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# Applied Problems and Use of Technology in Basic Courses in Probability and Statistics – A Way to Enhance Understanding and Increase Motivation

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## Abstract

Several authors have reported problems on service courses in basic probability and statistics: students may lack motivation, find the theory difficult or boring, others see no applications for the results. To remedy these problems we have developed a learning environment where two important components are applied problems and use of technology. However, the mere existence of applied problems and technology in the course does not automatically imply increased motivation or enhanced learning. Technology is helpful for the students if it is used to achieve learning goals, is integrated with the needs of the students and is aligned with the rest of the course. Real-life data and problems evoke interest if the students perceive they benefit from the task. We give two examples, one where active work with applied exercises and projects give a more positive attitude towards the subject, the other example shows that aligned web-based test and exercises increase the result on the final exam and also indicate a better conceptual understanding.

## Introduction

Most engineering students have a compulsory course in basic probability and statistics; for some students, it is their single course on the subject. Petocz and Reid (2005) reported problems on these service courses: students may lack motivation, find the theory difficult or boring, others see no applications for the results. At the department of mathematical statistics at Lund Institute of Technology (LTH), we have during several years developed course material and an active learning environment in order to reduce these problems. Two important components in this setting are applied problems and use of technology in various ways.

Neumann et al. (2012) report of how important it is for students' motivation to work with real-life data. Believing that motivated students are better learners than unmotivated, we have developed applied exercises and projects for different groups of engineering students, Zetterqvist (2010). However, presenting applied problems in the course does not automatically increase motivation, it is *how* the students work with real-life data that is important. According to Biggs and Tang (2011) students are motivated if they perceive their task reasonable and beneficiary in some way. It may be that they find the task helpful for understanding the theory, for the exam, or for future working life.

Mathematics software has been used for decades in probability and statistics education in order to analyse and visualise data and for simulation and illustration. Nowadays, many courses (including ours) also include several other uses of technology. Some examples are video clips presenting theory and solutions to exercises, web-based exercises and tests or "applets" where the students are able to interactively explore the theory. Chance et al. (2007) give an overview of the role of technology in improving student learning in statistics. But using technology does not automatically mean an enhanced student learning. Price and Kirkwood (2011) argue that technology is helpful for the students if it is used to achieve learning goals, is integrated with the needs of the students and is aligned with the rest of the course.

Here we present two examples where problems with low motivation, slow starters and misconceptions where reduced by using applications and technology in an aligned way. The methods of investigation are presented in next chapter. For each example we present the problem, our action and the results of our investigation. Our experiences are that active work with applied exercises and projects give a more positive attitude towards the subject. Investigations also showed that the introduction of web-based test increases the result on the final exam and also indicates a better conceptual understanding.

## Method of Investigation

How do we know that one group of students have an enhanced learning compared to another group? Or that the groups differ when studying motivation? Since we have no possibility to make a controlled experiment, we are forced to compare results different years. We measure an interesting variable before and after a change in the course and try to keep other factors as constant as possible. As an example, overall satisfaction with the course may depend on lecturer so we have the same course coordinator and lecturer for the course during the studied period.

Finishing a course at LTH, a student has the possibility to answer a web-based course evaluation questionnaire (CEQ). On average, the response rate is 50%. In this questionnaire, the student has to take a stand to statements that are presented. Two examples of statements are "I'm overall satisfied with the course" or "The course is important in my education". The student answers on the scale -100, -50, 0, 50 and 100 where -100 means "do not agree at all" and 100 means "totally agree". In this paper we present the result from different statements and we then use the distribution of the CEQ-value or the average CEQ-value.

We have recorded the proportion of students attending the ordinary final test and the proportion of students passing the test. The results on parts of the final test are recorded for different years (before and after a change). We have also studied students' solutions from comparable questions on two exams different years to look for changes in misconceptions.

### Example 1: "The problem with unmotivated students''

The course for civil engineers (90 students) was not working well in the beginning of the 2000s. The reasons were several, frequent change between lecturers and course coordinators resulted in a lack of continuity, the course was given over 3/4 of a semester of the second study year and was outcompeted by two parallel courses. Many students never "got into the course", those who did the final test had low points. There were several compulsory computer exercises, using Matlab, both for illustrating the theory and analysing data but many students came unprepared and was "ticking off" the moment. The produced reports from the project were of poor quality. There were several real-data sets and applied problems on lectures, exercises and projects but still the students thought the course was irrelevant for their education.

In 2007 and 2008 an optional test was given half-way in the course, resulting in an increase of the passing rate but not in the attitude. When the programme of civil engineering in 2009, after our urging, decided to concentrate the course in time to 7 weeks and also move it to the third year of studies, we also decided to act. We made a rearrangement of the computer exercises in Matlab, introducing a number of "mini-projects", where each student worked with two, one on distributions and the other one on regression. The mini-projects used relevant real-life data and the problems were written with open ended questions, simulating a situation where the students acted as consultants answering a client. Two examples are "Should we complain of the manufacturer to our bearings?" or "Is there a relationship between the price on my real estate and the distance to the railway?" We scheduled time for guidance and discussions of the corrected reports and focus on the exercises was put on methods and techniques, being able to answer the questions in the mini-projects in a correct way. Simulations and illustrations of the theory were also included, in the same amount as before, but now mainly using scripts in Matlab where the students could interactively explore the theory. We also made several connections between lecturers, exercises and computer exercises in order to have a better alignment between different parts of the course.

