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DEVELOPMENT OF AN E-EXERCISES APPLICATION FOR AN INTRODUCTORY STATISTICS COURSE AT UNIVERSITY LEVEL

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Abstract

This study describes the development and content of an e-exercises application for an introductory statistics course targeted at bachelor students of a business school. The course is offered in blended-learning format. The development was based on success factors in blended learning and it involved the customization of an already existing software to specific educational needs. The primary goal was to enhance learning by offering a web-based and easy-to-use exercises environment that gives students an opportunity to work at their own pace and to receive instant feedback. The purpose was also to lighten the workload of an instructor with large number of students on the course and to provide learning analytics data for teaching development and research purposes. The course instructor designed and coded the application using a learning environment with already existing features of course setup and maintenance (ViLLE). Exercises included probability theory and statistical inference. The application allowed for personalization of assignments and the system was set to be simulation-based with random starting values for each student. Statistical inference exercises included phases of verbal multiple-choice questions. This enabled interpretation of numeric results of hypothesis testing and confidence interval estimation, which simulated real-world statistical decision-making. A survey (n = 98) showed that the students were satisfied with the application. The large majority of respondents (more than 80%) considered the application to be simple, easy to navigate with and overall, a successful system. A majority of students saw the system as a good way to promote independent working. The system is currently in use in Turku School of Economics, Finland and approximately 400 students use it every year.

Keywords: *e-Learning, software development, higher education.*

1. Introduction

The use of educational software has spread rapidly during the past few years as the digitalization of society has intensified due to the COVID-19 pandemic. Universities all over the world promote studies independent of place and time, supported by the availability of a multitude of devices that enable both learners and instructors to exploit the possibilities of digitalization (Basak et al 2018). Digitalization has also profoundly changed the methods of interaction and working (Kurvinen et al 2020).

This article describes the development of an e-Exercises application for an introductory statistics course targeted at bachelor students at a business school. The application was introduced within the context of a massive blended course, and developed following software development life-cycle phases of planning and analysis, design with implementation and maintenance (see e.g., Davis, Bersoff & Comer 1988 for a review of such models). The development work aimed, firstly, to enhance learning by offering an easy-to-use environment that gives students an opportunity to work at their own pace and to receive instant feedback. Secondly, the purpose was to lighten the workload of an instructor, and to provide learning analytics data. The organization of the article is as follows: We first discuss the critical success factors which are the basis of the development process of the application. Secondly, we discuss content of the system with feedback received from the students. We conclude by acknowledging the challenges of the development and the need for an ongoing development process.

2. Success factors in blended learning

Blended or hybrid learning is a pedagogical approach that combines face-to-face and online teaching with the aim of enhancing the effectiveness of learning (Hockly 2018). Prior literature suggests that hybrid courses are more student-centred, promote active learning and student collaboration, and

increase student interaction with course content. The blended format is seen as supporting different learning styles by offering instructional material in diverse formats, and allowing students to work at their own pace with the online material. Hybrid courses add flexibility to students' schedules by allowing them to control when and where they work during the online part of a course (Marquis & Ghosh 2017; Bokolo et al 2022; Min & Yu 2023). However, as the number of face-to-face lessons is reduced with the insertion of online segments, negative effects caused by reduced social interaction and collaborative learning, are possible (Jazayeri & Li 2021). From the instructor's point of view, the blended format offers several advantages, such as improved availability of teaching material, convenience of communication and flexibility of homework distribution. However, the creation of suitable online elements combined with a larger number of students may increase instructor workload (Haughton & Kelly, 2015; Jazayeri & Li, 2021).

Min and Yu (2023) reviewed critical success factors for blended learning and identified six categories of factors (learner, instructor, course, design, technology and environment). These factors provide a general framework for our discussion on the development of an e-Exercise application. The critical success factors pertaining to learners include their learning speed, commitment, attitude, motivation, cognition, computer efficacy and experience (Min & Yu 2023). Instructors' substantive knowledge, pedagogical characteristics, course management skills, knowledge of computer systems and instructional implementation of technology have been identified as critical in blended learning (Ozkan & Koseler 2009; Min & Yu 2023).

The course-related success factors include course objectives, content and materials, course design, assessment and grading. As students on introductory statistics courses have to deal with subject information that is often novel and complex, it is recommended that the online learning environment and materials are designed to minimize extraneous cognitive load caused by the way information is presented and what students are required to do (Sweller et al 2019; Flores et al. 2023).

The critical pedagogical features of a blended course relate to design, such as the clarity of the learning objectives, teaching methods and learning strategies (Min & Yu 2023). Collaborative and active learning approaches, using real data that are directly relevant to students' fields of interest, solving genuine research problems and analyzing data from real studies have been proposed as means to engage and motivate students with statistics (Bromage et al., 2022).

