Developing integrated learning environment – analysis

Authors:

Vello Kukk, Tallinn University of Technology, Estonia vello.kukk@dcc.ttu.ee
Martin Jaanus, Tallinn University of Technology, Estonia martinj@ttu.ee
Kadri Umbleja, Tallinn University of Technology, Estonia kadriumbleja@gmail.com
Oleg Shvets, Virumaa College of Tallinn University of Technology Oleg.Shvets@ut.ee

Abstract — *This paper describes the way to field-based learning environment which opposes classical course-based developments. Although that was not initial intension, practical development resulted in integrated learning space consisting of large set of small actions (elements) which must be passed by a student to obtain enough credits making possible formation a course grade needed for formal assessment. Probably, the most important component is practical assignments which are also small experiments and must be repeated until the system confirms required level of skills. For students that has apperedto be much more complicated than solving problems on paper (on screen, in fact). From introducing home lab kits five years ago, the amount of work done by students at home have been constantly increasing and during last semester almost 80% of all learning activities (by time) have been performed at home. The field called CT (Circuit Theory) is common for 7 different courses and continues to grow including more related courses. The environment is driven by personal states of elements as feedback includes transition matrix applied to every action and taking into account forgetting prediction. There is no deadlines and so, student's progress depends mostly on his/her activity. Also, no limit is set to number of attempts and the only restriction is deadline set by dean's office for grading. There is no restriction to learning time and one can start any time (formal courses are always active). However, as forgetting mechanism is included, the states are degrading by time and after long interval a student has to start from lower levels. Experience shows that this is reasonable and restarting helps to obtain faster progress. In the paper, we present detailed analysis of learning activities, statistics concerning time of learning (per day, week, semester), number of attempts, differences in learning styles etc.*

Index Terms — *Control of learning process, embedding experiments, integrated learning environment.*

HISTORICAL NOTES

In the following we shall describe solutions and decisions that have brought us to present environment by scanning through history because that explains better why one or another decision was made. Many solutions that seemed to be promising were ended after real life proved their inconsistency. Sometimes that outcome was surprising especially when it concerned commonly accepted opinions. For example, when we proposed students to compile their own personal schedule for full semester, it failed very quickly because students could not follow this. When later we proposed 'runtime' scheduling, when students had possibility to reschedule semi-automatically during semester, it also failed. We asked students about their willing to use mobile services (GPRS, WAP) for some simple actions (reservations, questions), only one third gave positive answer in 2003. This ratio had not changed in 2008 despite of remarkable progress in hardware. However, getting answers to mobile phone had very positive reaction.
Similar situations were noticed when deadlines and mobile messaging were used to remember that borrowed home kits must be returned and that it is time to go on with learning activities. Deadlines did not work but sending SMS worked perfectly.

EARLY 2000S

Development of the environment started at the end of 1990-s by introducing simple web-based services as making course materials (lecture slides) available, setting up some tests processed automatically, communication tools (questions and answers), registration for lab events, lecture plans, and personal view of final grades. However, lab reports, home works were still presented as paper documents and consequently, processed by teacher with remarkable delay. Delays appeared to be remarkable (even weeks), particularly because of huge numbers of reports reaching one thousand. Obviously, processing of those reports became rather superficial.

However despite of rather limited facilities, students' reaction was very positive. For example, survey from year 2001 for Introductory Course in Electrical and Computer Engineering (CT) shows the following.

- About 56% of students used mainly their own computer

- To present reports – 95% preferred internet
- 75% preferred to get learning materials from internet (25% preferred paper)
- Exercising: 84% - internet, 12% on paper, 4% form textbook
- To get lecture notes: 60% - to download form web, 22% - all on paper from the beginning, 18% - before lecture
- Forming lab report: 33% in lab, on computer just after measurements, partly in lab, partly at home – 31%, on paper - 8%.
- To get support for solving problems: first place – getting explanation from teacher.
- The most critical remark – server faults.

