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Computational Thinking and Flexible Learning: Experience of Tallinn University of Technology

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Abstract. Computing and Information and Communication Technology (ICT) have quickly spread to all areas of human activities and it brings changes to related subjects in schools and universities. Recently, the term *Computational Thinking* has become very important [1, 2]. It defined the principles of the much greater attention to development work, modelling, analysis, design, algorithmization and programming. It is expediently considered to introduce the principles of creation of applications in addition to the use of this. At the same time, several countries research shows decrease in the level of computer skills in schools. Especially depth research has been performed in the US CSTA [3] and in the UK [4]. In view of this the US have adopted the CS standard [5] and new curriculum is being created, also a new curriculum is being created in the UK [6]. A similar situation is in Estonian schools, and this greatly affects the computer-related subjects at university. Significant variation in new students' knowledge and skills forced teachers of computer science to seek new techniques and forms of organization of teaching the subject. An important element here is the *flexible learning* [7] based on *e-learning*.

1. Introduction

Tallinn University of Technology has taught computer science for non-IT more than 40 years. In the beginning the principal subject was algorithmization and programming and then the information work was added. Currently, all non-IT courses are taught two subjects: Informatics I, and Informatics II. The main goals of these courses are:

- to develop logical, analytical and algorithmic reasoning skills and to further the ability of investigating in a systematic way the problems and tasks at hand;
- to give fundamental knowledge and basic skills of object-oriented programming and the use of development tools of mainstream application software (especially VBA) for creating applications.

The core of Informatics I is *information work*: text and table calculations, which we attempt to make into an ECDL (European Computer Driving Licence) certificate of advanced-level. Here is also presented modelling using UML.

Informatics II is aimed at *development work* and here we have lately tried to consider the principles of *Computational Thinking*. The main tools are MS Excel, Visual Basic for Application and UML. We are using Scratch [8] at the beginning (6-8 hours) – a graphical programming environment created in Massachusetts Institute of Technology for quicker understanding of basic programming concepts.

We should pay particular attention to the fact that these subjects are not meant for IT-specialists. These courses are designed for students of economics, social and technical disciplines. Each course lasts 16 weeks.

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2. Experiment

2.1 Statement of the Problem

Due to the intensive development of e-learning, the current situation in the prior knowledge and in academic achievements of students, changes in the teaching of subjects became necessary in order to improve the quality of education. There was a need for a *flexible* and *differentiated* approach to learning: using a range of learning activities, resource types, appropriate learning styles and individual needs of students. It also became necessary to develop new ways to interact with learners for better achievements of educational goals.

2.2 Situation in Academic Achievement

Consider the academic achievement statistics from 2007 to 2010 (Fig. 1, Fig. 2):

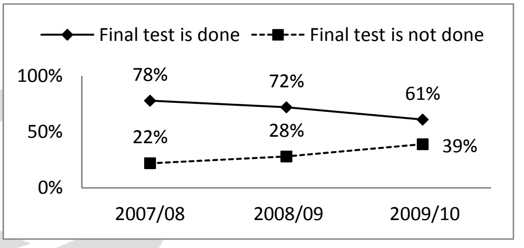

Fig. 1. Situation in Academic Achievements in Informatics I: fall semesters 2007 – 2009

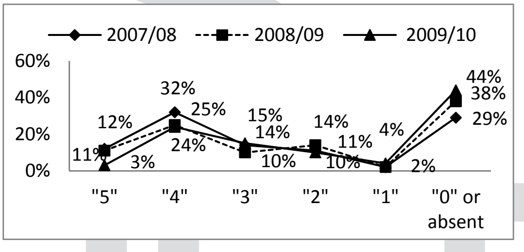

Fig. 2. Situation in Academic Achievements in Informatics II: spring semesters 2007 - 2010

The percentage of subjects academic achievements every year had been falling permanently. Especially academic achievement suffered in the Informatics II: the percentage of students who were absent from the exams had increased for three years from 29% to 44%.

To clarify the situation with students the interviews have been held. The processed and summarized results showed that due to the fact that the level of prior knowledge of Informatics I differs significantly, the process and pace of learning are prohibitive for lots of students. Also, some of these causes of poor progress in both subjects were lack of practical exercises to practice the new knowledge and difficult perceptions of theoretical material.

Also the number of disabled students, which has recently increased. These students cannot always be present in classes and the speed of their work is significantly different from normal students. Interests and abilities of this group of students also need to be considered when selecting educational material and school organization.

