Online Tools and Remote Labs for Making ICT More Attractive for Students to Prevent Dropout

Raivo Sell, Tiia Rüütmann, Kristina Murtazin
Tallinn University of Technology
Tallinn, Estonia

Külli Kori, Margus Pedaste, Heilo Altin
University of Tartu
Tartu, Estonia

Abstract—**Dropout in ICT studies is a big problem all over the world. This paper gives an overview of research in Estonian ICT student dropout and shows that progress in mathematics and programming courses is important in preventing dropout. Online tools could be used for making these kinds of courses more attractive and effective for students. Possibilities of online tools and two different conceptual remote labs are described in this study in more detail and a combined solution for preventing students' dropout is presented.**

Keywords—online tools, remote labs, robotics, student dropout

I. INTRODUCTION

There is a worldwide problem in the ICT labor market – lack of workers with good ICT knowledge and skills. In the European Union a forecast predicts that the unmet demand for ICT practitioners could, according to different scenarios, rise to 481,000–1,685,000 by 2020 [1]. However, these scenarios do not take into account the problem that the number of computer science graduates in the European Union has been decreasing since 2006 [1]. The forecast for Estonia suggests that by the year 2020, the number of higher education graduates needed will be between 6,661 and 8,456 [2]. If all ICT students who should start (number of available study positions) studying ICT in Estonia graduate as well, the number of higher education graduates will meet the demand of the labor market [2]. Unfortunately, many students will drop out of their studies, and the problem is worldwide.

In Estonia, the students who drop out will often still enter the ICT labor market, and therefore, more and more ICT workers do not have a higher education degree. Preventing dropout is becoming increasingly important, since a higher education degree is more valued worldwide. A study carried out in the USA (2000–2005) showed that the importance of a Bachelor's or higher degree in most ICT occupations had grown [3]. In addition, employees with higher education earned more within the same occupation [3]. Therefore, it is more beneficial for students if they finish their studies in ICT.

Engineering education today provides high-level engineering competences. Technology plays a key role in transforming classrooms into flexible and open learning spaces. Technology improves the equity, quality and attractiveness of educational opportunities, building creativity and making learning more student-oriented, leading to inquiry, helping to deliver learning materials, and supporting teacher activities [4]. Developments in educational technologies have produced new learning environments, online tools, remote laboratories, virtual experimentations, simulations, educational games, visualizations, mobile and robotic applications, etc. [5, 6, 7, 8, and 9].

By combining new technologies in e-education, our research results offer new ways to prevent dropout as well as encourage young people to choose engineering curricula, including various ICT curricula. One of the attractive applications in ICT technology is robotics. Robotics is quite popular among students, offering a 'touch and feel' experience for complex subjects, such as programming, mathematics, and physics [7]. The result of the programming activity can be immediately turned into a real world application. One of the drawbacks of applying robotics in ICT studies is the relatively high cost of the hardware and other consumables needed for a proper robotics course. In recent years, several research projects and other activities have been focused on online experimentation by trying to develop solutions for real remote experimentation in addition to simulated experiments [6]. Remote experimentation in robotics allows accessing robotic devices remotely and experimenting with programming without limitations in terms of cost and time as well as other resources.

The paper has three logical parts. In the next chapter, an empirical study about students' dropout is shortly presented and the problem of dropout is illustrated based on data collection in Estonian universities. The second part gives an overview of engineering education and online tools, and the third part presents an example system developed in Tallinn University of Technology in cooperation with an SME. The remote labs are described briefly, but more information is available in papers [5, 9].

II. ICT STUDENT DROPOUT

Dropout in ICT related curricula is considered to be a problem in many countries; the average student dropout rate for computer science students in Europe is around 19% [1]. According to the data collected during the first year of bachelor studies, ICT students in Estonia and many other countries are taught basic subjects, such as mathematics and programming, which are important in further ICT studies. Divjak et al. [10] have shown that mathematics courses are often too complicated for students, and this is considered to be one of the reasons for withdrawing from the study programs. Programming courses are also found to be difficult for many higher education students; in this case, the failure rates are quite high – based on the systematic literature review of introductory programming, the mean worldwide pass rate in an introductory programming course in higher education institutions is 67.7% for ICT students [11].