It was clear that students are declining to use electronic tools in every aspect of learning. However, in the course Operating Systems (OS) main activity from students remained home works to be completed by certain deadlines as it has been commonly accepted. As in many learning environments e-mail was used for submitting home works. Both of those exposed their negative impacts noted by probably all teachers. Firstly, roughing during last minutes before deadline means that reports have low quality, students have no time to think about what they are presenting, missing deadline by a minute or to two following complaints about server errors etc. This does not support learning. Secondly, new deadlines are usually set up and everything will be repeated again. Penalties assigned to additional deadlines may produce results contradicting the main goal – successful learning. Figure 1 shows typical rush before deadline demonstrating that submission rate increases to 20dB/day during last half day.

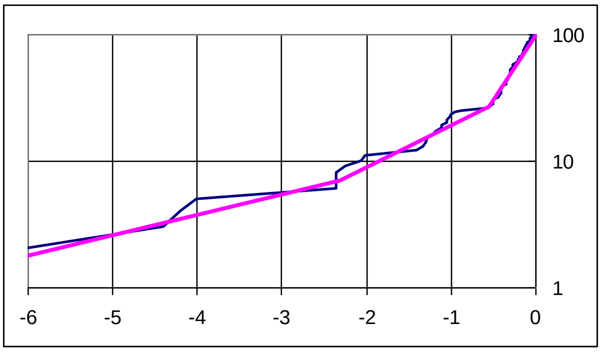

FIGURE 1.
NUMBER OF SUBMISSIONS VS TIME IN DAYS BEFORE DEADLINE

In 2002, uploading of home works into database was introduced that made much simpler their processing by teachers. However, delays were not reduced significantly. In CT, number of tests was extended from 6 to 9, tasks were generating stochastically but because of few levels of difficulty (10), average number of attempts per test and student was about 10 that is clearly too small for persistent learning.

2003

In 2003, experimental work (labs) was moved fully to web. That means electronic form for assumed preparation for lab at home, working in lab with computer only and uploading all results during the work. Certain verification was added lab software meaning that most common errors were marked by red color suggesting student to over check his work. Teacher processed the results using the same template.

In this version of labs we could see explicitly how students use instant feedback (colored results of measurement or calculation) – to get result accepted they started to 'tune' data. Using several colors indicating different levels of accuracy helped the students. More sophisticated 'calculation' was based on client-side scripts that are available to user. Students opened source code of the web page and then, extracting proper parts from it they could easily get correct results. That has been the most interesting in-site operation provided by students. Before that time file sharing (reports of home works, labs etc) was the most widespread activity in learning processes involving computer. During following years students' created many special web sites and/or Excel files that help student to get correct result. For some reason, analyzing client side code by students has dropped to almost zero, probably because learning software does not include relevant code at client side.

During this year two series of lectures (both CT and OS) were recorded as audio files. However, their usage was ner zero and therefore no more audio files were produced and links to those files were eliminated.

One important step was made this year: Students had asked several years to have a tool for exercising. Manual dissemination and what is more important, checking student's work was impossible because of large number of students. Using tests for that purpose was not appropriate because those were created for examination and therefore, no comments were issued. That is why Learning Court was designed to be open for all students independently of their current assignment activities. Tasks were collected into modules representing rather small topics, e.g. Ohm's law, units (DC and AC separately), series connection, parallel connection etc. Modules had hierarchical structure were higher module opened only when lower one(s) had reached certain level. Total number of modules that were initiated was 40 but only 268 tasks implemented. Number of difficulty levels was 6 which appeared to be far too small causing many complaints from students (the same task appeared). In 2004 the number of active modules was reduced to 33 and number of tasks increased to 332 and number of levels to 8.

Remarkable increase was noticed in usage. In 2003 (first year of implementation) this number was 6196 then in 2004 the number reached 36347. This confirmed that right tool had been found and further development was needed.

