Abstract. The paper presents an analysis of a one-semester technical course “Electrical facilities”. The goal of the paper is to show how a system of real-time knowledge testing at undergraduate level, using a radio-frequency clicker system and conventional knowledge assessment methods, was implemented on a single course at the University of Zagreb. Using statistical analysis, students are clustered in groups to show the influence of clickers on the student population. It is shown that clickers have a favorable impact on students and work in accordance with each student's abilities, as confirmed using conventional assessment methods.

Keywords. Interactive Education, RF clickers, Student-response system,

1. Introduction

The end of January 2008 marks a successful completion of a new course on electrical facilities in the Bologna process compliant curriculum at the Faculty of Electrical Engineering and Computing, University of Zagreb. 144 students attended the course. A novelty in the course is the first time use of a real-time student response system, consisting of radio-frequency (RF) clickers over the course.

Since the introduction of the new curriculum stemming from the Bologna process, the usual method of determining the level of student knowledge on the Faculty is through 2 midterm written exams and a final written exam, in most cases followed by an oral exam.

2. Motivation for real-time assessment

Although successful teaching typically involves interaction, a conventional classroom has several limitations such as time constraints and uneven opportunities for students in communicating with the teacher [8]. Using a classroom computer accompanied by a LCD projector supports one-way teaching, instead of two-way interaction between a teacher and students [11]. Teachers also have to manage complicated and demanding situations like personal, emotional, and social pressures of a group, in our case two groups of 72 students, in order to help them learn immediately and become better learners in the future [2].

Standards can only be raised if the teachers are able to fulfill this task more effectively. The teacher’s motivation is directly related to increased administrative duties that reduce work teachers are expected to do - teach students in the classroom [5].

Most theories on learning are based on behavioral theory [1]. Research shows that in order to learn something, students have to organize new information and fit it to what they already know, which is constructivism [9]. Information, answers, and memory have become the focus of class activity and student concern instead of conceptual understanding, process and reasoning [3]. Using student response systems such as “clickers” provides a way for teachers to change what they have traditionally done as educators. The student response system technology is confirmed as a way of transforming classrooms to be more learner, knowledge, assessment, and community-oriented [10].

Good questions asked in the right context have a significant tendency to uplift a classroom [1]. The transformation includes a lively active environment, students understanding the subject better and working harder in class, but enjoying it more and even doing more work out of class. Teachers become more aware of student challenges with the subject matter [7].

The clickers have been used in a wide variety of classes and learning environments, including medicine, engineering, natural sciences, psychology, business and economics [4].
3. Implementation

3.1. Course description

The course named “Electrical facilities” was held through 12 block lectures, 3 x 45 minutes each, with 144 enrolled students divided into 2 groups. Each lecture included theory, examples and numeric assignments. One lecture was given every week during the semester. Lectures were organized on the same day for both groups, one group in the morning, other in the afternoon. Groups interchanged between morning and afternoon timeslots. Each group had its lecturer but the same lecture content.

Midterm exams were held after 4th and 8th lecture and a final exam after 12th lecture, followed by an oral exam. The second midterm exam included some material from the first, and the final exam included the material from both midterm exams with the addition of new theory and numeric assignments.

A project task, with the work division within teams consisting of 5 students was assigned at the 3rd lecture, with a completion deadline at the 11th lecture. Each written exam and project assignment consisted of both theory and numerical assignments.

Student presence and knowledge on lectures were graded using the clicker system which will be described later. If the student entered an answer, he was counted as present in the class, regardless of whether the answer was correct or not. In case the answer was correct, the student was given extra knowledge points. All answers were contained in a custom-made spreadsheet which was updated after every lecture.

The students knew in advance that they can acquire a maximum of 100 points in class with the breakdown as illustrated in Fig. 1.

As the teachers were free to create their own set of questions before each lecture, the number of questions per lecture for each group differs, but not significantly to include the difference in analysis with the total of 87 questions in one group and 90 in the other.

No part of the course was mandatory, but students had to collect at least 35 points to be eligible to take the final exam, and over 50 to pass the course.

3.2. Issuing clickers to students

After acquiring a list of enrolled students, adhesive labels containing the unique academic student number (JMBAG) name and surname of each student were placed on the back of the clickers: Every ClickerID (unique to each clicker) was noted next to the student's JMBAG in an Excel file, thereby establishing a one-to-one link for further database development.

The Clickers were issued to students at the beginning of 2nd lecture (attendance was noted for the first lecture manually).

