LINKS BETWEEN TECHNOLOGY-BASED EDUCATION AND ENGINEERING EDUCATION RESEARCH – ELECTRIC CIRCUIT THEORY CASE STUDY

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Abstract
The paper underlines strong links between Engineering Education Research and ICT-Based Education. Relationships between ICT-supported components of a basic engineering course, for both Learning Content and Assessment Program, at the background of two fundamental theories for effective teaching-learning: Bloom’s Taxonomy of learning objectives and Dale’s Cone of learning experiences, are discussed. A course redevelopment, from the traditional model to ICT-supported model is presented on the Electric Circuit Theory case study. Based on the lessons learned, some guidelines are given. No categorical recommendations for best practices are offered, however, the following general conclusion is drawn. If teachers wish to live in a digital world in which today’s students live, then an immediate attention to the conduct of teaching has to be given, such that both students’ and teachers’ expectations are met, i.e. high standards in quality of education are maintained or even improved and “learning is fun” attitude dominate “learning is boring” attitude of students.

Key Words
Technology-Based Education, Engineering Education Research, Blooms Taxonomy, Dale’s Cone of Experience

1. Introduction
Today, Information and Communication Technology (ICT) Based Education (TBE) and Engineering Education Research (EER) are very hot research areas in the field of Innovative Learning (IL). These areas are strongly overlapping and more and more educators-researchers from all over the world are involved. The number of conferences on TBE and EER is enormously growing from year to year, hundreds of papers are published and some information chaos is created regrettably that way. Very significant contributions are immersed in the sea created by all other contributions of the second meaning. New powerful, ICT based tools are invented, new effective applications are proposed but they all are used by minority of educators – recalling the Rogers Diffusion of Innovation Theory [1], these educators may be classified as “Innovators” and “Early Adopters”, that account for 2% to 3% + 10% to 15% = 12% to 18% of all educators. Then, as confirmed by many authors, the main problem in TBE and EER is not to invent and adopt new tools and applications but to convince the majority of educators that wise usage of commonly available technology and new forms of teaching and learning is easy and inevitable. This paper does not pretend to be classified as a significant contribution, the Authors’ intention is to share their seven years experience in the fields of TBE and EER, to

- point out that these two fields strongly overlap,
- give some insight into the fact that learning is a complex process, built of many experiences that have to be thoroughly designed, using wisely the ICT, and applied sequentially, following two fundamental theories for effective learning: Bloom’s Taxonomy of Learning [2-4] and Dale’s Cone of Experience [5-7],
- give some guidelines for a basic engineering course redevelopment, from traditional to LMS structured model, share lessons learned, based on the Electric Circuit Theory (ECT) course case study.

2. TBE vs. EER, Bloom’s Taxonomy & Dale’s Cone of Experience
To demonstrate that TBE and EER are strongly overlapping fields of research, two commonly recognized 2011 conferences will be taken as the reference ones:

- 14th Annual International Conference on Computers and Advanced Technology in Education (CATE), organized under the auspices of the International Association of Science and Technology for Development (IASTED) [8],
- 2nd Annual Global Engineering Education Conference – EDUCON, organized under the auspices of the IEEE Education Society [9].
The following three main overlapping trends in TBE and EER may be enlisted – references to CATE 2011 and EDUCON 2011 topics are given in italic.

1. Development of new, ICT based tools supporting IL
   CATE:
   Advanced Educational Software and Hardware
   EDUCON:
   Infrastructure and Technologies for EE,
   including, among others:
   Learning Systems Platforms;
   Computer and Web Based Software.

2. New applications of existing tools
   CATE:
   Advanced Technology in Education and Training;
   Blended, Distance and Open Education
   EDUCON:
   Innovative Materials, Teaching and Learning
   Experiences in EE,
   including, among others:
   Innovative Engineering Courses and Labs;
   Digital Game Enhanced Learning.

3. Study on usage of existing applications of computers
   and advanced technology
   CATE:
   Policies on TBE; Institutional Issues on TBE
   EDUCON:
   Educational Methods and Learning Mechanisms in
   EE,
   including, among others:
   Rethinking Pedagogy in EE;
   Learning Models;
   E-Assessment.

This paper evidently falls into the third category.

It can be concluded, that development in all areas of TBE have to be strongly related with EER and its two fundamental theories for effective teaching and learning:

- Bloom’s Taxonomy of Learning [2-4]
- Dale’s Cone of Experience [5-7].

These two theories have been presented more than 50 years ago and it is commonly accepted that their general findings are still valid, also today they create foundations for effective teaching and learning, regardless of significant development of technology and use of new teaching-learning methods.