Figure 2 shows an instance of Learning Court in 2007. State of the student is shown by color code (red – low, blue – high). Relations between modules are shown only when mouse is positioned on a module; then numerical value of state is shown.. Gray flat button show that this module is not open (prerequisites are too low).

By summer 2004 we could declare that learning had been transferred fully to web-based environment [1].

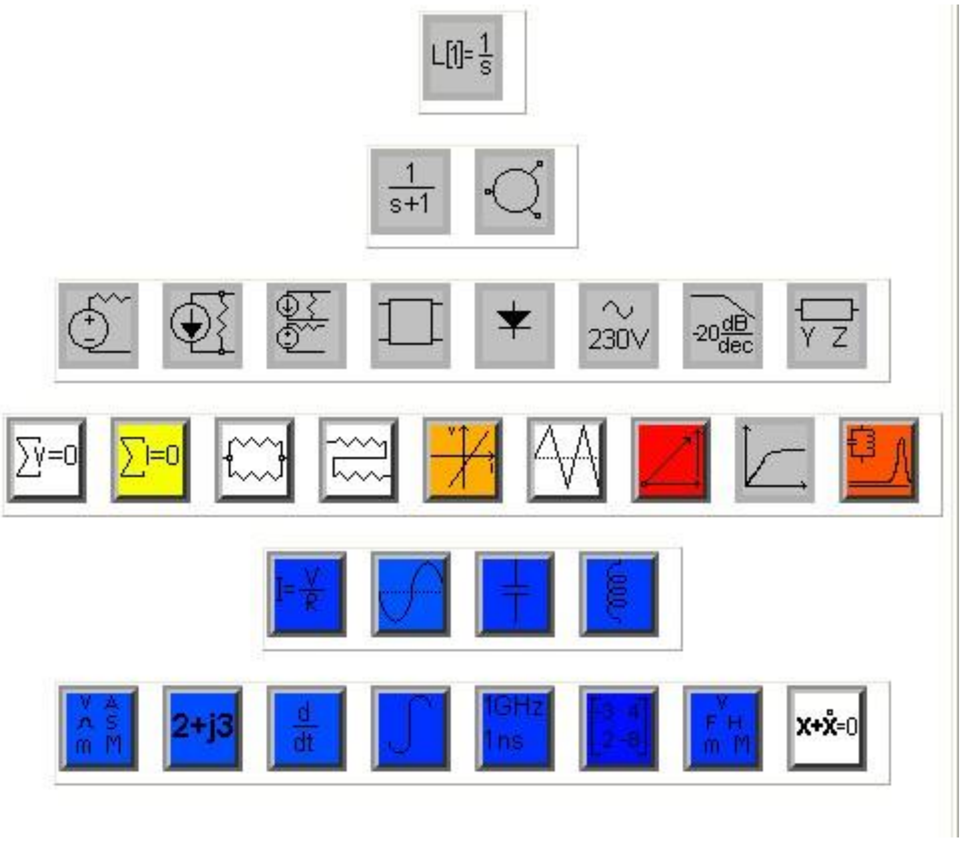

FIGURE 2
LEARNING COURT AS IT APPEARS ON WEB PAGE

2005

This year marks some very decisive actions. Success of Learning Court, problems with classical organization of labs, and inefficient control of learning process the following steps were made.

First, course was represented as a set of assignments, ordered in the same way as tasks on Learning Court accompanied by small amount of credit units so that sum of them was equal to credit units needed to pass the course. Number of levels assigned to assignments was 13 (from 0 to 12) with level 5 as minimum to be considered as positive outcome of particular assignment. In the course CT there were 12 assignments as tests, 7 labs, and 4 class works which covered several test assignments each. So, credit units accompanied with assignments were in the range 0.1..0.25, making together 3.5 cu.