The technology-related critical success factors cover the ICT system available and its accessibility, ease of use, quality, reliability, efficiency and privacy, as well as on information and the use of software. A related, but distinct category in Min and Yu's conceptualization is environment, which refers to the learning environment and learning management system adopted. The central features of the learning management system in a blended course are interactivity, diversity in assessment and evaluation methods, accessibility, ease of navigation and other features facilitating its use (Sun et al., 2008; Min & Yu 2023). Hence, issues such as the availability of statistical software and their suitability for building learning activities, and students' access to the software and computing resources needed for completing statistics assignments are at stake here (Biehler 1997; Bromage et al. 2022; Flores et al. 2023).

3. The development of the application

We begin by noting that the development of the application involved the customization of an already existing software to specific educational needs (Tchounikine 2011). A web-based learning environment, ViLLE (VisuaL Learning Environment), developed by the Department of Information Technology of the University of Turku, Finland, was readily available. ViLLE is an exercise-based learning environment, designed along constructivist views of learning (Laakso, Kaila & Rajala 2018).

A critical question to address when designing and considering the adoption of educational software is whether the new setting is expected to enhance learning. In this respect, the ViLLE environment offered several important features that could be incorporated in the application to bring added value to the blended course and to satisfy user requirements. Firstly, the automatic assessment of submissions with instant feedback in a massive course was possible. From the students' viewpoint, these features added time and place flexibility as the submission of assignments and receiving feedback is no longer tied to the weekly schedule of the course. The instant feedback provided by the application not only notifies whether submissions are correct or not, but also provides additional feedback on how the correct solution could be reached. Additionally, as students can retake assignments as many times as they want, they can study at their own pace. The number of points earned gave students information on their learning levels.

A very important value-adding feature of the ViLLE environment is its adaptability, i.e., an instructor can code and update the system as well as create exercises to account for changes in course content or teaching. The exercise code can be embedded into ViLLE user interface (exercise set-up, evaluation and feedback). Multiple sections can be used, for example, for mathematical calculations and verbal interpretations based on numeric results.

The application, hence, allowed for the personalization of assignments, i.e. the system could be set to be simulation-based with random starting values for an exercise. This feature also counteracts the problems of free-riding efficiently, making course management easier. At the same time, the application makes it possible to design similar exercise "stories" to enable teamwork and account for the social dimension of learning. From the instructor's perspective, these features enable the automation of working processes, leading to a lighter workload and freeing up time for other activities.

Many features of the application that relate to the technological and environmental factors in Min and Yu's (2023) framework were already implemented in the current system. The current system runs on a standard web browser with no additional plug-ins required, is device independent and an easy-access system. These features were set to be implemented in the new system as well. Ease of access means that students are able to log in using their own usernames and passwords to the university network without additional login information. Simple user interface entails that the new system can be utilized without any commands, but is menu-driven with a structure similar to the course.

The system's method for answering is either a numeric answer to an exercise or a choice out of several alternatives. The latter is the method in the final exam. Therefore, this helps students familiarize themselves with the method used in the final exam. Preparing for the exam is naturally the most important outcome of exercises from the students' perspective.

Four types of e-Exercises were set up in the application:

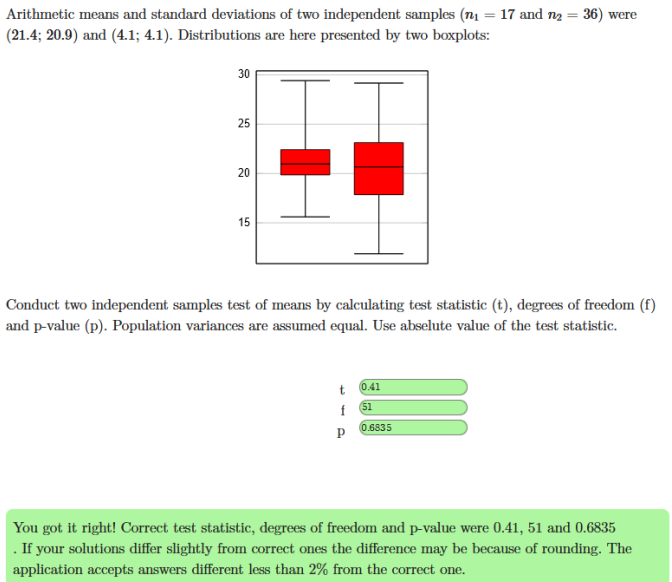
- Numeric: Random parameter value and/or data was generated. User-input and system-defined numeric answers are automatically compared (≤2% difference is allowed).
- Numeric: Random parameter value and/or data is generated, selection out of four numeric alternatives, one correct choice.
- Verbal: questions of substance, selection out of four alternatives, one fixed correct choice.
- Numeric and verbal: Exercise has two phases. First, numeric results are calculated and evaluated similar to items 1) or 2). In the second phase, the correct choice from several alternatives is defined based on numeric results.

