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Papers

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Developing Students’ Skill to Identify Properties of Cognitive Control Systems

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Abstract—Scientific and technological progress has significantly changed the very process of developing technical devices and significantly complicated their principles. Many modern systems are designed with using knowledge-cognitive systems, and they themselves use hard-formalized and fuzzy rules, often based on big data. Accordingly, there is an urgent task of adapting the modern education system to these changes. Soon, knowledge can't be transferred to trained engineers within the framework of existing teaching technologies; the skills of using, extracting and transforming knowledge become the basis for promising technologies of continuous self-education. This article suggests a model of the structure of cognitive management systems based on control levels. The levels of this model reflect the procedures for transforming of knowledge forms. As practical steps to introduce such an educational approach for engineers, it is proposed to increase the amount of research work of students of technical specialties. The article contains examples of the formulation of problems requiring research in the study of physics, electrical engineering, signal processing and other disciplines. The most simple to implement is the use of a "black box" to conceal the structure of the object for investigation or use non-standard modes and settings of well-known devices, for example, ADCs. Also, approaches are considered for assessing quality of knowledge that obtained under the cognitive control system.

Keywords—cognitive control systems, models of cognitive control systems, research assignments, engineering education

1 Introduction

The necessity of changing the existing engineering educational system is discussing nowadays from different points of view. The main cause of these discussions is a fact that the pace of technological innovations continues to increase rapidly in the twenty-first century. And there are no doubts that the educational system should give new generations of engineers the opportunity to thrive in modern professional environment [2].

In general, the main components of engineering education can be described as knowledge, skills, and attitudes that dictate the goals toward which skills and

knowledge are directed [14]. The process of transformation the educational system influences all these components.

In this paper, predominant attention is paid to one of skills which can be described as ability to identify the system’s emergent properties, capabilities, behaviours, and functions without looking inside the system and its parts/components/details [5]. This skill seems to be crucial so far as the Fourth Industrial Revolution is expected [15], and a person will be surrounded by artificial intellectual systems that will continuously explore an object of control, themselves and environment.

For building these so called cognitive systems, future engineers should have some knowledge about methods of their processing, and be able to extract and use new data and rules. It is necessary to emphasize that an approach to teaching engineering courses is changing: since the volume of information is increasing far more rapidly than the ability of engineering curricula to “cover” it, the focus shifts away from the simple presentation of knowledge toward the integration of knowledge [14]. For instance, in [6] was reported about teaching mathematics within electrical engineering courses; authors of [17] informed of a multidisciplinary course “Engineering Discovery” for first-year students; a model curriculum proposed in [2] merges the disciplines of mathematics, science, engineering, and computing.

The way of organizing the studying cognitive control systems and development students’ skill to identify the system’s properties without looking inside the system is considered below.

2 State of the art

It cannot be said that these issues are not given attention in the modern system of engineering education — research projects are present in university programs for graduated students. For example, students of Electrical Engineering Department of Zaporizhzhya National Technical University study a course “Automation and Informatization of Scientific Research” [1]. According to the framework of this curriculum, such methods of changing knowledge forms as signal processing, fuzzy logic, neural networks, cluster analysis, genetic algorithms, logical programming and others are considered.

However, a lot of study time is spent on learning principles of systems’ component operation, and confirming operability and effectiveness of a certain method. This leads to an undesirable situation when research potential of the future engineers does not accumulate, students do not develop skills to determine and choose a method for investigating an object of unknown structure.

The literature analysis allowed us to reveal some reassuring empirical results about teaching students to deal with such objects, so-called “black boxes”. For instance, in [9] the author described her experience of using black box method both in the classroom and in the education of future physics teachers. The author also noted that although the experiments with black box foster the creativity of students many teachers don’t seem to be familiar with it.

In [7] was reported about a laboratory course of Electrical & Electronics where a black box has been provided to each student during final exams. The authors claimed that in this way a student’s best creativity is highlighted. It is also worth to mention that results of educational researches in another field — a Computer Science/Software Engineering indicate in favour of this approach. In [3] was noted that software testing principles and techniques have been identified as one of the areas that should be integrated early in the curriculum.

We would like to emphasize that time is definitely an important factor for developing students’ research skills. There is no hope that it is possible to ensure appreciable changes during one-semester course at the end of university education. Therefore, it is necessary to create a specially constructed series of task which could be integrated in different courses starting with basic curricula such as Physics and Electrical Engineering.