Second, labs were still the same as previously and organized in the same way but a very important new xxx was introduced in fall semester 2005. In that year, a project was initiated to design HomeLabKits – boxes consisting of all components needed to perform labs at home. The first experience with the kits was so successful that after a couple of months it was decided that all labs both in university and at home will be based only on those kits. Figure 3 shows views of a kit of that time (1^{st} generation) [2].

Third, presenting regular lectures was ended and recorded videos accompanied by lecture slides were made available (DVD and Internet). Links to them was organized at slide level.

Fourth, all deadlines were abandoned and all limits for repeating actions were removed. This step was carefully considered, analyzing what had really happened. That was easy to do as all students' activities had been logged from 2000. Until 2005, tests were also open for certain time but they had to be reopened again and again to meet students' requests. Contrary to common understanding about deadlines, the most remarkable effect was that first students passed the course in 2.5 months instead of standard 4.5 months. What concerns late students, nothing changed: about 15% were always very late.

FIGURE 3
FIRST GENERATION OF HOMELABKITS: EXTERNAL VIEW ON THE LEFT AND OPENED BOX ON THE RIGHT

2007

In 2007, several more important steps were made. First, student forgetting model was introduced. Second, number of tasks in Learning Court was increased tremendously, to about 15,000. Third, labs were totally reorganized. The last action was supported by another project in which 2nd version of HomeLabKits was designed. In this project, several institutions took part and totally 200 kits were designed. Both those actions were supported by increasing number of knowledge levels to 128. That was absolutely needed for implementation of actions taken.

Learning without deadlines was success but showed clearly that assignment-based learning system has certain drawbacks: there is no mechanism to support remembering studied items. Passing something means no return to the topic. Also, there is no guidance which could tell the student that he or she has probably forgotten something. It causes surprises especially when some final examinations are provided. This was main reason to insert forgetting model into learning environment as a tool that should control learning instead of strict ordering.

The forgetting model implemented was rather simple: after every action taken by a student, not only new level of knowledge (difficulty, ability) was calculated but at the same time decay time constant was upgraded as well the floor - level that was assumed to be long term memory level [3]. This model needed more levels than used before; may be even real numbers could be used but it was decided that 128 levels would be enough to avoid discretization effects as it happens in common assessment practice where only 5-6 grades are used. Such small number of state values would not enable effective implementation of feedback control.

As assignments were kept as in previous models, a student could see last levels of all assignments and prediction for next 16 weeks as separate sheet. This number is approximately equal to length of semester and for calculating final grade, just the levels after 16 weeks are taken into account. It follows that short learning before final exam (formal deadline) becomes impossible or inefficient as evaluation is made for state four months later.

Forecast sheet as seen by student is shown on Figure 4. Note that all assignments with level falling below critical value 77 are shown in red and those must be improved. So, forgetting model became an important tool for students helping to decide which topic is to be studied (repeated).