2.3 Ways to solve problems

For solving the problems it was decided to transfer the main part of teaching subjects Informatics I and Informatics II into the e-environment. This made it possible to provide students with various kinds of educational materials, provide them with an expanded set of practical tasks and opportunities for self-testing. The rate of this training the student chooses for himself. It is also important that the e-environment makes it possible to communicate with the teacher and seek advice not in only reserved time for training and consultation in university.

In the fall semester 2010/2011 we started adopting a *flexible approach* to the educational process. The starting step was the separation of students in subjects Informatics I and Informatics II, in the e-environment into 3 groups according to the results of testing. It is assumed that students, who start studying Informatics I, have the knowledge and skills of the computer user skills certification (ECDL) level. Therefore, the test questions were related to the topics considered in the ECDL modules. Particular emphasis was placed on skills in table program (primarily MS Excel).

These groups were given the following names: Beginners - the limit test result 60%; Advanced - the limit test result 80%, Experts - the limit test result 100%. The purpose of this students' division - by providing a different number of tasks with different difficulty levels to equalize the level of students' knowledge in all three groups at the end of the semester. The test results indicate a low level of students' prior knowledge and most students were in the group Beginners.
Results of groups division were the following (Fig. 3, Fig. 4):

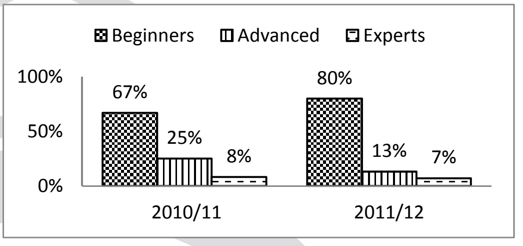

Fig. 3. Division into groups by test results. Informatics I. Beginning of fall semester 2010 - 2011

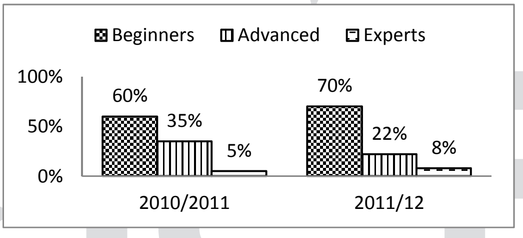

Fig. 4. Division into groups by test results. Informatics II. Beginning of spring semesters 2010 – 2012

Students belonging to various groups received different sets of practical exercises and tests in the e-environment. The levels of difficulty correspond to the levels of knowledge in each group. Beginners solve their tasks and tasks of Advanced and Experts; Advanced students solve their tasks and tasks of the students of Experts; Experts - only their tasks. The level and number of assignments and tests for the Experts' group correspond to the set of basic tasks in the subjects. This set of materials was previously received by all students who had studied Informatics I and Informatics II. Thus, due to the transition to e-learning we were able to increase the total number of exercises by 100% and vary them without increasing the subject's hours (Fig.5). The students' load is calculated and corresponds to the number of points received for the subject.

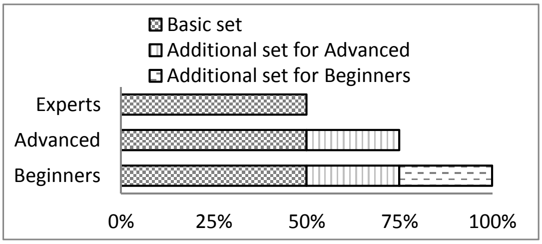

Fig. 5. The distribution of the set of practical tasks and tests

Furthermore, weekly self-summary practical assignments were adopted in the courses. Their fulfillment made it possible to have additional training and by e-environment tools - to have the possibility of getting the next assignment. Thus, it was possible to promote independent student work in parallel with the educational process.

Not only has the set of practical exercises and tests been changed in the process of transition subjects into the e-environment. Theoretical materials have also been updated and supplemented by many examples, worksheets and video reproducing practical exercises. Separately, we want to draw attention to the screencasts, allowing students to gain knowledge and skills in small portions to a better understanding. Such principles are used widely in the Khan Academy [9]. These changes in the theoretical material provided an opportunity for students who had no possibilities (for various reasons) to attend classes and learn with the rest. Thus, we were able to raise the attractiveness of courses, providing students the means for better understanding and effective learning subjects.

In addition, different psychological tests have been proposed to students in the e-environment during the semesters. The results of which influenced the distribution of educational tasks. For example, students with good academic achievements and leadership qualities were appointed leaders of student groups to implement team work. The groups also compiled according to the results of tests that identify learning styles and features of the perception of educational material. It also helped to identify the students who learned better by helping others. Consequently, we got rid of the level of learning motivation decline in weak groups.