3.3. Use of clickers in lectures

The implemented student response system was Interwrite's RF Cricket [6], consisting of a USB receiver connected to the classroom computer and Clickers which were given to the students. The range of the clicker’s system in free space is about 50 meters. There can be 2047 clickers per receiver.

In lectures, theory was taught to the students through PowerPoint slides. All the teachers on the course installed a proprietary PowerPoint plug-in on their computers and used it to insert questions within presentations. Question types supported by the Cricket system include Single Answer Multiple Choice (lettered or numbered), True/False (dedicated T & F buttons on 8-button Interwrite's RF Cricket), and Survey (lettered or numbered).

At the beginning of every lecture, students connect their clickers to the class by pressing a two-character Join Code, displayed to them via the overhead projector. On display of the PowerPoint slide with an integrated question, the plug-in on the lecturer’s computer starts the timer and opens the communication channel. The students can then enter their response on the clicker’s keypad and the answer is sent to the

![Figure 1. Breakdown of points for the course](image-url)
receiver. The Interwrite's RF Cricket has 4 LED’s to show the status:
- Battery LED turns green when the clicker is turned on;
- Connect LED slowly blinks when joined to the class;
- Received LED will turn green when a transmission has been received and
- Not Received LED will turn red when a transmission was not received.

Upon the end of the class, the computer to which the USB receiver was connected is used to extract student answers from the software to a text format. The software features answer analysis and grading, but due to the requirements of increased flexibility of analysis, the data was analyzed independently from the original software.

4. Results

The data have been prepared by converting absolute values from the previously described breakdown to relative as percent of the maximum value achieved per category, multiplied by 100 and rounded off to 3 decimals. All data have been analyzed using Statistica 7 (© Statsoft, Inc).

Abbreviation RFC will be used for correct answers from the clickers, MTE1 and MTE2 are two midterm exams, FE is final exam, O is oral exam and P is project assignment. Additionally, each student’s academic score (abbreviation AS) from all previous courses taken.

Table I displays basic descriptive statistics of both student groups. Linear correlation analysis through the use of Pearson r (product-moment) analysis has been performed. Both groups show a relatively low correlation between parameters. However, when the students from both groups are examined together, the correlations is quite good, as shown in Table II.

Correlation of variable P to other variables is near zero. This is expected since the project assignment was done in teams (the members of the team are randomly named) and the success of every team shared by its members equally. Further, as students were given only elementary deadlines for the delivery of the assignment without any additional parameters which follows the concept of problem-based learning [9], there was sufficient time to research and double-check the results after consultations. Hence, together with the fact that individual student’s effort on the project is hard to determine (due to the students’ sense of unity), project assignment will be removed from further analysis.

Histogram of final results on the course is given in Fig. 2, reflecting that students concentrated on achieving the minimum number of 35 points. Consequently, the median of the results is slightly shifted to the right.

The spread of results of the remaining 5 categories is shown in Figure 3. All results show an even spread, with median of variable RFC slightly elevated. This has been expected and explained by the fact that students sit close to each other in the classroom and since lectures are given with the basic intent to enable two-way communication between the teacher and students, the students shared their knowledge with each other during lectures.

The result median of the variable O is slightly lowered from 50% which is due to the fact that it was not obligatory and most students used it to add up points for purposes of achieving a better rank in their respective groups. For this reason, the oral exam will also be removed from further analysis.
Parameters for each class have a low correlation to the total class due to the fact that groups were different from the start. Additionally, AS and other scores are relatively lower for EE1 compared to EE2. This is explained by the fact that students with higher AS had the opportunity to enroll the course with different procedure than students with lower AS, which resulted in one group consisting of more successful students, and the other less successful.

5. Analysis and discussion

5.1 Scatter

MTE1, MTE2 and FE belong to the same group of knowledge assessment – in a strictly controlled environment students are given a limited but equal time to complete both theoretical and numerical assignments. The rate between theoretical and numerical assignments was 60-40 (in percent) for all exams. To identify systematic relations between variables MTE1, MTE2 and FE, since there are no (or no complete) a priori expectations as to the nature of those relations data from MTE1 was visualized, MTE2 and FE in a 3D scatterplot. Examining the initial scatterplot, no clear pattern of data was identified. Thus the dataset was approached by introducing smoothing using splines. Using this method, a surface is fitted to the XYZ coordinate data using the procedure of bicubic spline smoothing. For this case, X and Y coordinates were MTE1 and MTE2 and FE was used for the Z coordinate. The resulting spline was visualized using a 3D surface plot, as shown in Fig. 3.