Another important factor that should not be forgotten is the psychological atmosphere, the style of teacher-student interaction. It is doubtful that first students’ attempts to solve a problem of unfamiliar type will be successful, thus a teacher has to be able to encourage and inspire them.

This work is aimed at presenting a way of purposeful training for students to identify properties of cognitive control systems through several curricula. Certainly, the approach used for forming this skill must be linked to a structure of corresponding systems [10]. Since models of such structure are currently under formation, it was necessary to begin our study from elaboration a model of a cognitive control system.

3 Model of a cognitive control system

The proposed structural model of a cognitive control system is shown in Figure 1. This model describes a cognitive control system in the form of a hierarchy of control levels (from the target to the direct) where subsystems of a corresponding level are located. Describing cognitive systems, it is necessary to determine a knowledge base in a form which is typical for a given level; rules for converting this knowledge into a form of the next level of the knowledge pyramid [13]; goals of management in categories of activities and management functions at a given level.

An activity of a subsystem is formed by a finite-state machine (FSM) of this level and aimed at managing knowledge converters at this level, managing downstream levels and informing a higher level about the results of their activities.

The principle of knowledge homogeneity is applicable to subsystems of each level. According to this principle, both knowledge about a control object which is stored in a knowledge base, and knowledge which is underlying control algorithms can be processed. On the level of computing systems, this principle is known as the Von Neumann principle of memory homogeneity. Application of this principle allows to build hierarchies of controls in which the control device on the i -th level becomes the control object on the higher ($i + 1$) level.

An example of the described model possible application to a system which controls cooling of an oil-filled power transformer is shown in Fig. 2 and Fig. 3.