4. Results and discussion

The e-Exercise application was developed within the context of an introductory statistics course given at Turku School of Economics, Finland. The course is a compulsory, three-credit undergraduate course, lasting for six weeks and given in Finnish. It is usually taken during the second year of studies, and approximately 400 students attend annually. Students have different major subjects (accounting and finance, marketing, business management, information systems science, etc.) or none yet. The course is a recommended prerequisite for an advanced-level statistics course in the curriculum.

The main level user interface of the system was built with the blocks corresponding to the six weeks of teaching in the course. Figure 1 (translated from Finnish) gives an example of two independent samples test of mean. In this example, the user gave correct answers, which are indicated by the green feedback colour together with a positive feedback text.

Figure. 1. Example of a Problem Solution (Math).



In Figure 2a (translated from Finnish), first a false choice was selected. The correct choice was defined by numeric results presented in Figure 1. In this case, the null hypothesis was accepted because the p-value was greater than 0.05 (see Figure 2b).

Figure 2a. Example of a Problem Solution (Verbal), false choice.

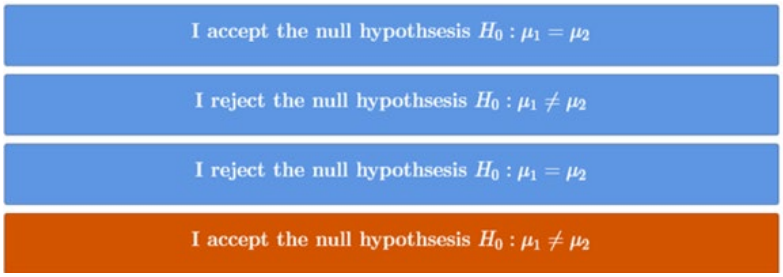
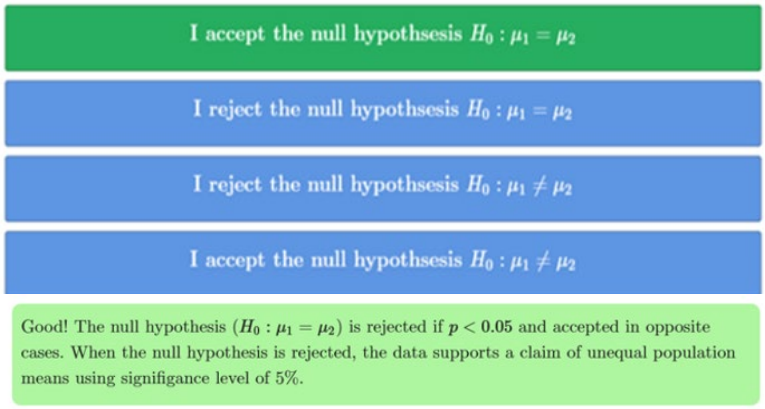


Figure 2b. Example of a Problem Solution (Verbal), correct choice.



A brief survey (n = 98) was conducted in spring 2024, and the results showed that the students were quite satisfied with the application (named as eTKMY3). In the survey, the statements were assessed using a psychometric scale of "Strongly agree", "Somewhat agree", "Neither agree nor disagree", "Somewhat disagree" or "Strongly disagree". The majority of respondents (80.6% and 87.0%) disagreed (strongly or somewhat) with the statements "Starting eTKMY3 was difficult" and "eTKMY3 was complex". Again, more than 80% of the students either agreed or strongly agreed with "eTKMY3 is a successful system", "I can manage my studying and exercises easily", "Navigation was easy". Interestingly, most considered individual starting values of most exercises as a good way to promote independent working (61.3% agreed with the statement somewhat or strongly). From the instructor's point of view, the weekly workload was lightened by several hours because the system gave students automated and instant feedback.

The limitation of the study is concentration on student experiences only. The analysis of eTKMY3's effect on course outcome (grade) requires different type of data which is to be collected in 2025. The data to be collected includes information on attitudes on statistics, course experience together with students' background. What comes to the limitations of the system itself a further question pertains to the lifespan of the ViLLE system, as the application developed is dependent on the maintenance of the system. What will happen to the coded applications after ViLLE is not supported is not clear. However, since ViLLE is currently maintained and supported by the University of Turku, and has more than 100,000 active users, it is unlikely that the lifespan of the system would end anytime soon. Another issue are the challenges created by the limited flexibility of the environment. For example, if a student gives a false answer, the application gives only one fixed type of feedback instead of allowing for different types of feedback after each false answer. On the other hand, because ViLLE is a ready-made environment, several functions supporting course management and implementation already existed.

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