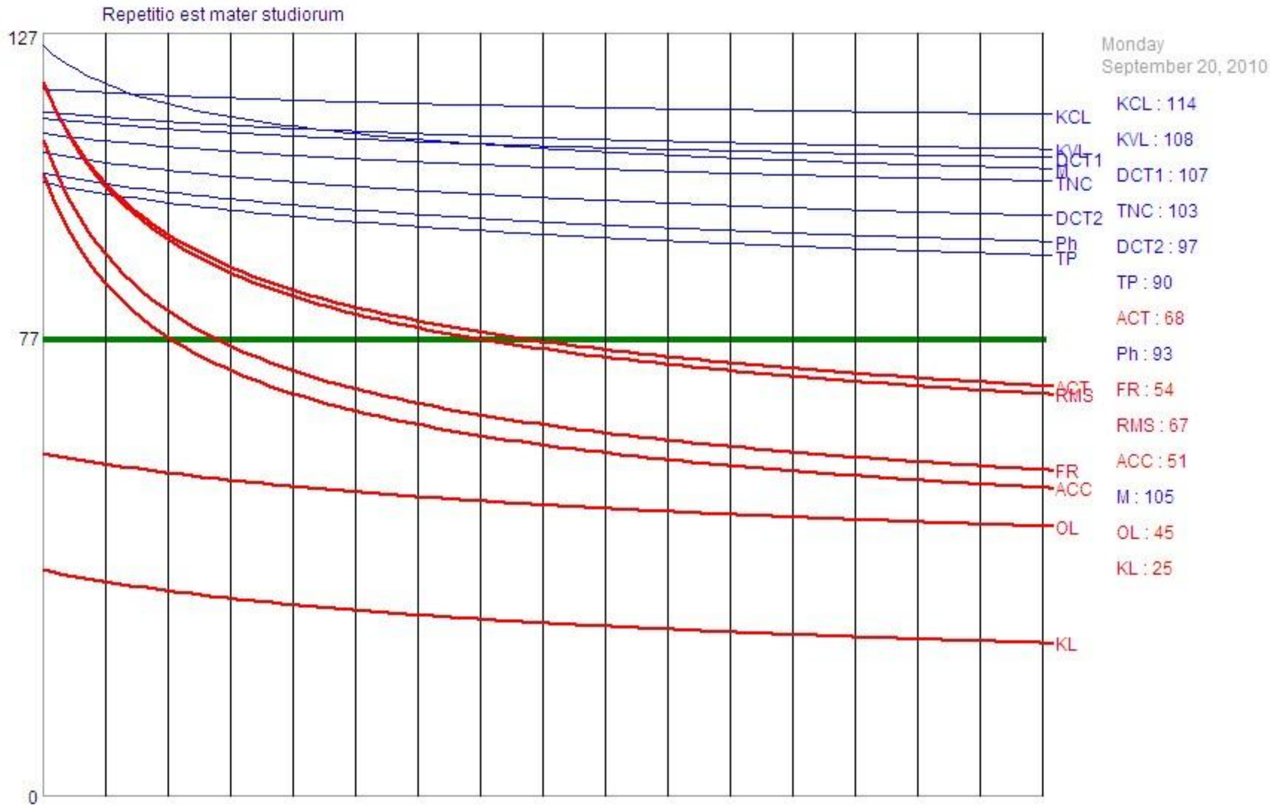

FIGURE 4
FORECAST OF ASSIGNMENT LEVELS AS SHOWN TO STUDENT (DATE: MAY 31, 2010)

Based on experience of previous years, recognizing students' claims of interest in practical work, declarations in publications and believing that engineering knowledge is based on experiments, the decision was made to transform labs to the same format that had proved its efficiency in learning theoretical material. It should be mentioned that 'theoretical' here means also very practical topics as tasks to be solved in tests and exercises were also problems not theoretical claims or theorems.

This decision together with absolutely necessary need to increase number of tasks in any module (assignment) determined a large development work. It was obvious that creating thousands of different experiments was not possible because of limited resources in HomeLabKit but also because of much more complicated processing of measurement results. From the other side, variety is automatically increased due to different contents of kits.

To create small and automatically testable experiments it was decided to choose limited format: every experiment must be represented on one web page (without scrolling), namely on 800*800 pixels field. An example of lab assignment sheet is shown on Figure 5. This is a simple measurement of voltage gain at one frequency of RC-circuit. Note that gain in dB may be calculated from gain but also found as difference of signal levels in dBm which are shown on ACScope screen. It is not prescribed which method to use. More experienced students prefer subtracting to taking logarithms.

The most important feature of such type of assignments is that reaction is immediate and student sees change of level just after sending the answer. It follows that selection of tasks is automated and controlled by feedback loop including evaluation of result, changing state, and selecting new task from the set assigned to new state.