The change in 2009 produced a further increase in the passing rate but also a dramatic change in the attitude towards the course. Figure 1 shows the proportion of students attending and passing the final test during the period. Figure 2 shows the average CEQ-value for the two statements "I'm overall satisfied with the course" and "The course is important in my education". During the studied period 2006-2011, the course had the same lecturer and course coordinator.

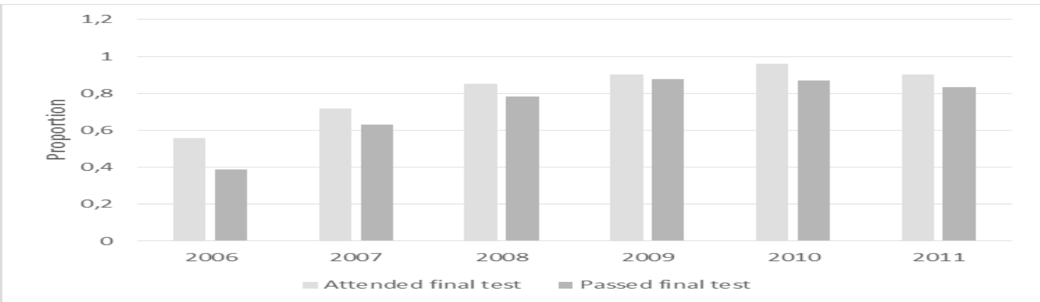


Figure 1. Proportion of students who attended and passed final test, 2006-2011

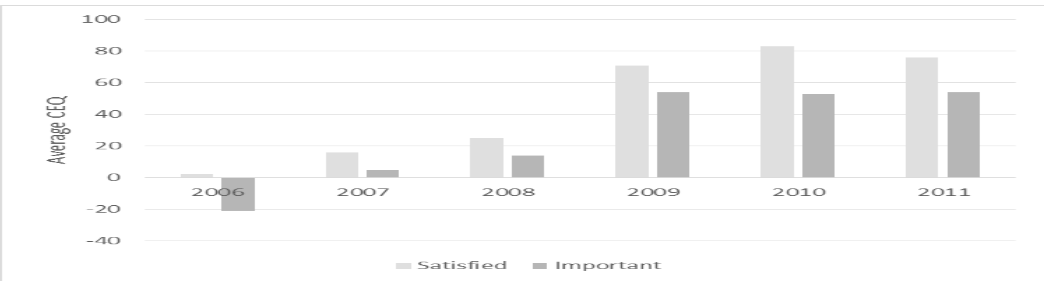


Figure 2. Average CEQ-values for questions about satisfaction with, and perceived importance of, the course, 2006-2011. Number of students who answered these questions are approximately 50 each year.

We also asked the students how they perceived the mini-projects and computer exercises. Figure 3 shows a typical answer from a year.

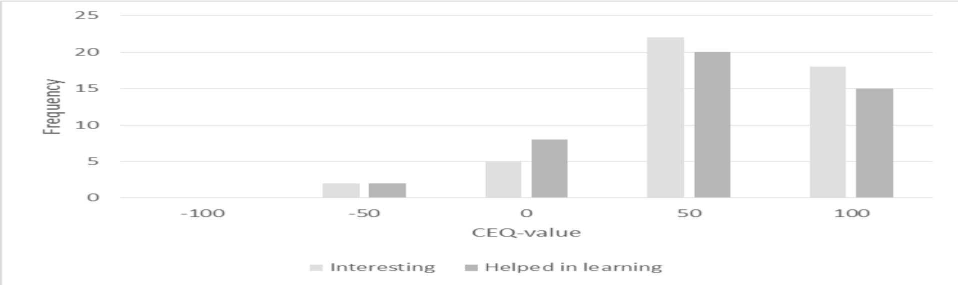


Figure 3. CEQ-distribution for statements: "Mini-projects were interesting" and "Computer exercises helped me a lot in the learning"; -100 do not agree at all, 100 totally agree.

**Example 2. The problem with slow starters and misunderstood concepts**

Typically, a course in mathematical statistics at LTH, starts with a number of basic concepts in probability, that are fundamental for understanding the subject. These concepts are non-trivial and not easily understood but necessary for the second part of the course. We wanted to speed up the learning of these concepts and assure that most of them are understood when starting the second part of the course. In the second part there is a further number of methods and concepts that are often misunderstood and treated more like a black box by the students. It is often the case that students can perform the calculations correctly but show grave misunderstanding of the concepts.

