The impact of distance learning on student success for electrical engineering professional courses

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Abstract - Electrical Engineering undergraduate study at Zagreb University of Applied Sciences for professional courses is performed in blended learning environment combining the advantages of both face-to-face teaching and computer-assisted learning. Usually, teaching process of a professional course consists of lectures, exercises and laboratory exercises. The data sets related to attendance and overall exam success were analyzed to validate the impact of blending learning components on the learning success with the focus on distance learning one. Distance learning proves to be a useful method as a complement to face-to-face teaching. In addition, it can serve as the main learning method for the late exams preparation, but with lower achievement success.

Keywords - Exam data analysis; Knowledge acquisition; Blended learning; Asynchronous online learning; Face-to-face teaching; LMS; Share of self-learning in average success

I. INTRODUCTION

Professional courses for undergraduate study of electrical engineering at Zagreb University of Applied Sciences are performed in blended learning environment, combining the advantages of face-to-face teaching and computer-assisted learning (i.e. asynchronous online learning) [1]. Face-to-face (F2F) teaching is dominant for lectures and exercises. Laboratory exercises are held in a standard laboratory environment where students work mostly independently with assistance of lecturer. All above mentioned teaching types are supported by different levels of learning management systems (LMS) for the purpose of group and individual student preparation, knowledge assessment and automatic grading during lecture period [2], [3]. LMS teaching contents can be reached remotely, so asynchronous online learning is enabled for each student’s preparation during all exam terms [4].

In previous research, it is shown that despite of all the trends in the development and implementation of technology mediated learning, the role of lecturer is still very important. Recent paper presents the positive correlation of students’ success on early exam terms and their attendance of F2F lectures and exercises for fundamental telecommunication professional courses [5]. Data modeling of students’ success on the exam and their attendance was performed by piecewise linear regression ("hockey stick" shaped model). High values of determination coefficient $R^2$ (0.82 – 0.92) are obtained for all analyzed courses, confirming strong relationship between student attendance and their success at exam terms within 2 and/or 4 weeks after lecture ends.

For all analyzed courses, “hockey stick” shaped model has the first linear segment with higher slope and the second segment with lower slope. According to hypothesis presented in [5] the first segment represents knowledge adoption of basic terminology, systematization and concepts related to course curriculum where F2F teaching ensures systematization into meaningful knowledge entities and their further clarification. The second segment lower slope indicates that students, after acquiring basic terminology and essential knowledge may use all the benefits of technology mediated individual (self) learning.

Abovementioned previous research excludes late exam terms results since the focus was on F2F teaching impacts. As part of the internal project: Research on the importance of blended learning components for student exam success continuation, data related to the late exam terms results are collected, processed and analyzed. Results and conclusions are presented in this paper. During lecture period, students acquire knowledge via F2F teaching and all ways of individual learning. In general, acquired knowledge fades over the time, therefore students that attend late exam terms have to put more effort on individual learning [6], [7], [8]. For students who were unable to attend lectures, the same applies for late exam terms as well as for early exam terms.

The aim of this paper is to examine individual learning and F2F impacts on achievement during all exam terms (early and late) during a single academic year. Due to the fact that for electrical engineering professional courses self-learning is enabled also by distance learning, the conclusions of the paper could provide directions how to improve asynchronous online learning to achieve benefits of F2F teaching (lecture attendance in a class or synchronous online learning).

The rest of the paper is organized as follows. In Section II, input data collecting, preparation and its graphical representation are described. In Section III, data analysis procedure is presented as well as results of
analysis in tabular and graphical form. Finally, in Section IV obtained results and possible guidelines for future development are discussed.

II. DATA COLLECTION, PREPARATION AND REPRESENTATION

The scope of this research are professional courses for undergraduate study of electrical engineering. For this purpose fundamental telecommunication courses Digital circuits, Signals theory and processing and Information theory and coding were selected. Teaching for these courses consists of lectures, exercises and laboratory exercises. Lectures and exercises are held in a F2F manner. Laboratory exercises are performed in a standard hardware or software oriented laboratory environment with F2F assistance of lecturer.