Before changes in 2007 class works (micro-exams) included only theoretical tasks. Then experiments were included and time slot was increased from 20 minutes to 40 minutes. Total number of assignments (modules) is 21 (12 tests and 9 experiments). In reality, average number of test tasks and experiments per one class work is almost equal. This confirms that experiments are more difficult for students. It is also seen form average results which are 1.68 for experiments and 1.90 for tests (in the scale 0.0 ... 3.0).

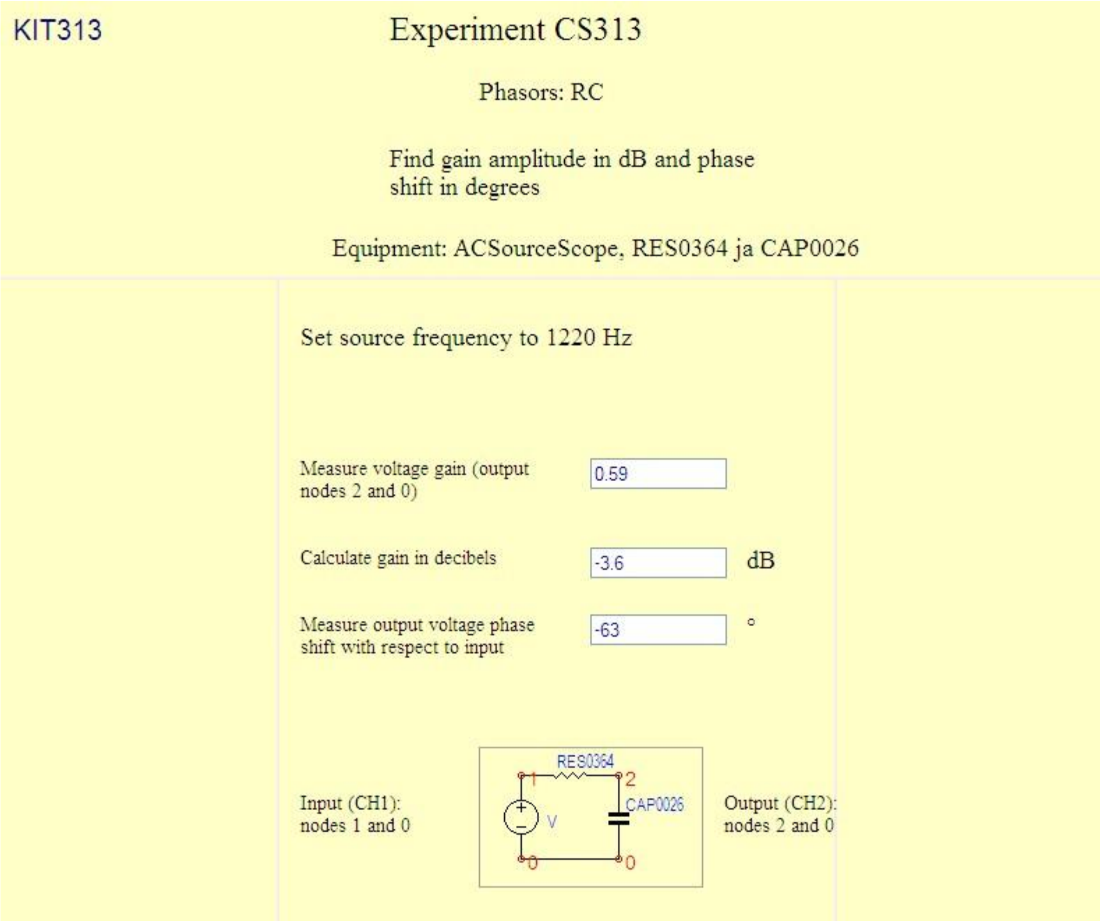

FIGURE 5
EXAMPLE OF LAB ASSIGNMENT SHEET

FIGURE 6
SECOND GENERATION HOMELABKIT

2010

After major changes in 2007, minor adjustments, more tasks, and some changes in control have been implemented. One of those is confirmation the final grade by student himself. When a student has reached required levels in all assignments (evaluated 16 weeks into future) grade is being proposed and student has two options: to confirm it or to continue to reach higher grade. This proposal is implemented as shown in Figure 7. (Note: grade will fall in time!)