Based on this review, we can argue that dropout from ICT studies and specific basic courses of these, e.g., mathematics and programming is an important problem to be solved. There is a need to find new interventions in teaching to lower dropout rates. In this study we hypothesize that combining online tools in teaching could help prevent dropout. Therefore, students' dropout should be investigated to understand what influences dropout and if dropout rates can be lowered by online tools.

To solve the research problem we have collected data from ICT students who started their studies in school year 2013/2014. Data was collected in Estonia from three universities and seven different curricula: Computer Science and Computer Engineering curricula at the University of Tartu (UT); Computer and Systems Engineering and Business Information Technology at Tallinn University of Technology (TUT); and IT Systems Administration, IT Systems Development, and Information System Analysis at the Estonian Information Technology College (EITC). Together, these three higher education institutions graduate the vast majority of the bachelor and master students in ICT in Estonia [12].

Some data were collected electronically during the admission process from all ICT student candidates. The Estonian Admission Information System (SAIS) was used for data collection. This is a service (www.sais.ee) for submitting electronic applications securely over the Internet when applying for study at Estonian universities, colleges, and vocational schools. Firstly, some information about students' background was collected, e.g., gender, last school where they studied, results of the mathematics state exam, universities and curricula they applied for. [12]

During studies, data were collected by using two questionnaires: (1) at the beginning of studies and (2) after the first semester. The aim of the questionnaires was to understand how students felt during the studies and what influenced their motivation, their previous experience related to ICT, reasons for studying, knowledge about the studies in their curriculum, and plans for the future.

Information about the dropout of the students during the first year of studies was collected from the student information systems of the higher education institutions.

783 ICT students in total entered the universities, 301 of whom participated in data collection, answering the questionnaires at the beginning of their studies and at the end of the first year, as the data were collected in two parts. The others did not fill in all the necessary questionnaires. 28% of the students were female – this is similar to the gender distribution in ICT studies in Estonia, where about 25% of the students are female. The youngest student was 18 years old and the oldest 43 years old; the average age of the students was 20.

According to the information, the average rate of ICT students who dropped out during the first study-year was 32.2%. The minimum rate of dropout in different universities was between 25.5 and 35.8%. The scores of the mathematics state exam taken at the end of high school were also collected during the admission process. The scores were divided into five categories: (1) 0–20 points; (2) 21–40 points; (3) 41–60 points; (4) 61–80 points; (5) 81–100 points. The average mathematics state exam score among the students who continued their studies after the first study-year was 4.2, whereas the average score among the students who dropped out during the first year of studies was 3.3. The difference was statistically significant ($p<0.05$), showing that performance in mathematics affects studies in higher education institutions for ICT students. In addition, other studies have shown that mathematics courses in higher education institutions are difficult and an obstacle for retaining ICT students [13]. Based on the results, it can be suggested that using online tools could support students' learning in mathematics, so that fewer students will drop out of their studies.

Programming courses are also considered to be difficult for some first-year students and are considered a factor increasing students' withdrawal (dropout) [14]. According to the results of the questionnaire for ICT students, 53% of them started studying programming at higher education institutions; 84% had had informatics courses at school; only 7% had already studied programming; 2% had studied website creation at school; and 16% had never studied informatics or programming. It was found that the students who had learned programming before university had higher weighted average grades (the mean weighted average grade was 3.56) in the first semester than the students who started learning programming at the university for the first time (the mean average grade was 3.21). So, the students who have learned programming before university are at an advantage at least in the first study year compared to those who start learning programming at the university for the first time. Moreover, the students who show lower academic performance in the first year are more likely to drop out later [15]. So, in addition to mathematics, programming courses could also be supported by online tools to lower dropout rates.

III. ENGINEERING EDUCATION AND ONLINE TOOLS

"If students don´t want to learn the way we teach, maybe we should teach the way they learn." - Ignacio Estrada

Online education has been strongly enhanced after the Bologna Declaration, which has contributed to the shift in the learning focus from the university to the student, with an emphasis on "learning by doing" using online laboratories. In this scenario, laboratory activities are considered essential for increasing the effectiveness of teaching and learning in engineering.