Courses and academic years

Data about students’ attendance on lectures and exercises as well as corresponding exam success data are collected for the following academic years:

In cases where data is available for more than one academic year, all course data are aggregated to obtain a more representative sample.

Attendance

Data for Attendance A are normalized to scale from 0% (no attendance) to 100% (attendance on all lectures and exercises). Attendance on laboratory exercises is mandatory for all abovementioned courses, so their data are excluded as irrelevant for finding correlation of students’ success on exams in relation to their attendance. Moreover, for students who did not complete the laboratory exercises successfully, data records are excluded in further processing. Students that re-enrolls courses are not taken in further processing, too.

Exam terms

During single academic year, knowledge assessments have the following time frames:

**Early exam terms**
- 1st term: Within 2 weeks after the end of lecture period. Includes grades from continuous course assessment from two mid-term exams held during lecture period.
- 2nd term: Within 4 weeks after the end of lecture period.

**Late exam terms**
- 3rd term: Approx. 4 months after the end of lecture period.
- 4th term: Approx. 8 months after the end of lecture period.

It is worth to mention that if students do not pass exams in the offered terms, they have to re-enroll the course in the next academic year.

Grades

Obtained Grades $G$ from exam terms are normalized to scale from 0% (no achievement) to 100% (maximum possible achievement). It is important to note that grades are in fact achieved points that have fine resolution (as opposed to ordinary grading in education). For students who have accessed more than one knowledge assessment, each attempt is recorded and included in analysis.

Graphical representation of grades over exam terms

Initially, a cumulative distribution function (CDF) was chosen to provide a complete view of student achievement across for all exam terms. However, the complementary cumulative distribution function (CCDF) has been shown to be more convenient for data interpretation [9].

$$S(g) = P(G \geq g)$$  (1)

Graphs presenting $(g, S(g))$ pairs for all analyzed courses are given in Fig. 1.-3. so that each point represents one student at certain exam. For example, on the first exam term for Digital Circuits course, there were 88% students that had 50% or more achievement $(g = 50\%; S(g) = 88\%)$ – see Fig. 1.

![Digital Circuits](image1.png)

**Fig. 1.** Complementary cumulative distribution function for all exam terms for course Digital Circuits; *x*-axis: grades $G$; *y*-axis: percentage $S(g)$ of students with $G = g$ or more achievement.

![Signals Theory and Processing](image2.png)

**Fig. 2.** Complementary cumulative distribution function for all exam terms for course Signals Theory and Processing; *x*-axis: grades $G$; *y*-axis: percentage $S(g)$ of students with $G = g$ or more achievement.
According to graphical representations shown in Fig. 1.-3., the highest grades are achieved at the 1st exam term. In addition, this representation provides information about number of attendances showing e.g. that early exam terms have denser dots. Relationship between attendance $A$ and grades $G$ is presented in the next chapter. By using CCDF (1) it is possible to make a quick comparison of students’ success on exams for all exam terms.

### III. DATA ANALYSIS AND RESULTS

From the graphic representation of average student success through obtained grades $G$ vs. their attendance of lectures and exercises $A$ for all exam terms for Digital Circuits course is shown in Fig. 4.-7. the monotone growth is noticed. Increase in attendance correlates with an increase of exam success, which is more noticeable for earlier exam terms. For showing a growth trend, without entering deeper into area of sophisticated modeling, linear trend line was applied. It is worth to say that the linear trend was calculated from all exam term result, not just from the average values of $G$ as presented in Fig. 4.-7.

It is also noticeable that if the exam term is later, the slope decreased and the intercept increases. In addition, it is noticeable that the majority of students who attend late exam terms belong to a group that rarely attended lectures. Namely, on the graphical representation, the points move to the left side of graphs, i.e. their higher density is near $A = 0$ (rare or no attendance).
courses, as well as other exam statistical results are given in Tab. I–III.