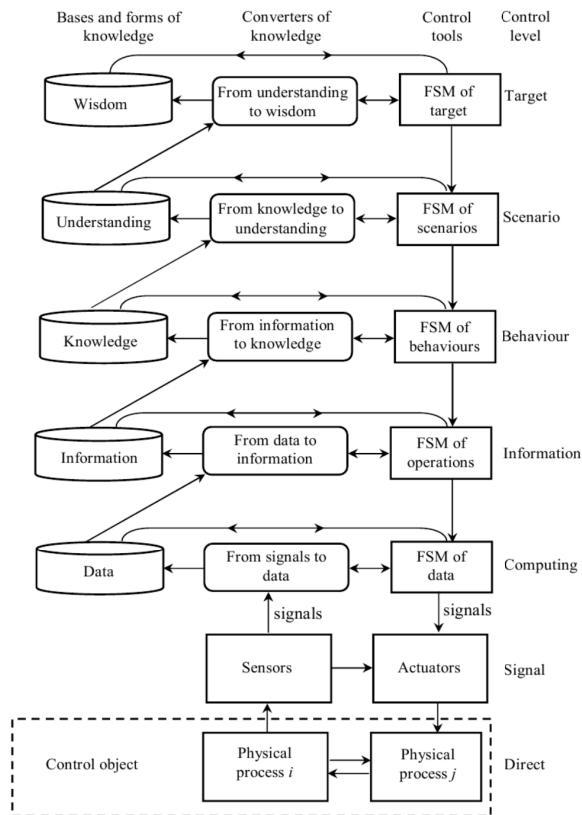


Fig. 1. Model of a cognitive control system

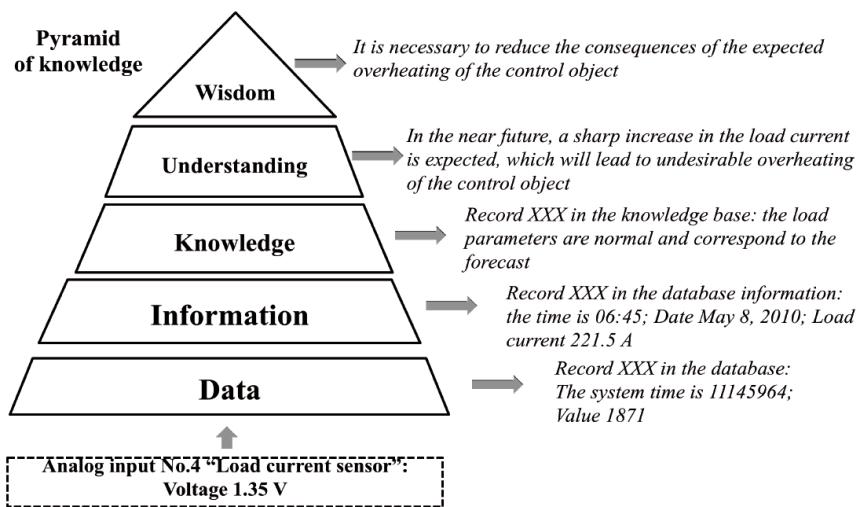


Fig. 2. Elements of a cognitive cooling control system based on pyramid of knowledge

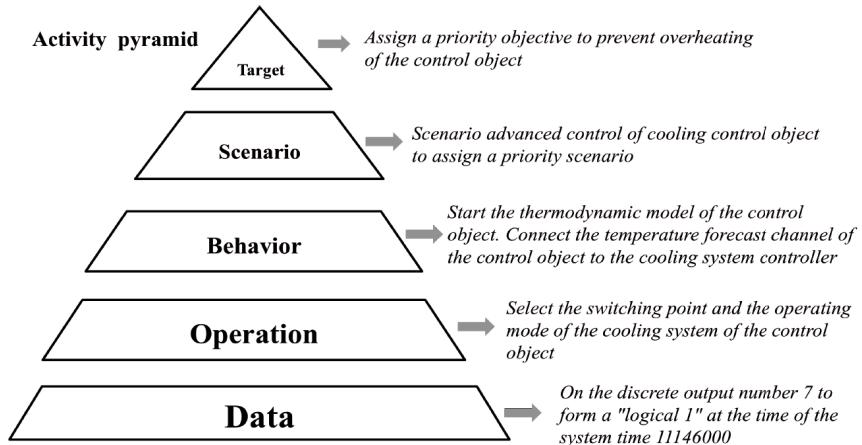


Fig. 3. Elements of a cognitive cooling control system based on activity pyramid

The proposed structural model of a cognitive control system allows to decompose it into simpler subsystems, to identify typical elements, to detail their interfaces and, ultimately, to organize appropriate learning process for students.

Research assignments for students have to include objects with unknown to them structure. A trainee should investigate them by examining signals, data, information, knowledge, understanding, and wisdom. Methods of extracting knowledge of higher forms from knowledge in lower forms must also be studied: data from signals, information from data, etc.

4 Research tasks on the study of a cognitive control systems

In this part of the paper we present a series of assignment examples which might favour the development such important skills for future engineers as commitment to self-education, and ability to work with unknown structure systems.

Example 1 (Physics).A three-pole “black box” with no more than three resistors inside is offered to students. They have to propose possible versions of these resistors connecting, and find their values. Electrical resistance between terminals A, B, and C of a “black box” is known. For carrying out experiments, both real ABC circuits and their software emulators with generators of random resistance values and topology of ABC circuits could be used.

An unexpected but crucial gap in our students' knowledge was found by one of the authors at the beginning of the semester when trainees could not solve this problem. It was quickly elucidated that the difficulty did not connect with knowing corresponding physics formulas. When students had to calculate the resistance between the external outputs of circuits (see Fig.4) almost all of them correctly identified these resistances using formulas for serial and parallel connection of conductors. However, when the group was assigned to research option with a “black box”, most of students could not fulfil the task, and needed a clue. After that the trainees carried out all possible exper-

iments, compiled and solved systems of linear equations for each of the possible configurations of the scheme under study.

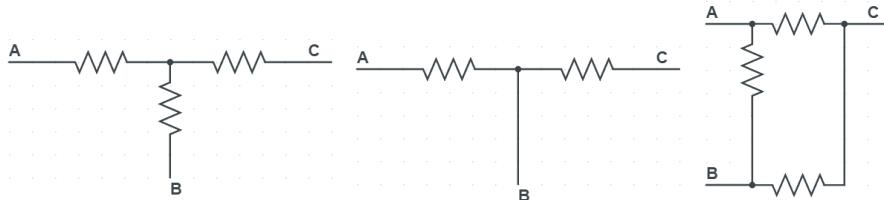


Fig. 4. ABC circuit options

This situation strikingly shows the need to expand the scope of research assignments, and include them in curricula learned from the first days of study at university.

