Abstract—Redevelopment of engineering course from traditional to blended model is a challenging prospect. Some general guidelines are given at first, then Electric Circuit Theory (ECT) case study is discussed. Over the last six years the ECT course, at the Silesian University of Technology (SUT), has been gradually converted into blended e-course, for both the Learning Content and Assessment Program. Some details of this conversion, which is continuously updated, as well as students’ feedback and the lessons learned are presented.

I. INTRODUCTION

Nowadays universities of technology are in a heart of global revolution in education, due to dynamic progress in Information & Communication Technology (ICT) and common access to Internet. These enable significant enhancement of quality of education, as many new forms of knowledge delivery and assessment may support the face-to-face (f2f) form. It can be concluded that ubiquitous usage of ICT make it possible for students of all backgrounds: home and international; teen, premature and mature; daily and extramural, to enter effectively this new learning environment. Construction of a blended engineering course is briefly discussed in Section 2, while in Section 3 Electric Circuit Theory case study is presented.

II. CONSTRUCTION OF A BLENDED COURSE

Four possible models of online course can be distinguished [1]:

- teacher-facilitated online,
- teacher-facilitated hybrid (teacher for both f2f and online portions),
- teacher-facilitated f2f plus self-paced online,
- self-paced online only.

When selecting the model, the following question has to be answered:

Are there activities which can not easily or satisfactorily be performed online?

If yes, and this is the case for any engineering course, then only hybrid, the so-called blended model may be applied. This model has been portrayed as a good solution to constraints and disadvantages of traditional (f2f) and online model and it is extensively developed in universities of technology and schools of engineering all round the world. Some general points of consensus about what is important in a blended engineering course can be enlisted and the following are the major ones [1]:

- selection of an appropriate Learning Management System (LMS),
- thoughtful integration of f2f and online elements,
- assurance of interaction and interactivity.

Interaction is the main factor determining the quality of education and the following strong correlations have been confirmed by many authors:

- between interaction and retention,
- between interaction and passing,
- between interaction and student satisfaction.

Then, the following major forms of interaction can be distinguished:

- student-teacher (lecture feedback - discussion, e-consultations),
- P2P (peer review, problem/project based learning),
- student-content (e-textbooks, self-assessment).

and all these forms have to be taken into account when redesigning a course to a blended model. This model should enhance quality of education but also it should bring improvement to organization context, e.g. organization of Assessment Program. To specify a blended course scenario, the following questions have to be answered:

What is the best mix of synchronous and asynchronous elements in a course?

What is the best mix of f2f and online elements?
In general, two major components can be distinguished in every course:

A. **Learning Content (knowledge delivery)**

B. **Assessment Program (knowledge assessment).**

Synchronous elements seem to be more suitable for knowledge delivery, while asynchronous elements seem to be more suitable for assessments. In-class, f2f knowledge delivery, followed by online discussions and assessments seems to be the better mix of these two components, rather than online knowledge delivery followed by f2f assessments.

Moreover, a course restructuring is a perfect opportunity to make changes and updates to the **Content**, not only introduction of ICT supported elements.

III. **ELECTRIC CIRCUIT THEORY CASE STUDY**

Restructuring of the engineering course, from f2f to blended model, will be discussed in details on the ECT example. In the SUT the Moodle LMS has been installed in 2004 and since then restructuring of the course is continuously developed, new elements are added and old elements are updated. Firstly, redevelopment of both components will be presented, then, students’ feedback and lessons learned.

A. **Learning Content**

The ECT course is organized as two-semester course, with three major learning sub-components:

1) Lecture,  2) **Practical Classes**,  3) **Laboratory**.

According to the Dale’s Cone of Experience, presented in Table I in its modified version, cited and accepted by many authors, however contested by few [2], an average retention rate is designated by the nature of involvement.