**TABLE I.**  DIGITAL CIRCUITS – EXAM STATISTICS

<table>
<thead>
<tr>
<th>Term</th>
<th>Term: 1</th>
<th>Term: 2</th>
<th>Term: 3</th>
<th>Term: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.497</td>
<td>0.463</td>
<td>0.479</td>
<td>0.353</td>
</tr>
<tr>
<td>Slope</td>
<td>0.257</td>
<td>0.232</td>
<td>0.027</td>
<td>0.151</td>
</tr>
<tr>
<td>Students at exam</td>
<td>179</td>
<td>50</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>Average attendance</td>
<td>0.502</td>
<td>0.262</td>
<td>0.160</td>
<td>0.114</td>
</tr>
<tr>
<td>Average success</td>
<td>0.626</td>
<td>0.523</td>
<td>0.483</td>
<td>0.370</td>
</tr>
</tbody>
</table>

**TABLE II.**  INFORMATION THEORY AND CODING – EXAM STATISTICS

<table>
<thead>
<tr>
<th>Term</th>
<th>Term: 1</th>
<th>Term: 2</th>
<th>Term: 3</th>
<th>Term: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.549</td>
<td>0.377</td>
<td>0.539</td>
<td>0.185</td>
</tr>
<tr>
<td>Slope</td>
<td>0.202</td>
<td>0.253</td>
<td>-0.134</td>
<td>-0.030</td>
</tr>
<tr>
<td>Students at exam</td>
<td>118</td>
<td>13</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Average attendance</td>
<td>0.445</td>
<td>0.266</td>
<td>0.144</td>
<td>0.105</td>
</tr>
<tr>
<td>Average success</td>
<td>0.639</td>
<td>0.444</td>
<td>0.520</td>
<td>0.181</td>
</tr>
</tbody>
</table>

**TABLE III.**  SIGNALS THEORY AND PROCESSING – EXAM STATISTICS

<table>
<thead>
<tr>
<th>Term</th>
<th>Term: 1</th>
<th>Term: 2</th>
<th>Term: 3</th>
<th>Term: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.479</td>
<td>0.391</td>
<td>0.495</td>
<td>0.590</td>
</tr>
<tr>
<td>Slope</td>
<td>0.259</td>
<td>0.188</td>
<td>0.174</td>
<td>-0.345</td>
</tr>
<tr>
<td>Students at exam</td>
<td>57</td>
<td>31</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>Average attendance</td>
<td>0.519</td>
<td>0.317</td>
<td>0.280</td>
<td>0.178</td>
</tr>
<tr>
<td>Average success</td>
<td>0.613</td>
<td>0.451</td>
<td>0.544</td>
<td>0.528</td>
</tr>
</tbody>
</table>

**TABLE IV.**  AGGREGATED EXAM STATISTICS

<table>
<thead>
<tr>
<th>Term</th>
<th>Term: 1</th>
<th>Term: 2</th>
<th>Term: 3</th>
<th>Term: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.515</td>
<td>0.430</td>
<td>0.490</td>
<td>0.382</td>
</tr>
<tr>
<td>Slope</td>
<td>0.234</td>
<td>0.207</td>
<td>0.126</td>
<td>0.071</td>
</tr>
<tr>
<td>Students at exam</td>
<td>354</td>
<td>94</td>
<td>57</td>
<td>31</td>
</tr>
<tr>
<td>Average attendance</td>
<td>0.486</td>
<td>0.281</td>
<td>0.217</td>
<td>0.142</td>
</tr>
<tr>
<td>Average success</td>
<td>0.628</td>
<td>0.488</td>
<td>0.517</td>
<td>0.392</td>
</tr>
<tr>
<td>Share of intercept in av. success</td>
<td>81.9%</td>
<td>88.1%</td>
<td>94.7%</td>
<td>97.4%</td>
</tr>
</tbody>
</table>

It is important to note that in the case of a small number of students at exam, unexpected negative slope can occurred. This is unexplainable and the reason should be sought in too small a sample (usually in case of late exams). Therefore, in Tab. IV. aggregated exam statistics for all courses in scope are presented. Such aggregation is justified because all courses belong to the group of fundamental telecommunication courses.