Example 2 (Electrical Engineering). Students have to determine if there are reactive elements or p-n junctions in a circuit.

Such tasks could be used with the purpose of complicating the experiments from the previous example. Semiconductor diodes connected in series or in parallel to the resistors are inserted in the ABC circuit. Students have to diagnose the presence of diodes by differences in measurement results obtained in forward and reverse directions of a circuit.

This assignment could be extended by asking students to measure resistors in the ABC circuit which were connected in parallel to the p-n junctions as it showed on Fig. 5. For fulfilling this task students have to measure resistances at voltages less than 0.3 V when the p-n junctions of the diodes have a high electrical resistance both in reverse and forward directions.

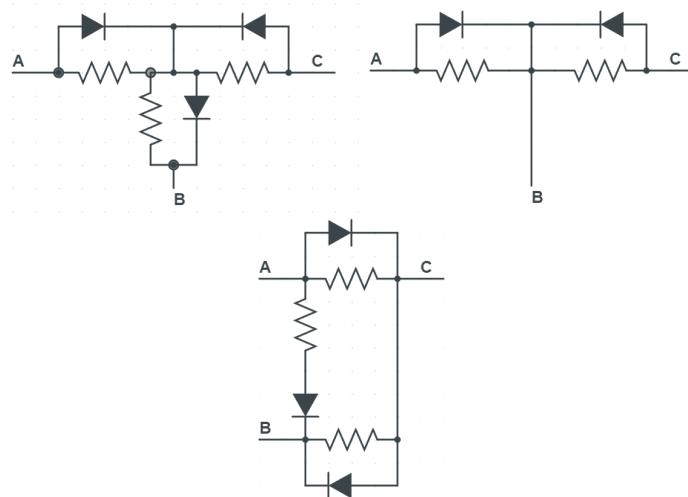


Fig. 5. ABC R-Diode circuit options

Example 3 (Electrical Engineering). Students have to measure a frequency of a harmonic signal using information obtained from digital readings during analog to digital conversion (Fig.6).

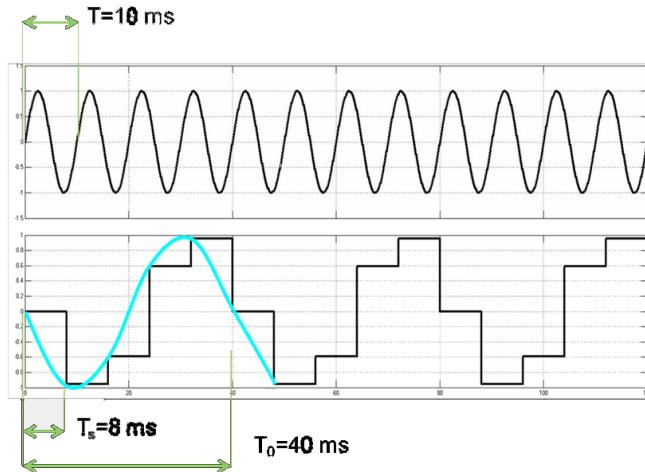


Fig. 6. Definition: T – period of signal; T_s – sampling time; T_0 – period of recognized signal

The standard logic of researchers in this situation is to adjust the analog to digital convertor (ADC) to the maximum sampling rate and get the maximum number of samples. For instance, let a trainee use an ADC at a maximum sampling rate $f_s = f_{\text{smax}} = 175 \text{ Hz}$. As a result of measurements, a number of values are obtained, and on the basis of these values a student's concludes that the original signal had the frequency $f_{01} = 75 \text{ Hz}$ (Fig.7).

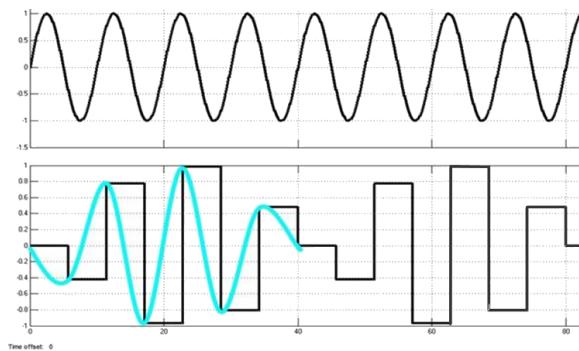


Fig. 7. The results of experiments at a maximum sampling frequency $f_s = f_{\text{smax}} = 175 \text{ Hz}$

However, it is useful to show students that sometimes this statement is not true. An additional experiment with a frequency $f_s < f_{\text{smax}}$ should be performed. Fig.8 shows a number of values obtained at a sampling frequency $f_{01} = 125 \text{ Hz}$. The signal reconstructed from these values has a frequency $f_{02} = 25 \text{ Hz}$.