A1. Lecture

Lecture is the basic sub-component of Learning Content. Knowledge is delivered in a systematic manner, in fifteen 90-minute modules per semester. The core of this component generally remains unchanged, however, “chalk and blackboard” presentation is replaced by ppt presentation, supported by interactive computer animations and simulations. It is a common opinion, that slide presentation is ineffective, does not allow tracing a problem deduction, and then it is against interaction, worsens the quality of education. This statement is obviously true as long as presentation is made with a use of standard PC. To attract students’ attention and increase interaction, use of tablet PC seems to be necessary. Some parts of the Lecture content, e.g. circuit diagrams, and data of exemplary problems, can be initially preset on slides. Then, all derivations and calculations may be added, hand written on a PC screen, the same way as it is done on a traditional blackboard.

Retention rate of 50% can be reached (see Table I), if interactive simulations and animations are added to slide presentation. In case of ECT course, professional simulation software PSpice is available. For didactic purposes the freeware version can be effectively used and it can be downloaded from the course website or directly from PSpice website. Today, web-library of animation software is not available, however some efforts in creating such library have been already reported. Then, the software has to be created by teachers’. It is very time consuming and it can be partially done by students, as part of B.Sc. or M.Sc. project. The ECT lecture at the SUT is supported by few animations. Animation of travelling waves in a transmission line connected to step generator is one of them. The user, teacher in a lecture room or student at home, may set the load and generator impedance as well as line parameters and observe the mechanism of voltage waves interference along the line and voltage time plot at line output (load) or input. The analyzed circuit (generator+line+load) and a screen shot are presented in Fig.1.

A2. Practical Classes

During Practical Classes, fifteen 45-minute modules in the first semester and fifteen 90-minute modules in the second, students may verify knowledge possessed during Lecture, by solving theoretical, the so-called academic problems as well as the practical ones. This sub-component is ICT supported the same way as Lecture sub-component, i.e. ppt presentation with the use of tablet PC, supported by simulations and animations.

A3. Laboratory

To better understand some aspects of the course, delivered during Lecture and verified by Practical Classes, students attend Laboratory, that consists of six 90-minute modules per semester.

<table>
<thead>
<tr>
<th>retention %</th>
<th>nature of involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>reading textbook - passive</td>
</tr>
<tr>
<td>20</td>
<td>listening audio files - passive</td>
</tr>
<tr>
<td>30</td>
<td>watching video, still images - passive</td>
</tr>
<tr>
<td>50</td>
<td>participating in interactive animations/simulations - active</td>
</tr>
<tr>
<td>70</td>
<td>collaborative practicing by doing - active</td>
</tr>
<tr>
<td>90</td>
<td>teaching others - active</td>
</tr>
</tbody>
</table>

**TABLE I. DALE’S CONE OF EXPERIENCE**

![Fig. 1 Screen shot of transmission line animation](image)
With this scenario of Learning Content delivery, either student or teacher is able to determine at any time, which tasks have to be handled at this time. Communication teacher-student, student-content, student-student is clearly stated. The so-called “lost in e-learning” situation is practically impossible.

B. Assessment Program

For more than four years the ECT course Assessment Program is developed and continuously updated. The repository of more than 500 problems has been created, filed on the course website. These problems are used:

- during Lectures and Practical Classes,
- in pre-lab quizzes,
- in formative tests (assessments)
- in final examination (summative assessment).

In the first case, the problems are used f2f, during knowledge delivery stage, i.e. are part of Learning Content.

Pre-lab quizzes are assigned to individual exercises and they are solved online. Then, to avoid cheating, same quizzes are repeated in-lab, in a traditional manner (pen + paper).

Formative tests are solved online, in an asynchronous manner. Student can access a test at home, may choose time of completion, given 2-4 window of opportunity. Tests are non-anonymous and obligatory, however they do not effect on the final grade, which is given only based on final examination. Number of tasks per pre-lab quizzes and formative tests is variable, subject to the scope of the checked material.