All team and individual work in the course subjects gave students the opportunity for self-expression and self-realization due to the fact that only the general requirements have been formulated in these works in accordance with educational themes. Students have the opportunity to choose the area and topic of implementation by themselves. Here we have actively practiced the principles of computational thinking: students formulate the problem, analyze and organize data, model, look for solutions, summarize it and use in practice. This aspect was a very strong motivator for those students who work. They can realize their studying and work connections.

All things considered, we managed to make the learning process more flexible by using e-environment opportunities: the students themselves chose the shape and learning tempo, types of educational materials, and themes of individual and group work.

2.4 Results of experiment

At the end of each semester, we conducted a retest of the students. The results of this testing showed that the level of knowledge has leveled off. Now, most students were in the group Advanced.

The results of the tests at the end of semesters (Fig. 6, Fig. 7):

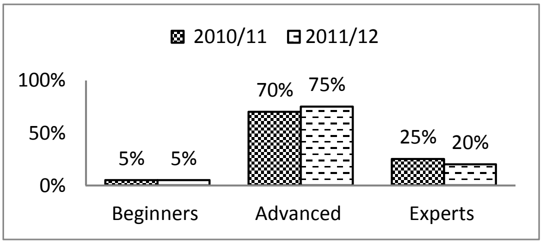

Fig. 6. Division intos groups by test results. Informatics I. End of fall semesters 2010 - 2011

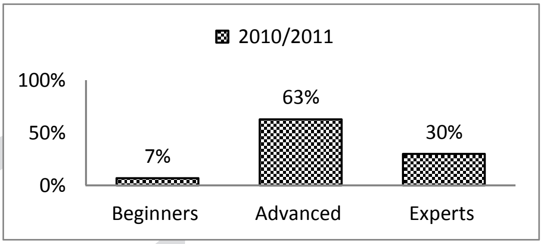

Fig. 7. Division into groups by test results. Informatics II. End of spring semester 2010

The introduction of a differentiated and flexible approach to learning has led to *increased* academic achievements.

The percentage of academic achievements is follow (Fig. 8, Fig. 9):

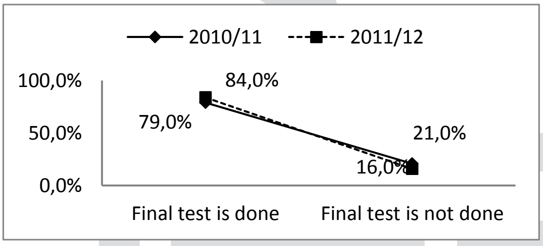

Fig. 8. Situation in Academic Achievements in Informatics I: fall semesters 2010 - 2011

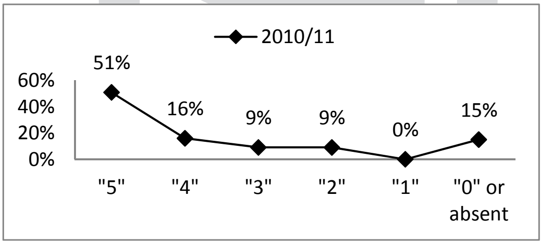

Fig. 9. Situation in Academic Achievements in Informatics I: spring semester 2011

These data suggest that the division of students into groups based on their prior knowledge and implementation of modern e-technology has a positive effect on learning and provides opportunities for more effective training of students and teachers for creative work.

However, much additional further work needed to *adapt the curriculum* and increase student interest and motivation.

3. Further work

Our further work is analysis of academic achievements of students in spring semester of 2011/12. Major work in our chosen direction is more depth studying and analysis of students' data and adaptation of curricula and teaching materials in accordance with their interests, goals, preferences and individual characteristics. It is planned to make the enhanced students' e-portfolio in e-environment with information about their personal achievements and personal qualities on the basis of these data. These portfolios should give teachers information about students in order to improve the quality of teaching, and students - stimulus to learn better.

4. Summary

In conclusion it could be said that the transition to e-learning and differentiated approach to the student allowed us to increase and diversify the teaching materials and assignments without increasing the hours of subjects. It was possible to promote independent student work in parallel with the learning process by advanced tools for better understanding and effective learning. The level of courses attractiveness has increased. We managed to avoid the falling of the level of motivation. All this has led to increased levels of academic achievements, proving the effectiveness of a flexible approach to learning.

A new problem solving method, used by us in training - computational thinking teaches students to analyze and logically organize the data, modeling, correct problem formulation, possible solutions, automation and generalization, and use this solution to other problems.

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