper, we described the transformations that were necessary in order to move laboratory exercises and exams to electronic examining. Finally, we evaluated the effects of Moodle introduction to our courses. We have shown that Moodle met our expectations, as both students and teachers benefited from its introduction.

In the future, we plan to work on the integration of Moodle and our school information system in terms of user authentication, and exchange of data. That step would significantly increase the usability of the system, as it would add interoperability between those systems, and ease student enrollment and final grade submission. Also, we recognized the need to set up our own Moodle server in order to avoid reliability issues. On the other hand, we would like to conduct a survey among students and potential employers to assess their satisfaction with the system, and electronic examining.

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