**Bloom’s Taxonomy** is a classification of thinking skills and learning objectives within education. The Taxonomy was first presented in 1956 [2], then revised in 2001 [3], and this revised version is presented in Fig.1. Six categories of thinking skills are distinguished and they are arranged in increasing order, from Lower Order Thinking Skills (LOTS) to Higher Order Thinking Skills (HOTS). Each of the categories (taxonomic elements) has a number of key verbs associated with it, some main verbs are cited below [4].

- **Remembering**: Recognising, Describing, Identifying, Retrieving, Locating, Finding
- **Understanding**: Interpreting, Summarising, Inferring, Comparing, Explaining, Exemplifying
- **Applying**: Implementing, Carrying-out, Using, Executing
- **Analysing**: Deconstructing, Attributing, Outlining, Solving, Structuring, Integrating
- **Evaluating**: Checking, Experimenting, Testing, Detecting, Monitoring
- **Creating**: Designing, Constructing, Planning, Producing, Inventing

**Dale’s Cone of Experience** is a classification for varied types of mediated learning experiences. The classification was first presented in 1957 [5], then modified by many authors. In the original version, Dale enlisted ten levels of learning and teaching methods, summarized in a pyramid (cone), with no percentages assigned to each level. Then, number of levels has been reduced to seven and percentages have been added in 1967 [6] - the modified **Learning Pyramid** is depicted in Fig.2. People generally remember...
• 10% of what they „read”
• 20% of what they „hear”
• 30% of what they „see”
• 50 of what they „watch” (hear and see)
• 70% of what they „say or write”
• 90% of what they „do”, as they perform a task

The percentages have been accepted by many authors, however contested by few [7]. It has been questioned that the Learning Pyramid is a model without any demonstrable research and should not be used as a fact. Nevertheless, the experiences assigned to levels and their order are not questioned. It is commonly accepted that learners retain more information by what they “do” as opposite to what is “heard”, “read” or “observed”. Today, “learning-by-doing”, also known as “Experimental Learning” or “action learning” is foreseen as the most effective learning experience, it is commonly observed that students migrate towards self-directed learning experiences. Then, the modified Learning Pyramid with no percentages will be considered further on.

It can be concluded, that there is a strong interaction between the EER in all aspects of Innovative Learning, such as collaborative learning, experimental learning, lifelong learning, application-based learning and TBE on one hand, and the revised Bloom’s Taxonomy and modified Learning Pyramid on the other hand, as depicted in Fig.3. Then, it is clear that an engineering course designed in an innovative manner should be extensively supported by the ICT on one hand and take into account both learning objectives (Bloom’s Taxonomy) and varied types of learning experiences (Dale’s Cone) on the other hand. Redevelopment of a course, from traditional model to ICT supported model, taking into account both Bloom’s Taxonomy and Dale’s Experiences, will be discussed on the ECT course case study.

3. Course redevelopment – ECT case study

Typical engineering course consists of many components and few overlapping classifications may be distinguished. Generally, all components are divided into:

1. Learning Content Components,
2. Assessment Program Components.

Then, Learning Content Components may be divided into:

1.1 Lecture
1.2 Practical Classes
1.3 Laboratory
1.4 Project

The knowledge is transferred along the student-teacher-content triangle, as presented on Fig.4.

Next, three forms of knowledge transfer may be distinguished [10], for both Learning Components and Assessment Components:
In case of f2f form, knowledge is delivered in-class, while in case of on-line form, knowledge is delivered purely through the web educational Platform (LMS). Blended form is a combination of f2f and on-line, and today this form is commonly perceived as the best form of knowledge delivery and acquisition.

Distribution of commonly used components on the Bloom’s Taxonomy vs. Dale’s Experiences plane will be illustrated on the Electric Circuit Theory (ECT) example. The ECT course is the basic engineering course, delivered to undergraduate students of practically all engineering fields of study, normally organized as two-semester course. Then, it is obvious that it is impossible to incorporate all six levels-experiences of the Learning Pyramid to the full extent, however each of these levels should be incorporated to the maximum possible extent, with extensive and wise support of ICT. For web-based components, Moodle LMS (Platform) has been extensively used by the Authors for more than six years. The distribution has been presented in Fig. 5a and all components have been classified into five categories, subject to their time of use:

1. components used in the past, not foreseen for the future use – single crossed boxes,
2. components used at present, not foreseen for the future use – not crossed and shaded box,
3. components used at present and foreseen for the future use – thin framed and shaded boxes,
4. components not used at present and foreseen for the future use – bold framed and shaded boxes,
5. components not used in the past, at present and not foreseen for the future use – double crossed boxes.