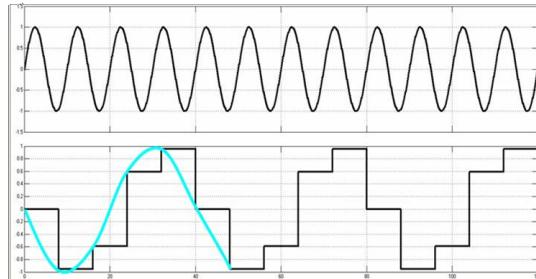


Fig. 8. The results of experiments at a maximum sampling frequency 125 Hz

Example 4 (Automation and Informatization of Scientific Research). As is generally known, information of daily and weekly cycles which is received as a result of processing a power system are used for obtaining knowledge about the load parameters in a forecast horizon. The forecast are given to students and they have to implement a strategy of advanced control and optimize operating modes of power system equipment.

The stages of forecast transformation into power system control parameters are shown in Fig. 9. The transformation procedure involves several steps, each from them is a separate cognitive stage and uses own methods. It all begins with the accumulation of energy consumption monitoring data, which are used to train the cognitive system for building forecasting model. On the other hand, a power system model which built using conventional methods for calculating power electronics will be used.

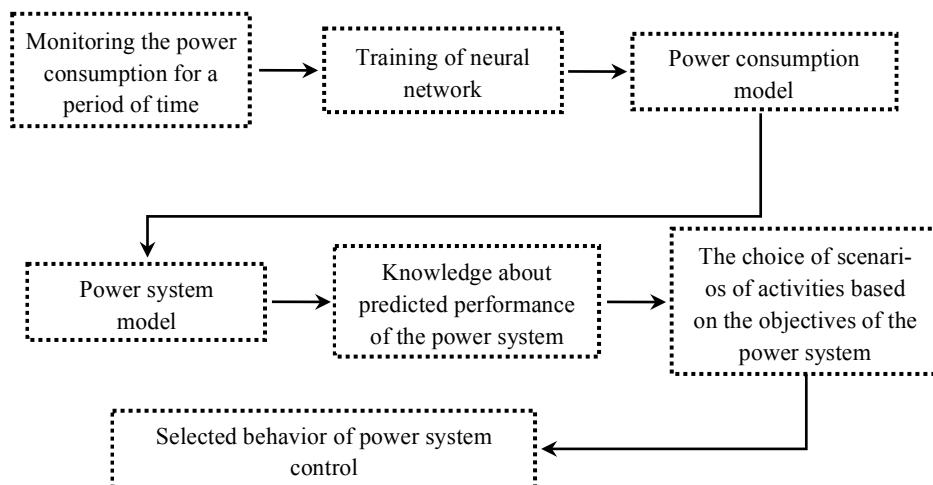


Fig. 9. Using a forecast about power consumption for choosing the behavior of power system control

Using both models, students can select the optimal scenario for controlling the power system based on certain limitations, for example, optimizing the cost or load on the power network.

Example 5 (Automation and Informatization of Scientific Research). The Cyber Physical System of a remote laboratory can include false knowledge into the knowledge base of an investigated object. Models that provide such possibilities are considered in [11]. Students have to discover these contradictions by the methods of logical programming.

Consider an assignment about assessing completeness and consistency of available knowledge obtained from a cognitive control system of power transformer cooling. Parameters of the transformer control system are the load current L , the cooling system operating time T , the thermal resistance between a transformer and external environment R , and oil or a transformer winding temperature θ .

These parameters are described by ternary variables and can take values from a set (“-”, “0”, “+”) which means “decreases”, “does not change”, and “increases”. For example, if L is equal “+” this is corresponded to a situation in which the load current of a transformer increases with time.