According to [16], research indicates that in the next five years, the following existing technologies have "clear and immediate potential" to be applied for teaching and learning: (1) Online Experimentation (including Virtual and Remote Laboratories), which has been a key trend alongside other technologies, such as (2) Cloud Computing, (3) Mobile Learning, (4) Open Content, (4) 3D Printing, (5) Blended Learning (including Flipped Classroom), (6) Augmented Reality, and (7) Virtual Reality (including Simulations).

In today's ICT-enhanced teaching/learning, a shift from e-learning to cloud and m-learning has occurred. It offers new possibilities to structure and perform effective and motivating learning processes. However, using technology to enhance education does not mean that we should move classes totally online. Students need face-to-face social interaction [4]. The point is not only to "teach with technology" but to use technology to convey content more powerfully and efficiently, taking into account the learning styles of our current students. This is why flipped classroom and active learning have turned into some of the most effective technologies in teaching engineering [17]. The net-generation, e-/i-generation, digital natives and other definitions in use describe the characteristics of the current students [4]. They have also been called the C-generation, or generation C, where C stands for cloud [18].

The most effective online tools in engineering education aim for a blended experience and flipped classrooms, where lectures are delivered online by adding videos, problems to be solved and exciting tools but personal contact is retained – and augmented – by working on problems together in team-based learning and virtual group work.

New teaching methods may be integrated in teaching, while using online experimentation and flipped classroom [19, 20, 21, and 22]. The current technology allows students to be immersed into impossible spaces or environments thanks to virtual reality techniques. Online experimentation helps students to better understand the real behavior of the concepts they learn in class, thus comparing theoretical calculations they learn with the real world processes [see also 6].

Online experimentation is one of the highly powerful tools of blended and creative learning, promoting inquiry and helping students to higher-order cognitive skills (such as critical thinking, applying, synthesizing, decision making, and creativity), thus providing a deep understanding of the material to be learned and didactically integrating labs into collaborative and team-based learning systems in order to create and share materials [see 6]. Online experimentation is based on the constructivist learning approach in general and inquiry in particular, enhancing curiosity and motivation and developing multi-perspective thinking [5].

Personal and mobile devices, such as tablet PCs and smart phones offer increasingly valuable support for creative learning. Students only need to have Internet access in order to be engaged in blended and online learning and build up their own knowledge by online experimentation reaching for original ideas. Online tools make students learn more independently, help them search for information, plan and conduct experiments, make decisions, and foster their ability to think about questions or problems from different perspectives.

IV. Robotics and Online Experimentation

One of the attractive applications in ICT technology is robotics [7]. Robotics is quite popular among students and offers a 'touch and feel' experience for complex subjects, such as programming, mathematics, and physics. The result of the programming activity can be immediately turned into a real world application. One of the drawbacks of applying robotics in ICT studies is the relatively high cost of the robotics hardware and other consumables needed for a proper robotics course. In recent years, several research projects and other activities have been focused on online experimentation by trying to develop solutions for real remote experimentation in addition to simulated experiments. Remote experimentation in robotics allows accessing robotic devices remotely and experimenting with programming without limitations in terms of cost and time as well as other resources. In the framework of research and educational projects [23, 24, and 25] and in cooperation with the industry, a fully functional remote lab system is being developed. Below, two different remote labs and online experiment concepts extracted from our remote lab system are described.

A. Remote Lab for Microcontroller Programming

Nowadays, the most required skills in engineering are related to integrated systems. There is a huge lack of educated software developers. Software development is not a pure ICT skill any more but also very much needed for mechatronics, robotics, etc. It is also well known that learning and teaching programming for robotics and other integrated systems is not a trivial process, as it requires specific hardware study kits. These kits are often quite expensive and not accessible for students on required time and place. This results in loss of interest in studying programming and related engineering subjects. A remote lab solution can contribute significantly to solving this issue. Hereafter, a robotic and microcontroller programming remote lab solution is presented in detail.