The surface plot leads to a conclusion that 3 basic groups of students exist in division by success on midterm and final exams, which are the most common way to assess student's knowledge. The first group consists of students with the very low scores (green area on the graph). The second group of students strategized among the three exams thus creating equal extremes next to the axis, near XYZ coordinates (0,100,80), and other near (100,0,80). The third group are students who were equally successful on all exams. To reduce uncertainty associated with students developing their own approaches to individual midterms (i.e. whether some preferred to study more or less for MTE2 after MTE1), the division to three groups will be used. This assumption is later justified in v-fold cross validation of the dataset.

Since FE includes material from both MTEs, and the goal is to statistically determine the impact of the clickers on students, the first step was to observe the scatterplot of FE vs. RFC variables. A linear regression and an ellipse prediction interval with coefficient 0.9 for control limits was added to examine outlier cases. The result is shown in Fig. 5. To create additional information for observing trends in data, a scatterplot with variable histograms was also plotted, as shown in Fig. 6.
Since the ellipse is determined based on the assumption that the two variables follow the bivariate normal distribution (which is true as shown in Fig. 6), and the orientation of the ellipse is determined by the sign of the linear correlation between the two variables (the longer axis of the ellipse is superimposed on the regression line), it can be established that most values fall within the confidence interval. Only few outliers exist and will in subsequent courses be influenced on by introducing additional minimum limits on both RFC and FE for passing the course (i.e. set minimum of 40% for both).

5.2 Clustering

For purposes of testing the hypothesis on groups of students and analyzing the impact of the clickers on overall performance, centers were assigned to represent the clustering of N points, each point representing a student, with 4 variables (RFC, MTE1, MTE2 and FE). The points are iteratively adjusted starting with a random sample of N points and assigning each one to a cluster, each cluster being a mean of its assigned points. Computationally, k-means clustering is similar to analysis of variance (ANOVA). Starting with k random clusters, the goal is to move every point from dataset of N between those clusters with the goal to minimize variability within clusters and maximize variability between clusters. The significance test in ANOVA evaluates the between group variability against the within-group variability when computing the significance test for the hypothesis that the means in the groups are different from each other. In k-means clustering, each point in the dataset (in this case composed of 5 variables) is moved in and out of groups (clusters) to get the most significant ANOVA results. Among other results, the ANOVA results are part of the standard output from a k-means clustering analysis.

In general, the v-fold cross-validation method
can be applied to a range of numbers of clusters, and observe the resulting average distance of the observations (in the cross-validation or testing samples) from their cluster centers. The best number of clusters using this cross-validation method for our dataset is 3.

The result of clustering analysis is shown in Fig. 7. The cluster analysis was performed on the clickers’ data for every lecture with the same parameters, and the result is shown in Fig. 8.

6. Discussion and conclusions

Variable AS served as an indicator of students’ prior performance and is used as a reference for clustering. Clustering results show a clear correlation between student success throughout the study with other variables observed in this paper. Observing variables AS and RFC especially, it can be concluded that clickers have a favorable impact on the student population and work in accordance with each student’s abilities.

The results show grouping of students into clusters consistent for all 5 observed variables. Thus, from Fig. 7 it can be concluded that Cluster 3 represents the best students and Cluster 2 students who planned to fulfill the minimum requirements.

From Fig. 7 and Fig. 8 it can be concluded not only that the clickers have no adverse effect on students who were successful before starting the course, but have a positive influence by rewarding those who aim at high grades and reprovves those who only try to reach the passing margin. Cluster 3 in Fig. 7 can be observed as similar to Cluster 1 in Fig. 8 which would be a cluster of the best students attending the course. Their superior performance was confirmed by introducing clickers, with all the positive effects mentioned earlier in the paper. Pattern of Cluster 1 in Fig 7 and cluster 3 in Fig 8 in our interpretation, are those whose potential would be better utilized were the requirements stricter.

Cluster 2 in Fig. 7 and cluster 2 in Fig. 8 represent underperforming students for whom additional ways of teaching and motivation should be implemented, as it is clear that the traditional methods of knowledge transfer and assessment are inadequate to their needs. Even though a positive attitude towards all students must be maintained at all times, it must be expected that confronted with the lecture material a certain number of students have lost interest beyond restore. The clickers bring their positive quality to those students as well, as they are indicative in real time of how well the student understands the lecture material being presented at that time.

7. References