Final examination is done on-line, in the synchronous manner, with all students sitting in computer labs, guarded by teachers, to avoid cheating. The e-exam tasks are drawn automatically from the repository, taking into account six attributes - $Q_i$ is number of tasks of the $i$-th attribute, $x$ is the attribute descriptor.

1. Chapter: $Q_{1DC}$, $Q_{1transient state}$, $Q_{1AC}$, $Q_{1transmission line}$
2. Solution format: $Q_{open-ended}$, $Q_{close-ended}$ (multi-choice)

3. Solution presentation: $Q_{3numerical}$, $Q_{3graphical}$, $Q_{3symbolic}$
4. Easiness: $Q_{4easy}$, $Q_{4moderate}$, $Q_{4difficult}$
5. Character of reasoning: $Q_{5forward}$, $Q_{5reverse}$
6. Complexity: $Q_{6single-concept}$, $Q_{6multiple-concept}$

Two exemplary tasks: DC and AC, are depicted in Fig.2. The DC task has been classified numerical (open-ended) and easy, the AC task has been classified close-ended, graphical and moderate, both as forward reasoning and single-concept.

During the last four years the ECT final e-exam has been applied as the only form of examination, with more than 300 students examined each year. Then, the following general parameters of e-exam have been experienced as the optimum ones:

- Number of tasks: $Q=15$
- Total time: $T=90$ min
- Number of choices for multi-choice task: $M=5$
- Score for correct answer: $S_{corr}=1$
- Score for no-answer and incorrect numerical: $S_{inc}=0$
- Penalty score for incorrect multi-choice: $S_{pen}=-0.5$

For numerical (open-ended) task, the correct answer score of 1 is granted, if the answer is within ±10% margins of the correct one. Then, the following shares of tasks within each attribute have been experienced as the optimum ones:

1. $Q_{IDC}=5-6$, $Q_{transient}=3-4$, $Q_{1AC}=4-5$, $Q_{transmission line}=1-2$
2. $Q_{open-ended}=Q_{3numerical}$, $Q_{multi-choice}=Q_{3graphical}+Q_{3symbolic}$
3. see above
4. $Q_{4easy}=2-3$, $Q_{4moderate}=12-13$, $Q_{4difficult}=2-3$
5. $Q_{5forward}=11-12$, $Q_{5reverse}=3-4$
6. $Q_{6single-concept}=12-15$, $Q_{6multiple-concept}=0-3$

At first, total of $Q=20$ tasks have been set. Then, number of tasks have been reduced to 18 [3] and finally to 15 tasks, with no change of the total time $T$. That way, time per task has been elongated from 4.5 to 6 minutes. The initially set penalty score of $-0.25$ has been increased to $-0.5$, to eliminate wild guessing, which was common during the first two years of e-examining. At first, all tasks were multi-choice tasks. Today, number of multi-choice tasks is around the same as numerical (answer) tasks, which can be considered as open-ended. If student gives a wrong answer to numerical task, then it does not necessarily means that he/she does not understand the problem. In numerical tasks students are often making silly mistakes in calculations, mainly due to carelessness. However, students must learn that in engineering calculations accuracy of the final result is as important as the process they follow up to obtain it.

Designation of the proper Pass/Fail threshold of the final e-exam is of a crucial importance. This threshold has been established empirically, based on Information Theory. A test can be considered as measurement of digital data. Such measurement can be modeled by discrete information channel

Fig.2 Screen shot of exemplary e-quiz/exam tasks
and then, the optimum mutual information designates the optimum threshold [4]. The following optimum Pass/Fail threshold has been experienced: \( P=0.6S_{\text{top}} \) where \( S_{\text{top}} \) is average score of the 5% top scores. Five years experience with e-exam proved that this threshold is really the optimum one, however percentage of scores designating \( S_{\text{top}} \) has been increased to 10%.