The remote lab system has a hierarchical structure where lab hardware devices are grouped into logical labs, which are often also physical labs. At the same time, all labs are grouped into "Location", which usually also refers to a physical location, e.g., university. The devices are additionally grouped into several sub-groups according their type: mobile robots, manipulators, PLC-s, etc. A video feedback system is connected to one lab (usually two cameras) or to every device. The number and focus of video cameras is related to the nature of the lab. In the case of moving objects, such as mobile robots, the lab usually has general cameras focusing on the arena where robots can drive around. As for attached devices, such as Robotic HomeLab test bench or manipulator, every device has its own camera. In this case, the camera can precisely focus on the device [9]. The microcontroller remote lab, which is based on the Robotic HomeLab kit, has a browser based programming interface. The user can insert a microcontroller specific code, compile it and upload to the booked device. After a successful upload, the user can open a real-time video link and see the real system running the user program. Fig. 1 below illustrates the user interface of the remote lab focusing on the remote programming of the microcontroller based system.

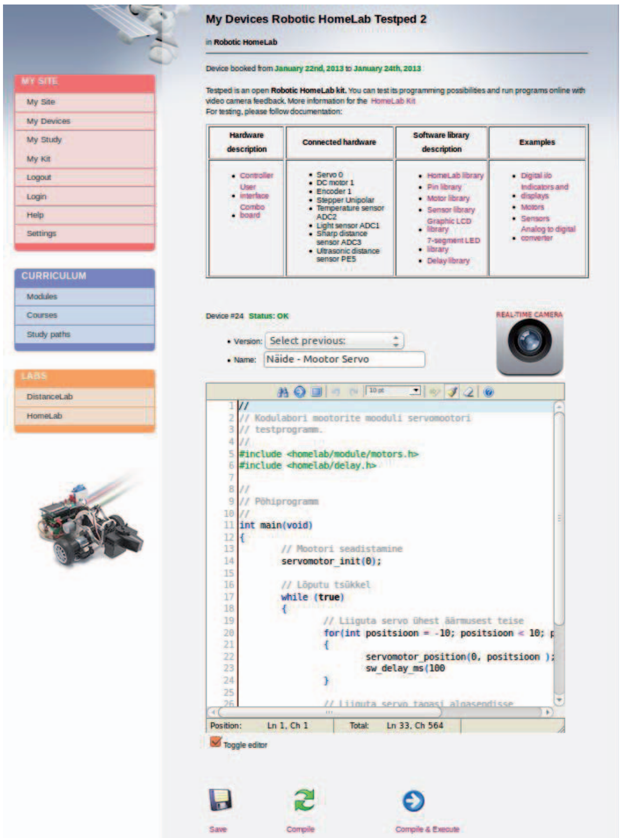

Fig. 1. C-programming interface of microcontroller remote lab: DistanceLab in robolabor.ee

B. *Remote Lab for 3D Printing*

In contrast to the pure programming interface, there are also several specific device dedicated remote labs. The purpose of these kinds of labs is, above all, to learn and use a specific device rather than acquire general knowledge, such as programming. However, the different types of labs can be successfully hosted in the same remote lab portal as it archived in remote lab portal - the host system of remote lab centers [9]. Here, an interface of a popular 3D printer lab is shown (Fig. 2).

Fig. 2 demonstrates that the host system is the same as in the C-programming lab, but the device specific interface is completely different. This feature allows hosting very different kinds of remote labs in the same system.

The purpose of applying the remote lab in the study process is to save the cost of hardware by sharing it with other universities or organizations and allow students to access real hardware remotely by eliminating the limitations of lab opening time and location. As a result, this solution offers a great opportunity to reduce the risk of losing interest in studying engineering subjects, including programming in ICT and therefore lowering dropout from ICT curricula.