By 2010 it became clear that enough experience has been collected to start creating more sophisticating processing of action results. This work is based on log files from which it is possible to extract knowledge elements. The main goal is to find out where and why students make mistakes or what has been misunderstood. Analysis performed by spring 2010 shows that in average about 4 instances of elements can be extracted from any task. Principal difference from previous processing is that instead of evaluating just this assignment from which the task was presented, from every answer implication for several elements are made. It has been problem in all previous solutions because we have to produce some summative grading what is difficult and sometimes even misleading. For example, in lab measurements a student has to find a frequency to be used. If this has been determined incorrectly, all other measurements are also wrong and it is impossible to represent this case in one-dimensional state space. If we consider other results for wrongly determined frequency then we miss learner's inability to determine frequency. Otherwise, our evaluation of measurement skills is wrong or we mix everything evaluating with some medium grade what may cause the same type of task to be given again. This is well-known dilemma of summative assessment. In a new model we are going to avoid such inconsistencies.

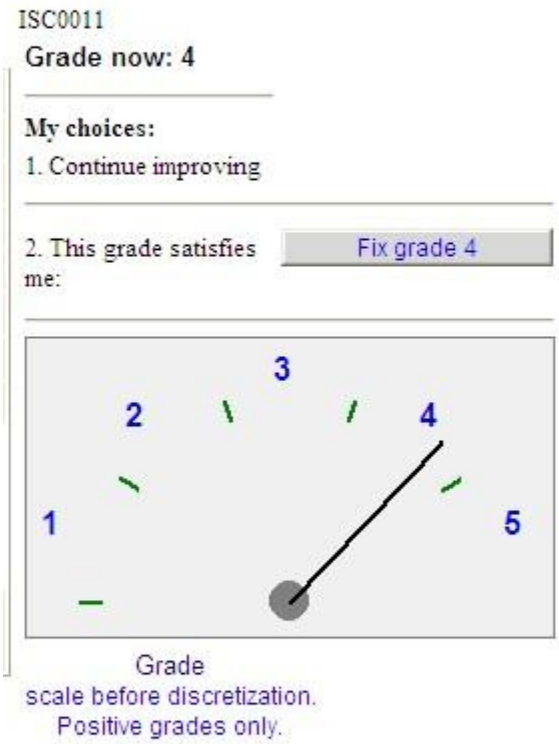

FIGURE 7
GRADE-O-METER SHOWN TO STUDENT FOR DECISION MAKING

HOMELABKIT

Reconfigurable HomeLabKits are compiled in several different versions depending upon which course(s) the student is going to pass. List of components is the following (wires not shown in the list):

- Multimeters (AVM360, M830)
- DC Source with two voltage outputs and one current output
- AC Source and Scope, powered and controlled by USB-connection; output voltage waveforms are sine, rectangular, and triangular but can be set to any other format by software; frequency range is from 10 Hz to 50 kHz, level about 1V RMS; there is one output of AC signal and two scope inputs;
- Active twopole, powered by internal battery
- Resistive two-ports
- Resistors fixed and variable
- Capacitors
- Inductors
- OpAmp: downgraded, variable gain 10 …100, corner frequency 100 Hz
- 3-phase source

STUDENT

Students are not only questioned about their opinions but their behavior has been analyzed over the years. Some characteristics have been almost the same despite of changes in environment. For example, after abandoning internal deadlines the behavior shown on Figure 1 can be noticed only once per semester, just before official end of semester but intensity is much weaker:

Activity vs. daytime is also the same over years with maximum at noon and minimum at 5 am. Some local maximum can be noticed about 8 pm.

During a week clear minimum can be found between 6 pm on Saturday and 6 pm on Sunday. This time slot had been used for updates closing web site for students during some hours just inside that slot.