The automated form of e-exam allows post-exam statistical analysis. For each task its: easiness, discrimination and percent choosing is calculated. Then, the repository is updated. Badly defined problems are deleted or modified before re-use. Easiness of each task is verified. “Moderate” tasks can be changed to “easy” or “difficult”, “easy” and “difficult” can be changed to “moderate” [4].

C. Students’ Feedback, Lessons Learned

Every year, since 2004, students are surveyed to express their opinion about IT-enhanced Learning Content and Assessment Program.

Students appreciate the new form of Learning Content delivery, replacement of “chalk & blackboard” presentation by ppt presentation, supported by computer simulations and animations. On the other hand, students absolutely neglect presentation with a use of standard PC – only use of tablet PC with manually added, on a computer screen, derivations and remarks is accepted. Today’s students are members of computer games generation, and it does not make sense to keep teaching them using traditional techniques [5] - the more-game like is presentation the greater part of it is understood and remembered. This goal can be achieved by adding attractive and interactive simulations and animations. Replacement of “chalk & blackboard” presentation by tablet PC presentation not only improves its quality but also gives savings in time – average 15 minutes per 90 minutes lecture module. During this time some more exemplary problems can be solved, what additionally enhances quality of knowledge delivery.

Some major results of 2007/2008 survey related to Assessment Program [6] have been repeated in Table II, in %. It has been observed, from the very beginning, that majority of students accept e-exam, prefer this form over the traditional one.

The first experience with web-based formative assessment included non-obligatory quizzes. Unfortunately, students’ feedback was disappointing – not more than 15% tried to solve quizzes. Conclusion drawn from feedback given by students who did the quizzes was also disappointing. They admitted that the given test was repeated as many times as possible, in order to get the correct answer to each problem.

Similar finding has been reported by other authors [7]. Then, since 2008, formative assessment quizzes are obligatory, however they do not affect the final score. That way, students’ strategy of multiple attempts to formative quizzes has been eliminated. As the result of this change, students have been forced to more systematic learning. Also increase of student-teacher interaction has been observed – the most difficult problems are now reported by students and then, discussed thoroughly during Lecture or Practical Classes. Majority, more than 80% of students, declare usefulness of the repository, however, the common strategy is to possess the minimum knowledge enough to pass the e-exam, to learn not all the content but only the simplest part of it, to learn solutions of typical problems by heart. This strategy is very risky, as it does not give any safety margin – failure in any task from the selected part causes failure of the whole e-exam. It is very difficult to fight with such strategy, change of students’ mentality, attitude to studies is the key to success.

IV. CONCLUSIONS

Based on more than six years experience with the ECT course redevelopment to a blended model, the following general conclusions-guidelines can be repeated.

The in-class, f2f and synchronous knowledge delivery followed by on-line knowledge assessments, asynchronous formative and synchronous summative, seems to be the best model.

Table PC ppt presentation, with slide handwriting and interactive simulations/animations, is the best form of the Learning Content delivery. Development of animation software library is the first main challenge.

Comprehensive e-repository of problems is the main element of the Assessment Program, i.e. formative e-quizzes and final e-exam. Preparation of such repository is very time consuming but time spent is repaid after 2-3 years. Development and constant update of the repository is the second main challenge.

REFERENCES


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<thead>
<tr>
<th>Question</th>
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<tbody>
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<td>I prefer e-exam over the traditional one</td>
<td>8</td>
<td>5</td>
<td>87</td>
</tr>
<tr>
<td>My score is adequate to my knowledge</td>
<td>10</td>
<td>16</td>
<td>74</td>
</tr>
<tr>
<td>I find problem repository useful</td>
<td>3</td>
<td>13</td>
<td>84</td>
</tr>
<tr>
<td>I solve problems systematically, during semester</td>
<td>20</td>
<td>41</td>
<td>39</td>
</tr>
<tr>
<td>Formative quizzes should be obligatory</td>
<td>56</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>

TABLE II. STUDENTS’ FEEDBACK