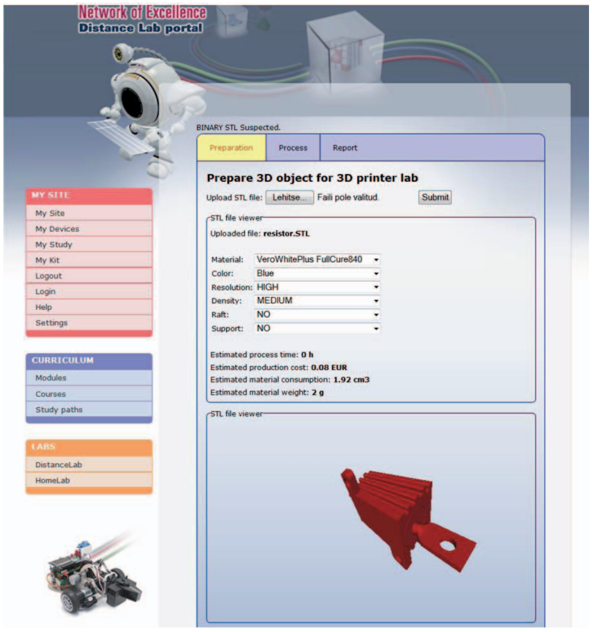

Fig. 2. 3D printing interface - Preparation view

V. CONCLUSIONS

Our studies have shown that many ICT students drop out of their studies and therefore, new methods to support their learning are needed. In three Estonian higher education institutions, the drop-out rate was 32.2% already during the first study year, which is higher compared to the international average. The students who dropped out also had a lower score in the mathematics state exam. Therefore, we argue that a change in learning methods is needed already in the comprehensive school.

Integration of contemporary online tools into modern personal learning activities offers novel opportunities to foster students' creative learning in engineering education: developing self-reflective and independent learning skills, tackling curiosity and motivation, evolving multi-perspective thinking, and reaching for original ideas. Students reach high-level learning outcomes, develop basic fundamental competences, and develop responsibility. For reducing student dropout, the principles of contemporary engineering education – the use of online tools, including flipped classroom based on creativity, critical thinking, communication and collaboration, providing virtual group work and team-based problem solving – should be taken into account.

Thus, contemporary motivating engineering education has moved to providing new transformation tools, from e-learning to portable m-learning and mobile services, and is thus using the latest mobile devices and requiring new skills from students and teachers. Flipped classroom along with online experimentation, simulations, educational games, and online questioning taking account of students' different learning styles and individual differences has become a powerful and motivating tool in teaching engineering.

The combined solution to prevent dropout is described as a blended learning concept which includes online tools and different forms of e-learning and methodology combining everything together. Based on our data analysis, it is clearly seen that students' initial interest and motivation in studying ICT must at least be sustained, but also risen. This is only possible if the study process is supported by contemporary learning and teaching technologies as well as appropriate methodology. If students feel that ICT is taught in a conventional way and through a classical lecture-practicum approach, they will lose their motivation and dropout will increase rapidly.

ACKNOWLEDGMENT

This research was supported by the European Union through the European Regional Development Fund. It is financed in the project "Conceptual Framework for Increasing Society's Commitment in ICT: Approaches in General and Higher Education for Motivating ICT-Related Career Choices and Improving Competences for Applying and Developing ICT". The research of online tools development was supported by Estonian Research Council grant ETF8652 and USORA framework.

REFERENCES

[1] Hüsing, T., Korte, W. B., Fonstad, N., Lanvin, B., van Welsum, D., Cattaneo, G., Kolding, M., & Lifonti, R. "e-Leadership. e-Skills for Competitiveness and Innovation Vision, Roadmap and Foresight Scenarios Final Report," 2013. Available: http://ec.europa.eu/enterprise/sectors/ict/files/eskills/vision_final_report_en.pdf

[2] Jürgenson, A., Mägi, E., Pihor, K., Batueva, V., Rozeik, H., & Arukaevu, R. „Eesti IKT kompetentsidega tööjõu hetkeseisu ja vajaduse kaardistamine" (in Estonian). Praxis, 2013. Available: http://www.kutsekoda.ee/fwk/contenthelper/10373139/10493920/IKT_uuringu_l6pparuanne.pdf

[3] Sum, A., Khatiwada, I., & Palma, S. "Employment Prospects in Information Technology Jobs for Non-College-Educated Adults," Challenge, vol. 50, no. 1, pp. 97-114, 2007.

[4] Rosen, L.D (2010). *Rewired: Understanding the iGeneration and the Way They Learn,* Palgrave Macmillan

[5] Sell, Raivo; Rüütmann, Tiia; Seiler, Sven. (2014). Inductive Teaching and Learning in Engineering Pedagogy on the Example of Remote Labs. International Journal of Engineering Pedagogy, 4(4), 12 - 15.

[6] Pedaste, M.; de Jong, T.; Sarapuu, T.; Piksööt, J.; van Joolingen, W. R.; Giemza, A. (2013). Investigating ecosystems as a blended learning experience. *Science*, *340*(6140), 1537 - 1538.

[7] Altin, H.; Pedaste, M. (2013). Learning approaches to applying robotics in science education. *Journal of Baltic Science Education*, *12*(3), 365 - 377.