The result of assessing the quality of knowledge is also described by the ternary variable. A result Q can take values from a set (“-”, “0”, “+”) which means “contradictory”, “incomplete”, and “consistent” respectively.

Students should develop a logical scheme for assessing the quality of knowledge. An example of such a scheme is shown in Figure 10.

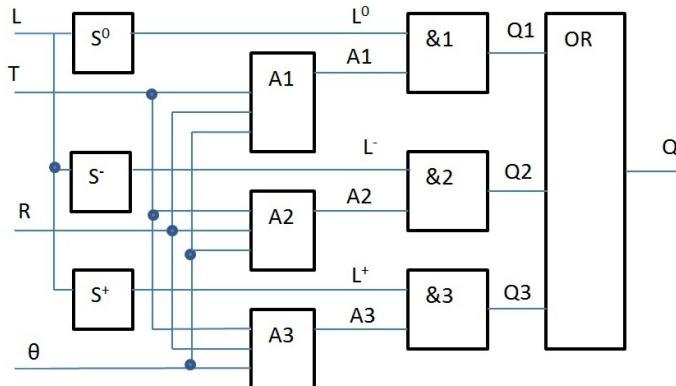


Fig. 10. Logical scheme for assessing the quality of knowledge

All elements of the circuit in Figure 10, except A_1 , A_2 , A_3 , are described by known truth tables. For example, the table for S^0 element is shown in Table 1.

Table 1. Truth table for S^0 element

Input	-	0	+
Output	-	+	-

Elements A1, A2, A3 should take into account specifics of a subject area. For instance, the table for element A1 is shown in Table 2.

Table 2. Truth table for a ternary logical element A1

T	-	-	-	-	-	-	-	0	0	0	0	0	0	0	+	+	+	+	+	+	+	
R	-	-	-	0	0	0	+	+	+	-	-	0	0	0	+	+	+	-	-	0	0	0
θ	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-
A1	0	+	0	-	-	+	-	-	+	+	-	-	-	-	+	+	0	-	+	-	-	+

It is expected that students carry out the analysis of the circuit (Figure10) by using the programming language Prolog [12].A fragment of the Prolog program is shown in Figure11.This fragment contains the description of **Q_logic(L, T, R, θ, Q)** of the circuit, and the specification of the ternary logic element S⁰.

Prolog can create a list of situations as an answer to a question. Students may use:
? Q_logic (L, T, R, θ, "-") –for a question “at what value of the variables L, T, R, and θ is the result should be considered as contradictory?” or
? Q_logic (L, T, R, θ, "0") – for a question “at what values of the variables L, T, R, and θ is the result should be considered as incomplete?”

```

Q_logic(L, T, R, θ, Q) :- OR(Q1, Q2, Q3, Q), AND1(L0, A1,
Q1), AND2(L-, A2, Q2), AND(L+, A3, Q3), A1(T, R, θ, A1),
A2(T, R, θ, A2), A3(T, R, θ, A3), S0(L, L0), S-(L, L-),
S+(L, L+).
So("-", "-").
So("0", "+").
So("+", "-").
....

```

Fig. 11.Fragment of the Prolog program for the logical conclusion about the quality of given information

An example of a contradictory set of knowledge is the set L = “0”, T = “-”, R = “+”, θ = “+” that is determined by the thermodynamic model of a transformer. If its thermal resistance R increases, and the load L is constant, than the oil temperature θ and the cooling time T must increase. However, in presented knowledge T = “-”, that is the reason for the final answer Q = “-”.

5 Conclusion

Development the ability to work with cognitive control systems and to research them has to be in the focus of learning process for future engineers. Corresponding training, studying models of such systems, methods of obtaining and transforming knowledge could be realized in different courses of engineering curriculum by organizing students' researches and practical works with objects of unknown structure

(“black box”). The examples of assignments which can be used for studying elements and components of complex cognitive control systems are described in the article.

The presented approach for engineering training is expected to be implemented in curriculum that are being developed at the Zaporizhzhya National Technical University according to the framework of the projects of the European Commission within the program Tempus “DesIRE” and “ALIOT”.