We developed questions and introduced web-based exercises and tests. The system Maple T.A. was used. The different courses used the exercises and tests in slightly different ways, but all of them had a compulsory test half way in the course on basic concepts in probability. We compared the results on the final exams in the course for mechanical engineers in two years, one year without the web-based test and one year with the test. We looked at questions on the final test where knowledge on basic probability are tested, the maximum score on this part of the test is 28 points.

| Year | Average points | Standard Deviation | Number of Students |
|---|---|---|---|
| 2013 (no web-based test) | 20.9 | 6.3 | 107 |
| 2014 (with web-based test) | 23.5 | 4.2 | 128 |

Table 1: Result on the probability questions for mechanical engineers.

There is a significant difference between the expected number of points between the two years, a 95% confidence interval for the expected difference is (1.3, 4.1).

In the small course in biostatistics (25 students), web-based exercises and test were also used in statistical inference in the second part of the course. Here we also compared the results on final exams two different years (with or without test) but now looking for conceptual misunderstandings. When comparing two questions that were directly comparable on the two exams, we found that the number of students who could set up the correct hypotheses was very significantly increased when using Maple T.A. There also seems to be an increase in the number of students who could correctly motivate and calculate a confidence interval for a proportion, however the total number of students is too small to draw any statistically significant conclusions.

We also asked these students how the perceived the web-based test and exercises, see Figure 4.

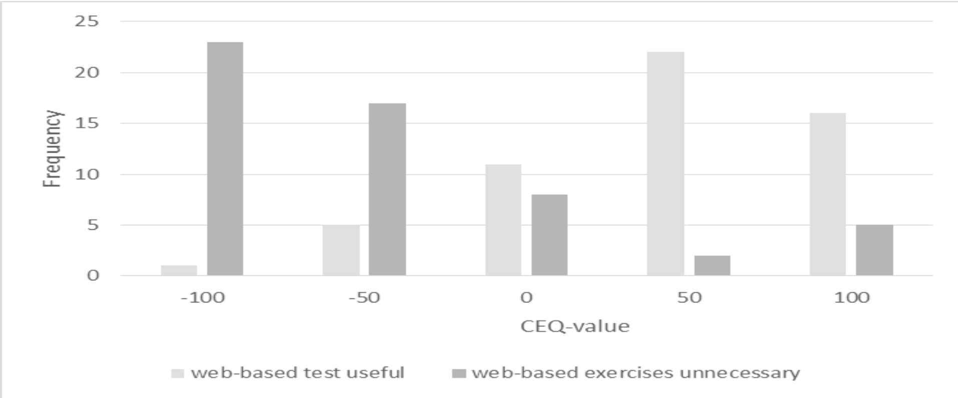


Figure 4. CEQ-distribution of the two statements: "The web-based test gave me a good idea of my knowledge and what was expected of me" and "The web-based exercises felt unnecessary"; -100-do not agree at all, 100-totally agree.

## Findings and Discussion

Both examples illustrate how using applied problems and technology in an aligned way may increase motivation and enhance student learning. In example 1 (unmotivated students) the mere existence of computer exercises with real-life data and problems to work with were not enough to evoke interest. But presented in a setting were the students worked in a "consulting role", it did. We moved focus on the computer exercises from ‘’copying Matlab commands’’ and looking at (not so interesting) data sets to using the computers as a natural tool for reaching the answer on interesting questions. We showed the students that by using their knowledge on basic probability and statistics, they are able to solve problems relevant in a future profession. Interestingly enough, the amount of theory presented and illustrated on the computer exercises were almost the same as before but "rearranged" and presented using scripts in Matlab where the students could interactively investigate the theory. Connecting the computer exercises and use of Matlab with ordinary exercises and lectures also made an aligned appearance for the students. The concentration of the course and that the students are a bit older (and wiser?) may also have some effect on the results.

Example 2 (slow starters and misunderstood concepts) shows how useful web-based exercises and tests can be for the students in their learning. We found that introducing a web-based test on basic probability, three weeks in the course, not only speeds up the learning, it also results in a small (but significant) increase in the result on the final test eight weeks after the web-based test. Based on a small investigation on biostatistics students, we also found indications that web-based exercises and tests in the second part of the course increase the conceptual understanding of hypothesis and confidence intervals at the final test.

The students seem to appreciate both web-based tests and exercises. The latter are training students' conceptual understanding and the students benefit of them most if the web-based exercises are well integrated with the ordinary paper-and-pen exercises.

Ideally, on an exercise lesson, the student should alternate between the two types of exercises, a strategy which nowadays is facilitated by students' increased use of computers and tablets on lessons.

Our approach has been to use real-data exercises and projects in order to show the students how their knowledge in probability and statistical reasoning can be used in other courses, in everyday situations or in a future profession. The developed material, real-data problems, web-based exercises and scripts in Matlab for exploring theory, are presented in Zetterqvist and Lindström (2016). Many exercises in this material are specific for each student programme; for examples, exercises suitable for environmental engineers, exercises suitable for mechanical engineers and so on. We think the effort put in the developing process is rewarded by an increased motivation and a more positive attitude towards the subject.

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