Project Based Learning (PjBL) and Problem Based Learning (PBL) are not foreseen during the course, due to its basic and unilateral character, however knowledge possessed during the course may be used when solving complex projects and problems at the post-graduate level of studies. Nevertheless, some mini problems and projects may be incorporated in the Laboratory component. As can be seen, the major efforts in course redevelopment concern its main part, the Lecture, and five phases of the Lecture redevelopment can be distinguished.

Lecture

Before the ICT era, “chalk & blackboard” technique of presentation has been used. It has been observed, that majority of undergraduate students treat the Lecture as an occasion to record the content, rather than an opportunity to remember and understand, and this bad habit can be observed even today, when ICT supported techniques are in use. Most of the students limited their in-class activity to copying blackboard writing and eventually to audio recording teacher’s narration. That way, primitive podcasts have been created and distributed hand-to-hand among students. For that reason, this component has been classified to “Hearing” level of Dale’s Cone of Experience, not to the “Looking” one.

Lecture

Replacement of the “chalk & blackboard” presentation by the “standard laptop ppt” presentation did not improve the content comprehension or even worsen it. Students interested in remembering and understanding lost this opportunity, as they lost the chance of tracing the way the content is created – the narration is overlapping with writing of the content, while, for better understanding, it should be in parallel with content creation. Students motivated only in recording the content have lost this motivation, as ppt handouts were uploaded on the Platform. According to Polish regulations, students are not obliged to attend lectures, and significant drop of students’ attendance has been observed. It can be concluded, that this technique of the content presentation is absolutely ineffective, however commonly applied by teachers. It has been commonly observed, that the slides act as a lesson plan and an insurance against forgetting one’s lines rather than as a means to use illustrations, animations and key points to enhance the explanation of difficult concepts [11].

Lecture

Replacement of “standard laptop ppt” presentation by the “tablet PC ppt” presentation of the content, supported by interactive animations and simulations was the next phase of the Lecture redevelopment and this form is used at present. The slides contain only essential information, such as circuit diagrams and data of exemplary problems. The rest of the content is added manually, hand-written on the PC screen, the same way as it was done on the traditional blackboard. All used animation and simulation software create podcasts, uploaded on the Platform, and can be used by students at any time, to follow demonstrations done by the teacher during the Lecture. Unfortunately, no significant improvement in students’ attendance, and then, in the retention rate has been observed. It looks that the bad habit of attending a lecture only to record the content prevailed, also very limited number of animations and simulations can be an explanation. To remedy this situation, two drastic steps have been undertaken.

- The ppt handouts have been removed from the Platform, only podcasts with animations and simulations have been left.
- Presence is randomly checked, during 3-4 lectures per one semester (15 lectures). No punishment can be imposed, however bonus can be granted - students that attend majority of the selected lectures receive upgrade of the final mark, by one level.

These measures have been introduced recently, and there is no solid evidence of their effectiveness, however the first observations are optimistic – more students attend lectures.
Fig. 5a Distribution of the ECT course components on the Bloom’s Taxonomy vs. Dale’s Cone of Experience plane

Fig. 5b Distribution of the ECT course components at the targeted stage of its redevelopment
Video recording of the lectures and uploading the podcasts on the Platform may be considered as the next step of the Lecture redevelopment. That way the “podcast-based” presentation can be created. It has been acknowledged, that students who downloaded the podcast seemed to do better with taking notes and paying closer attention to what was being said, as they were able to go back and repeat parts of the Lecture they had trouble understanding [12]. Then, it has been referred, that podcasts can be foreseen as supplementary tool to the f2f lecture, that can help students gain a better understanding of the material, and also help free up teachers from answering repetitive questions [13]. However, the Authors’ experience leads to conclusions, that are not so optimistic. It is difficult to expect, that students would like to watch the podcast prior to the given lecture, without any additional motivation. Then, to create this motivation, introduction of the “podcast based” presentation in the modified version is foreseen, as discussed further on.

Lack of students’ activity, both at pre-lecture and post-lecture stage, seems to be the main problem in effective usage of this sub-component of the Learning Content. To stimulate students’ activity and improve teacher-student interaction the “modified podcast-based” presentation is foreseen. The assumptions of such presentation are as given below.

- All lectures are professionally video-recorded and uploaded on the Platform, for constant use.
- The in-class (f2f) lecture takes place only 4-5 times during the semester, i.e. every fourth lecture as an average.
- During the in-class lecture, the teacher presents solutions to problems related to topics of previous lectures delivered on-line and all these problems are prompted by students, taken from the Students’ Discussion Forum.
- Each student is obliged to post on the Forum at least one problem during the semester, however problems may be posted by an individual student or group of 2-3 students.
- Presence at in-class lectures is checked and a bonus is granted, the same as in Lecture’s scenario.