Students' activity inside semester is also followed by more or less the same curve which can be approximated by logistic curve. However, one can find differences depending upon the modes used in particular course. Home works that are more time-consuming, usually not repeatable and would wait for human reaction, are postponed as far as possible (causing K-curve as on Figure 1). If a course is based mostly (or only) on interactive learning then logistic curve is centered and near half of work has been done by mid-semester. This is the reason why we are going to convert all learning into interactive and to preserve home-works in the classical form only in very special cases.

Students can perform almost all learning at home (outside university). The only action that can be performed only in fixed rooms (and computers) is class work (partial exam). This may need from 3 to 10 times 40 minutes depending on learner's learning style and psychology. Anyway, part of learning at home has been increasing and reached in fall semester 2009 the following distribution: Largest group had performed 90% of learning time at home; the next group is 70%, then 80% and then others. Note that in university students time is used for experimental work, consulting, discussion, and class works. Only 2 classical lectures are given in the beginning of semester.

Forgetting model helped to decide on what topic to work – this claim was supported by 75% of students. At the same time 30% are claiming that model predictor showed faster forgetting then they assumed. The last claim is not fully supported by independent data analysis, probably it reflects that overestimation of forgetting causes more emotional reaction than underestimation. If forgetting is assumed to be slow then system does not propose repetition and this has certain psychological effect.

CONCLUSIONS

- Main conclusion from 10 year experience is that interactive learning has extremely high motivating power. Sometimes it is also called playing games but our experience shows that there is no need for extreme illustrations etc. Even very formal tasks appear to be attractive if they give immediate reaction and demonstrate progress (and failures) of the learner (immediate and engaging, [5]).
- Transforming lab experiments into reactive environment makes them as attractive as onscreen tasks.
- Introducing HomeLabKits has additional effect – as reported by students, at home sometimes whole family was engaged in problem solving (so, scope of learners was extended implicitly).
- Anything showing progress is great – for example, final grade can be used for that despite its real value is very low due summative character and high discretization step. Presentation that grade as shown in Figure 7 has been also very motivating. Color code on assignment map has demonstrated the same activating role.
- An intriguing question is how to build up global learning environment. In engineering such factors as cultural differences are less relevant that in some other areas and consequently sharing of tasks and interpretation of results should be rather simple. However, that may need different culture of collaboration and recognizing that seems to be not very simple at least in higher education [6]. However, harmonization and avoiding unnecessary parallel work seem to be a core problem of the future education.

REFERENCES

[1] Kukk, V. "Analysis of Experience: Fully Web Based Introductory Course in Electrical Engineering", *Proceedings of the 1st International Workshop on e-learning and Virtual and Remote Laboratories*, Setubal, Portugal, August 24-25, 2004. pp. 111-118

[2] Jaanus, M., Hein, N., Kukk,V., Sullin, A. "HomeLabKits for Introductory Course In Electrical Engineering", *Proceedings EUROCON 2007, The International Conference on "Computer as a Tool"*, 9-12 September 2007, Warsaw, Poland. Warsaw, Poland:, 2007, 2676 - 2679.

[3] Kukk, V.; Jaanus, M. "Student Forgetting Model: Practical Experience", *EAEEIE 2008 proceedings CD-ROM: 19th EAEEIE Annual Conference*, Tallinn, Estonia, June 29 - July 2, 2008. , 2008, 112 - 117.

[4] Wozniak, P.A. " Effective learning: Twenty rules of formulating knowledge in learning.", http://www.supermemo.com/articles/ 20rules.htm.

[5] Redfield, C.L., Larose, G. "Intelligent Tutoring and Mentoring for Effective Learning", *EDUCAUSE Quarterly*, Vol 33, No 1, 2010.

[6] Gonick, L.. "Future of Higher Education", *EDUCAUSE Quarterly*, Vol 33, No 1, 2010.