[8] Kori, K.; Pedaste, M.; Leijen, Ä.; Mäeots, M. (2014). Supporting reflection in technology-enhanced learning. *Educational Research Review*, *11*, 45 - 55.

[9] Sell, R. "Remote Laboratory Portal for Robotic and Embedded System Experiments", International Journal of Online Engineering 2013; vol. 9 Special Issue: Exp.at'13,pp. 23-26, 2013.

[10] Divjak, B., Ostroski, M., & Hains, V. V. "Sustainable Student Retention and Gender Issues in Mathematics for ICT Study," International Journal of Mathematical Education in Science and Technology, vol. 41, no. 3, pp. 293-310, 2010.

[11] Watson, C. & Li, F. W. B. Failure Rates in Introductory Programming Revisited, Proceedings of the 2014 conference on Innovation & technology in computer science education, pp. 39-44, 2014.

[12] Kori, K.; Pedaste, M.; Niitsoo, M.; Kuusik, R.; Altin, H.; Tõnisson, E.; Vau, I.; Leijen, Ä.; Mäeots, M.; Siiman, L.; Murtazin, K.; Paluoja, R. "Why do students choose to study Information and Communications Technology?" The European Procedia Social and Behavioral Sciences (x).Elsevier [in press], 2014.

[13] Chen, R. Institutional Characteristics and College Student Dropout Risks: A Multilevel Event History Analysis. Research in Higher Education 53: 487–505, 2012.

[14] Watson, C. & Li, F. W. B. Failure Rates in Introductory Programming Revisited, Proceedings of the 2014 conference on Innovation & technology in computer science education, pp. 39-44, 2014.

[15] Allen, J., Robbins, S. B., Casillas, A. & Oh, I.-S. "Third-year College Retention and Transfer: Effects of Academic Performance, Motivation, and Social Connectedness", Research in Higher Education, vol. 49, pp. 647- 664, 2008.

[16] Dziabenko, O.Garcia-Zubia, J. (2013) IT Innovative Practices in Secondary Schools: Remote Experiments. University of Deutso

[17] Zappe S, Leicht R, Messner J, Litzinger T, Hyeon W.L., "Flipping" the Classroom to Explore Active Learning in a Large Undergraduate Course, ASEE Annual Conference & Expo, 2009.

[18] Pickett, P. (2012).Who Is Generation C? Characteristics of Generation C. How Can You Categorize These Digital Natives? About.com, http://jobsearchtech.about.com/od/techindustrybasics/a/Generation_C.htm (20.11.2014)K

[19] Kipper, H.; Rüütmann, T. (2013). Teaching for Understanding in Engineering Education. International Journal of Engineering Pedagogy, 3, 55 - 63.

[20] Pedaste, M.; Mäeots, M.; Leijen, Ä.; Sarapuu, T. (2012). Improving Students' Inquiry Skills through Reflection and Self-Regulation Scaffolds. Technology, Instruction, Cognition and Learning, 9(1-2), 81 - 95.

[21] Mäeots, M.; Pedaste, M.; Sarapuu, T. (2009). Developing students' transformative and regulative inquiry skills in a computer-based simulation. In: Proceedings of the IASTED International Conference on Web-based Education: The Eighth IASTED International Conference on Web-based Education; Phuket, Thailand; 16-18 March 2009. (Toim.) V. Uskov. ACTA Press, 2009, 60 - 65.

[22] Pedaste, M.; Sarapuu, T. (2007). Web-based Inquiry Learning Environment "Young Scientist". In: Proceedings of the IASTED International Conference on Web-based Education (WBE): Chamonix, France; 14-16 March, 2007. (Toim.) V. Uskov. Calgary: ACTA Press, 2007, 35 - 40

[23] Learning Situations for Embedded System Study Lab – NetLab, 2011-0019-LEO05-TOI-01, Life Long Learning project, 2011.

[24] Unified Solution of Remote Access in Practical Vocational Engineering Education - USORA, 2013-1-PT1-LEO05-15527, Life Long Learning project, 2013.

[25] Virtual & Distance Labs environment for Industrial Engineering education - ViReal, LLP-LdV-TOI-2012-LT-0104, Life Long Learning project, 2013.