It is foreseen to introduce this form of Lecture in the next academic year 2011/2012, and the following positive effects are expected.

- Significant increase of students’ attendance, however this attendance will be mostly virtual.
- Stimulation of students’ activity, making alive the Student’s Discussion Forum.
- Better understanding of the material and then, better retention rate.
- Breaking the barrier between students and the teacher.

Components-experiences of both Learning Content and Assessment Program, at the targeted stage of the ECT course redevelopment have been repeated in Fig.5b - obligatory experiences have been denoted by boxes with shaded frames. All Formative Assessment activities, in the form of on-line quizzes, are obligatory, however the results do not affect the final grade [14]. All tasks for on-line quizzes are taken from the repository of more than 500 tasks, uploaded on the Platform and disposed for students.

To achieve success in the learning process, students’ engagement in all experiences is absolutely necessary. Then, motivating students to active engagement in non-obligatory components, such as: podcast-based lectures, text-book and the Platform repository of tasks, seems to be the main problem for effective implementation of the proposed teaching-learning scenario, depicted in Fig. 5a. Change of students’ attitude to learning is crucial. Today, for most of the undergraduate students, obtaining the certificate is the main motivation, not possessing the professional skills. When attending the course, undergraduate students are first of all interested in passing the final examination. Then, they bypass all non-obligatory components and limit their efforts to learning by heart solutions of tasks taken from the unofficial repository created by the students from final examination tasks of few previous years. The Authors are aware that to change this attitude, teachers have to reorganize the Learning Content in its all three components: Lecture, Practical Classes and Laboratory, in such a manner that “learning is fun” attitude will replace “learning is boring” attitude. Answering the question “how to increase attractiveness of the Learning Content” is out of the scope of this paper. Generally,

- increasing the number of application-based interactive animations and simulations [14,15].
- reorganization of laboratory experiments such that they become application-based and attract students [16].

are the most desirable and inevitable changes.

3. Conclusions

Links between TBE and EER have been demonstrated. Topics of two well recognized 2011 conferences, focused on these fields of research, have been compared to show that the fields strongly overlap. Today, TBE became a common practice all over the world. However, it has to be emphasized that technology should foster the educational process not hinder it [17] and to achieve this goal fundamental theories of EER: Bloom’s taxonomy of learning objectives and Dale’s cone of learning experiences, have to be taken into account when redeveloping a course from traditional model to blended model. Redevelopment of the basic engineering course, for both Learning Content and Assessment Program, has been discussed, on the background of both fundamental
theories for effective teaching-learning, based on the ECT course case study. Findings, drawn from the lesson learned, have been presented and the following conclusions can be formulated.

- Today’s students are Digital Natives, while the majority of staff are Digital Immigrants [18]. Today’s students have not tinkered, they are impatient, think that software is everything [16]. Then, it does not make sense to keep teaching students using only old classical techniques, such as chalk and blackboard technique.
- The properly balanced mix of the modern, IT enhanced, and the classical techniques seems to be the best solution.
- The act of learning itself is no longer seen as simply a matter of information transfer, but rather as a process of dynamic participation in which students cultivate new ways of thinking and doing, through active discovery and discussion, experimentation and reflection [19]. Then, in-class f2f Learning Content components should evolve into the discussion forum direction.
- The ubiquitous Virtual Learning Environment (VLE) permits students to access their work from anywhere. Then, teaching should be constructed in such a manner that it can be pursued in absentia [20], as proposed in the targeted scenario of the ECT course redevelopment (Fig. 5b). Today, physical absence is the norm for non-obligatory experiences and perhaps with students working asynchronously on-line, this might well impact on constructing and distributing of both Learning Components and Assessment Components and engage students in all non-obligatory experiences, such as podcasts and discussion forums.
- Getting the students to tinker while understanding the links of practice to theory, providing them with experiences that would excite and motivate is the key issue [16].

The Authors intention was to take part in the debate on whether changes in educational process, caused by the IT revolution, are desirable and to what extent. No categorical conclusion can be offered, however the following two general conclusions can be drawn.

- If teachers wish to live in a digital world in which today’s students live, then an immediate attention to the conduct of teaching has to be given, such that both students’ and teachers’ expectations are met.
- Technology should be used deliberately, taking into account both learning objectives and experiences – TBE not linked with EER is just art for art’s sake and wasteful spending, EER not linked with TBE is just out-of-date theoretical research and shoddy work, only TBE linked with EER leads to excellence, as depicted in Fig. 6.

Fig. 6 Correlation between TBE and EER

References:


