Abstract. The interruption of contact group work in universities due to coronavirus quarantine in the spring semester of 2020 posed serious problems for all courses that used traditional approaches to organization laboratories, control tests and examinations. In contrast to this, the mobile task-based learning ISC-system, characterized by flexible individual time schedule planning and application of mobile home lab kits for practical tasks, demonstrated almost complete immunity to emergency isolation requirements. ISC is a task-based e-learning system developed in Tallinn University of Technology since late 90s (abbreviation ISC comes from code of Chair of Circuits and Systems). In this system a learning process without teachers’ continuous interference is implemented and the students can practice as much as needed to get the grade they desire. As an additional beneficial feature, system allows teacher to monitor the detailed activities of students related to solving the hundreds of theoretical and practical tasks associated with actual study course. In paper we formulate the key features of the newest 3rd generation version of ISC-system, provide an assessment of immunity of ISC-system key features to quarantine conditions and present a study of student behavior changes due to the quarantine conditions on the basis of more than 216,000 task solving records from years 2019 and 2020.

Keywords: Task based learning · Competence based learning · Mobile home laboratories · Flexible timeschedule learning · Student data analysis

1 Introduction

Due to the COVID-19 crisis and following the actions taken by many countries, on March 12th 2020 the Estonian Government established the quarantine rules that recommended to cancel all public events including classroom work in schools. Universities were forced to switch to distance learning that lasted actually until the end of the spring semester in June. Those special circumstances revealed that surprisingly many teachers, using still traditional learning technologies, faced noticeable difficulties with organization of practical laboratories, control works and exams in classrooms with fixed time schedule. From viewpoint of modern IT-supported teaching technologies, these time- and space-limited student progress control methods can be considered as unnecessary bureaucratic waste of time that takes away teacher's time from creative
supervision or task design work. In contrast to abovementioned difficulties faced by courses relying on traditional approaches, the mobile task-based learning ISC-system [1–8] with mobile home laboratories and flexible individual time planning demonstrated almost undisturbed functioning in emergency isolation conditions.

In the present paper we touch the following themes:

1) A detailed classification of innovative key features of task-based mobile ISC-system in order to give the reader a basis for comparison with other learning systems and to prepare a logical structure for user satisfaction surveys for the system improvements in future;
2) Assessment of quarantine readiness of ISC-system using the constructed list of key features;
3) Study the student behavior changes due to coronavirus quarantine on the basis of more than 216000 task solving records from years 2019 and 2020.

2 Characterization of Task-Based Mobile ISC-System

Actually the development of interactive e-learning technologies in Department of Computer Control at Tallinn University of Technology (TUT) by the working group of Prof. Vello Kukk was started already in 1998 [1]. At that one of the main ideas was replacement of traditional lectures and exams based learning with solving of large number of tasks online.

In the 2003 the online evaluation of answers and systematic storing of test performance records in database was started that may be considered the launching time of the 1st generation of ISC-system [1, 6]. Abbreviation ISC comes short code of former Chair of Circuits and Systems in Department of Computer Control. In 2005 the first version of Home Laboratory Kits (HLK) and in 2007 the 2nd version of HLKs were introduced (see Fig. 1).

Fig. 1. Home Laboratory Kit of ISC-system. The crucial hardware component of the system to ensure the site-independent learning.
With introduction of HLKs the ISC-system acquired an important mobility feature that ensured that the same practical test tasks could be performed by students at home, in training lessons and also in control works in university classroom [1]. HLK contains components for basic electronics including signal generator and oscilloscope or optional microprocessor programming board [9].

Starting from 2010 the competences based evaluation (in contrast to subjects based evaluation) and the opportunity for self-decided grade acceptance (i.e. free individual course ending choice) were offered for students [2–6]. This may be associated with development of 2nd generation of ISC system that ended in 2017 [2]. Competence-based assessment forces students to penetrate more into the content of tasks and makes more difficult mechanical memorizing of the correct answers. The introduced volume-quality map for self-decided grade acceptance is illustrated by Fig. 2 below.

In 2017–2018 was started development of 3rd generation of ISC system [7, 8] by introducing more reliable php-language based programming, a compact one main page design, immediate ubiquitous switching between Estonian and English presentations, better compatibility with mobile phones and tablets, and readiness for remote laboratories. In May 2020, the quality sign of Estonian Information Technology Foundation for Education HITSA was awarded to the ISC-system [10]. The convenient compact design of main working field of 3rd generation ISC-system is shown in Fig. 3 below.

![Fig. 2. Volume-quality plane of student progress. Grade areas from “1” to “5” are shown by colored zones. The right end point of yellow progress line shows the currently achieved grade by tasks confirmed in control work mode in university classroom. The black line characterizes the home made tasks that are not yet confirmed in control work mode in university.](image-url)
Up to now system has been used by more than 5400 students who have obtained over 5300 grades from over 40 courses in between 2003 and 2020. Some important moments of ISC-system development timeline are summarized in Table 1.

By now, ISC-system has been used by 5 institutions in 2 universities:

1) Tallinn University of Technology;
2) Tallinn College of Tallinn University of Technology;
3) Virumaa College of Tallinn University of Technology;
4) Tallinn University;
5) Haapsalu College of Tallinn University.

**Fig. 3.** The one main working screen design of ISC-system [7, 8]. Colored boxes show the state of competences (or tasks) associated with the course. White indicates yet unresolved competences/tasks, light green marks exceeding of the threshold (77) and dark blue reaching an excellent level of ability (118–127). Line above the colored boxes show the available other courses. Right part of screen serves for ordering of Home Lab Kits, for reservation of labs (i.e. training lessons in classroom) and reservation of test places (i.e. control work hours in classroom to confirm the tasks made at home). The language switch button is on the top right part of screen. Button “Homework” serves for uploading of the optional homework files in pdf-format. Teachers can switch between modes “teacher”, “design of new tasks” and “testing as student”.

Up to now system has been used by more than 5400 students who have obtained over 5300 grades from over 40 courses in between 2003 and 2020. Some important moments of ISC-system development timeline are summarized in Table 1.
3 Formulation of Key Features of ISC-System

In order to construct a methodology of assessment and development of innovative learning systems, it is reasonable to construct a list of main features that are expected from an advanced learning system.

Below in Tables 2 and 3 is proposed one possible formulation of key features of the ISC-system. Table 2 describes the 7 main key features with the comments and Table 3 adds the 9 secondary key features of ISC-system. First reason for this kind of decomposition is to give the reader the opportunity to compare with other similar systems. Another reasoning is preparation of the logical structure for introducing feature-based questions for user satisfaction surveys for the further improvement of the system.

### Table 1. ISC-system development timeline facts.

| Characteristics                  | Years          | Comments                                                                                                                                                                                                 | Generation |
|----------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Instant feedback and database    | 2003 spring    | Online answer evaluation and systematic functioning via database introduced                                                                                                                                | 1          |
| Student’s memory model           | 2007, 2010     | Exponential model 2007 – 2010, power law model from 2010 [1, 2]                                                                                                                                               |            |
| Home laboratory kits HLKs        | 2005, 2007     | Mobility feature realized, HLK version 1 in 2005, version 2 in 2007 [1]                                                                                                                                 |            |
| Competence based control         | 2010           | Multiple atomic competences corresponding to every learning task                                                                                                                                             | 2          |
| Self-decided grade               | 2010           | Student decides grade accepting moment by achieved quantity and quality                                                                                                                                     |            |
| Value added mode                 | 2015           | Different individual starting levels of students considered [4]                                                                                                                                              |            |
| Distant laboratories             | 2017–2020      | Remote use of permanent laboratories in university (under development)                                                                                                                                      | 3          |
| Reprogramming and redesign       | 2017–2020      | Reliable and compact one main page design, ENG/EST double language operation [7]                                                                                                                            |            |

### 3 Formulation of Key Features of ISC-System

#### Table 2. Decomposition of main key features of ISC-system.

| No. | Short denotation | Explanation                                                                                                                                  | Reasoning                                           |
|-----|------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| 1.  | TBL/CBL          | Task/competence based learning. Student must solve a great number of tasks to achieve wanted grade (see Figs. 2 and 3 above)                  | Solving of tasks stimulate engineering creativity    |
| 2.  | IAF24/7          | Immediate automatic feedback 24/7. (Exception is greater homeworks with report in pdf format)                                              | Makes possible place-independent and all-time learning. High student satisfaction |

(continued)
Table 2. (continued)

| No. | Short denotation | Explanation | Reasoning |
|-----|------------------|-------------|-----------|
| 3.  | FL2T             | From lectures to tasks. Replacing passive lectures with solving of well-designed training tasks | Lectures are too passive form of learning, more effective is solving of tasks where lecture materials are needed |
| 4.  | HLK              | Home Laboratory Kits | Courses with practical tasks become possible. Real mobility of learning introduced |
| 5.  | FlexCont         | Flexible timeschedule of control works. Student decides itself when to reserve hours in classroom to confirm the tasks solved at home in control work mode | Teacher must not waste time on control works management. Control works occur through all semester. Teacher can use time for preparation of quality tasks |
| 6.  | NoEX             | No traditional exam. Grade is formed on the basis of performed tasks (confirmed in classroom in control work mode) | Teacher must not waste time on management of exams and follow-up exams. However more training classes are needed in the end of semester |
| 7.  | Flexit           | Flexible grade acceptance and course ending | Student can decide how much he/she is ready to work to obtain the wanted grade. Teacher is freed from subjective decisions |

Table 3. List of secondary key features of ISC-system.

| No. | Short denotation | Explanation | Reasoning |
|-----|------------------|-------------|-----------|
| 8.  | 2Lan             | Full double (or multiple) language capability | Learning of international terms (nearly mandatory in IT field!). Accuracy of presentation of tasks. Increased number of involved students. Less need for parallel courses (economy!) |
| 9.  | RepBL            | Repetition based learning. Task must be solved multiple times (5–10) with different data to achieve excellent ability level | Student must assure that the content of task is understood |
| 10. | MeMod            | Memory/forgetting model of student included | Estimate forgetting and compensate loss of knowledge by smart repetition of tasks |
| 11. | LessLec          | Smaller number of lectures planned. Lectures replaced by on-demand training lessons in computer class | Better learning of lecture materials via solving of tasks. Increased efficiency of time usage for teachers and students |

(continued)
Assessment of ISC-System Performance Under Quarantine Conditions

As explained above, the learning process in ISC-system that uses HLKs for practical tasks has a considerable level of freedom in terms of both timing and location. Following the introduction of coronavirus quarantine conditions in Estonia on 12th of March 2020, most of the key functions of the ISC system listed in Tables 2 and 3 retained full functionality despite the cancelling of all group work in classrooms. Only the following few actions were partially affected:

1) Scheduled group training lessons in computer classes;
2) Control works in computer classes for several students at the same time to confirm the home work results;
3) Lending and collecting of home laboratory kits.

Below in Table 4 are commented only those 2 key features from Table 3 that were influenced by the coronavirus quarantine. The remaining 14 key features could be rated “full immunity”.

Table 3. (continued)

| No. | Short denotation | Explanation | Reasoning |
|-----|-----------------|-------------|-----------|
| 12. | MultiParT       | Multiple output parameter tasks | More complex homework type tasks can be included. Difficulty to guess correct answers by random trials without understanding the content. |
| 13. | VarDifT         | Variable difficulty (and weight) of tasks. Teacher can compose tasks with difficulty from elementary level to complex homework type tasks | Freedom of course construction. Possibility to add homework tasks with automatic instant feedback. |
| 14. | SAoL            | Situation Awareness of learning. Availability of detailed individual task- and competence based progress statistics | Students and teachers are aware about exact situation of the learning process. Necessary corrective actions can be planned. |
| 15. | OneScr          | One main screen design | Ease of use. Short learning time. |
| 16. | RemoteL         | Remote laboratories readiness | Sophisticated laboratory tasks with advanced equipment may be included. |
Study of Quarantine Influence on the Student Behavior by the Task Solution Statistics

The previous section provided the feature-based explanation of the reasons why the ISC system retained its core functioning capabilities under quarantine conditions that suspended all direct people contact based group work activities in university. Here, in order to demonstrate the SAoL (Situation Awareness of Learning) capability of ISC-system and to investigate the student behavior changes due to the quarantine, the detailed statistics of task solving is analyzed for 2 courses for spring semesters of years 2019 and 2020. Table 5 summarizes the student numbers for the involved courses.

Table 4. Feature-based assessment of quarantine immunity capability of ISC-system.

| No. | Short denotation of key feature | Immunity to quarantine | Comment |
|-----|--------------------------------|------------------------|---------|
| 4.  | HLK                            | Partial                | Lending and collecting of home laboratory kits was possible only by individual agreements |
| 5.  | FlexCont                       | Partial                | Control works in university computer classroom were suspended. Teacher was able to replace the missing information by individual contacts and the results achieved at home (black progress line in Fig. 2) |

Table 5. Student numbers for two courses of bachelor level involved in statistical study.

| Year and semester | Courses                              | Summary |
|-------------------|--------------------------------------|---------|
|                   | ATR0110 Analogue and Digital Engineering |         |
|                   | ISC0100 Cyber-Electronics             |         |
| 2019 spring       | 76                                   | 50      | 126     |
| 2020 spring       | 53                                   | 73      | 126     |

Table 6 presents the numbers of theoretical (Q) and practical (L) tasks included in the present statistical analysis. The statistical extract in both years corresponds to the period from semester beginning on February 1st until May 28th that is a date corresponding to approximately 1 week after the nominal end of the auditory work in spring semester under normal conditions. The practical tasks were performed either at home or in university with Home Lab Kits. It should be emphasized that summary number of tasks equals 216556 that makes this kind of statistical analysis practically impossible for teachers using traditional non-computerized learning technologies.
Table 6. Total numbers of theoretical (Q) and practical (L) task solving attempts.

| Year and semester* | Courses |      |      |      |      |      |      |      |      |      |      |      |      |
|--------------------|---------|------|------|------|------|------|------|------|------|------|------|------|------|
|                    | ATR0110 | ISC0100 | Summary |
| Q   | L  | Q   | L   | Q   | L   | Q + L |
|-----|----|-----|-----|-----|-----|--------|
| 2019 spring | 46516 | 3137 | 52337 | 3537 | 98853 | 6674 | 105527 |
| 2020 spring | 35369 | 1650 | 70067 | 3943 | 105436 | 5593 | 111029 |

* - Time span is from February 1st until May 28th in both years

Table 7 summarizes the workloads in a more concise form, where the average numbers of task solving attempts per student are presented.

Table 7. Average numbers of solved theoretical (Q) and practical (L) tasks per one student.

| Year and semester* | Courses |      |      |      |      |      |      |      |      |      |
|--------------------|---------|------|------|------|------|------|------|------|------|
|                    | ATR0110** | ISC0100 | Average |
| Q   | L  | L/Q | Q   | L   | L/Q | Q   | L   | L/Q |
|-----|----|-----|-----|-----|-----|-----|-----|-----|
| 2019 spring | 612 | 41.3 | 0.067 | 1047 | 70.7 | 0.068 | 785 | 53 | 0.067 |
| 2020 spring | 667 | 31.1 | 0.047 | 960 | 54 | 0.056 | 837 | 44.4 | 0.053 |

* - Time span is from February 1st until May 28th in both years

** - Number of tasks smaller than for ISC0100 due to 3 mandatory homeworks with high weight

Comparison of student activity in two consecutive years 2019 and 2020 is presented in Fig. 4. One can immediately see that coronavirus quarantine in 2020 changed drastically the student behavior. Since most of traditional courses in university faced serious problems after March 13th and could not offer for students learning tasks, the students of ATR0110 and ISC9100 courses who used the ISC-system started to perform the theoretical and practical tasks with 4-fold activity. It should be emphasized that solving of the practical experiments with Home Lab Kits continued even with higher activity than solving of theoretical tasks. At the same time when ISC-system demonstrated in April and May nearly perfect functioning capability, many other courses in university discussed postponing of exams and laboratory works to the fall semester.
Next, in Fig. 5 is compared the daily activity of students for two consecutive years 2019 and 2020. As one can see, the coronavirus quarantine is shifting the student activity to evening and night hours. Curves reveal also the fact that in year 2019 the students liked to solve the theoretical and especially practical tasks in university classrooms.

Finally, Fig. 6 presents a more detailed comparison of the student daily activities change in year 2020 after establishment of coronavirus quarantine restrictions in university on March 13th of 2020. The results confirm the previous conclusions – shift of activity to evening and night hours and disappearance of 2-h period classroom usage peaks during quarantine.
Fig. 5. Daily activity of students for two consecutive years 2019 and 2020. Upper part a) shows solving of theoretical tasks, lower part b) shows solving of practical tasks with Home Lab Kit. As one can see, the coronavirus quarantine in 2020 is shifting the student activity to evening and night hours. That student activity with practical and theoretical tasks continues until 3AM and 4AM at night time, respectively. The curves of year 2019 are strongly influenced by 2-h period of availability of university classrooms and home activity is remarkably lower than in the case of year 2020.

Fig. 6. Comparison of daily activity of students before and during coronavirus quarantine period for year 2020. Upper part a) shows solving of theoretical tasks, lower part b) shows solving of practical tasks with Home Lab Kit. As one can see, the quarantine is shifting the student activity to homework evening and night hours and the characteristic 2-h period caused by university classrooms availability disappears.
6 Conclusion

The interruption of all contact group work in universities due to coronavirus quarantine in the middle of the spring semester of 2020 posed serious problems for teachers and courses who used traditional approaches to organization of laboratory works, control tests and examinations. In contrast to this, the mobile task-based learning ISC-system developed in Tallinn University of Technology with implemented innovative ideas of flexible timeschedule planning, replacement of exams with continuous task solving and realizing of practical works with mobile laboratory kits, faced no noticeable difficulties due to switching to forced distant learning.

In the present paper we:

- Explained the development timeline and construction logic of the mobile task-based ISC-system;
- Offered a classification of innovative key features of ISC-system;
- Provided an assessment of immunity to quarantine conditions of ISC-system key features;
- Performed a study of the student behavior changes due to the quarantine restrictions on the basis of more than 216,000 task-solving records from years 2019 and 2020.

The results of the statistical analysis show up to 4-fold increase in student activity in April 2020, which can be explained by the low ability of other study courses to switch to distance learning. Another interesting result is the desire of students to work late at night even until 4 o'clock.

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