As can be seen from the Tab. IV., values for Average success and Intercept decrease on late exam terms. In order to have an insight into the share of self-learning in exam success, the introduction of new indicator Share of intercept in av. success is proposed, calculated as follows:

\[
\text{Share of intercept in av. success} = \frac{\text{Intercept}}{\text{Av. success}}
\]  (2)

Values of new indicator is added in the last row of the Tab. IV. According to aggregated exam statistic data from Tab. IV., comparing the results of earlier exam terms with later one it can be concluded the following:

a) Slope – decreases;

b) Number of Students at exam – rapidly decreases;

c) Average attendance – decreases;

d) Average success – decreases;

e) Share of intercept in av. success – increases.

In the abovementioned comparison, comments about intercept trend is intentionally omitted. On first site, the expected increase of Intercept, which can be a measure of self-learning amount, is not evident due to the decrease of Average success. However, the introduced indicator Share of intercept in av. success (2) shows that Intercept has an increasing share in Average success. Accordingly, in the acquired knowledge that has been assessed at the exam, the part corresponding to the self-acquired knowledge increases in later exam terms.

Therefore, in the acquired knowledge that has been assessed at the exam, the part corresponding to knowledge obtained through F2F teaching (dependent on the attendance) decreases in later exam terms. At the same time, the part corresponding to the self-acquired knowledge (independent on the attendance) increases.

### IV. DISCUSSION

Based on results from the previous Chapter, the following findings arise for the role of distance learning (i.e. asynchronous online learning) in self-learning part of knowledge acquisition:

**The need for self-learning for students who rarely attend lectures and access late exam terms**

The results confirm that students who access the exams at a later term are, as a rule, rarely attending lectures (Monotone decline of Average attendance from Tab. IV.). The rise of Share of intercept in av. success (which is in fact share of self-learning in acquired knowledge) for late exams confirms that there is a considerable need for self-learning for students who rarely attend lectures and access late exam terms.
The need for continuous and repetitive learning

Also, students who attended lectures regularly, need to repeat/review acquired knowledge if they access to late exam terms. Therefore, the role of self-learning is for acquiring of the new knowledge (for students who rarely attend lectures) as well as for repetition (for students who attended lectures regularly).

Repetition/review is necessary because acquired knowledge fades soon after initial learning and the rate of memory retention (%) then gradually declines [7]. Fig. 8. illustrates the effect of the review.

![Fig. 8. Alteration of the forgetting curve through repetition/review](image)

**Students who access late exam terms have lower average success**

Monotone decline of *Average success* is noticed from Tab. IV, for late exam terms. In fact, students who attend lectures rarely, cannot compensate their absence with self-learning neither with asynchronous online learning. Therefore, asynchronous online learning have potentials for improvement.

On the other hand, the demands of the typical student in higher education include the use of ICT in teaching methods, flexible timing and location to complete studies, and real world applicability of courses [10]. In the era the ubiquitous Internet (anywhere, anytime and on any device) instant access to distant learning materials and supporting content is a starting point that need to be provided for students.

Consequently, development of online learning should go in three directions:

- Improving education content and content delivery enabling additional attention;
- Improving motivation for students to acquire knowledge;
- Finding optimal balance of asynchronous and synchronous online learning.

V. CONCLUSION

The data sets related to attendance and overall exam success for three professional courses of electrical engineering undergraduate study were analyzed. The results showed the following:

- Average success is higher if face-to-face lecture attendance is higher;
- Students who access late exam terms have lower average lectures attendance;
- Students who access late exam terms have lower average success;
- Share of self-learning is higher for late exam terms.

In case of frequent absence from lectures, the benefits from face-to-face lectures attendance or synchronous online learning are difficult to compensate. As the support for self-learning, Zagreb University of Applied Sciences offers distance learning via LMS. Based on all stated findings, possible directions for development of online learning are given.

Currently, the main task is to find the optimal balance of asynchronous and synchronous online learning, especially as response to challenges in Covid-19 pandemic crisis. Certainly, the crisis has resulted in a paradigm shift in education. Further research will validate and supplement stated findings by analyzing data collected during pandemic crisis, when F2F learning in the classroom was substituted by synchronous online learning.

REFERENCES