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Particular Results of a Research Aimed at Curricula Design of Teacher Training in the Area of Didactic Technological Competences

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Abstract—The paper presents particular results of the first phase of a research aimed at improving pre-graduate teacher training in the area of didactic technological competences. The main goal of the prepared research is to modernize and optimize relevant parts of study programs of teacher trainees at Slovak higher education institutions (inclusion and structure the relevant subjects in the study programs, their content and time assignment). The results are related to a questionnaire survey of the current state and perspectives of the continuing professional development of primary and secondary school teachers contributing to their didactic technological competences improvement and development. Main attention is paid to an analysis of the selected questionnaire items in which the respondents assessed significance of the use of various interactive educational activities and digital means in teaching process to increase efficiency of selected specific aspects of education. The presented analysis is based on the segmentation of the respondents on the factor of the category and sub-category of the teaching staff the respondents belong to.

Keywords—teacher training, teacher professional profile, didactic technological competences, interactive educational activities, digital didactic means

1 Context of the research and its goals

Didactic technological competences constitute increasingly important integral part of a teacher professional profile as they significantly influence teaching performance quality and efficiency of every teacher [1, 2, 3]. In principle all higher education institutions offering study programs in teacher training have incorporated in these programs some subjects or courses aimed at the didactic technological competence training. However in practice there are considerable differences in numbers of the relevant subjects included in the study programs, their position within the study program structure, in syllabi of these subjects as well as time allocation assigned to them [4].

A question is how an optimal model of the pre-gradual teacher training in the area of didactic technological competences should be designed, which aspects of the current requirements on the teacher competence profile and quality teaching assurance should be met and how these should be incorporated into the appropriate optimal training model [5]. To find out answers to these questions has become a task of a research, financially supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic, main goal of which is to support modernization and optimization of the pre-gradual teacher training related to formation and development of teacher trainee professional didactic technological competences.

In the first phase of the research, the current state and perspectives of the continuing professional development of primary and secondary school teachers in Slovak Republic relating to the development and improvement of their didactic technological competences were surveyed. The survey was based on the screening of the in-service teachers' opinions and attitudes about this issue.

In the second phase of the research, an analysis of the inclusion of different subject and courses focused on the use of modern digital technologies in primary and secondary education (ISCED 1, ISCED 2 and ISCED 3) in teacher training study programs at various Slovak higher education institutions will be done. Assessment of the observed subjects (courses) content (syllabi) will be done from the students – teacher trainees' point of view.

Results of the analyses processed within the first two phases of the research will be used to design a proposal of a draft of measures to innovate and modernize the corresponding parts of the pre-graduate teacher training.

2 Screening of the in-service teachers' opinions on the needs of their didactic technological competences improvement

Methodology of the analysis of the current state of the continuing professional development of primary and secondary school teachers in Slovak Republic aimed at identification of the needs of further development and improvement of teachers' didactic technological competences has been based on screening opinions of these teachers.

For the purpose of the screening a questionnaire involving 41 items was designed. The questionnaire items were structured into four parts:

- part A consisting of 4 nominal items (A1 – A4) focused on the respondents' identification data (gender, length of service, category and sub-category of the teaching staff they belong to);
- part B consisting of 7 nominal items (B1 – B7) focused on the use of interactive educational activities and digital means in respondents' teaching practice (how they use them);
- part C consisting of 13 ordinary items (C1 – C13) focused on the assessment of the significance of the use of various interactive educational activities and digital means in teaching process for selected specific aspects of education;

- part D consisting of 17 ordinary items (D1 – D17) focused on the respondents' self-assessment of their knowledge and skills, i.e. in principle competences, to work with software applications and digital means within the scope of their own teaching practice.

Specification of the given parts resulted from an extensive search work of available sources describing relevant research done in Slovakia and abroad, too [6, 7, 8], on consultations with experts dealing with these or similar issues and not least on personal discussions led in community of experts having extensive professional and educational experiences in tertiary education practice as well as in continuing education of primary and secondary school teachers aimed at topics relevant to our research interest area [9, 10]. The above-mentioned parts of the questionnaire were proposed with the intention to enable a transformation of the qualitative features of education (training) in the field of selected computer applications, digital teaching tools and objects into the quantitative characteristics, what opens broader possibilities to final evaluation using a wide scale of methods of quantitative based research.

At the nominal items B1 – B7 the respondents chose from the offered alternatives the one which corresponded with their opinion best. Besides that, the items B1 – B6 offered the respondents also the possibility to give other, their own response. Because all these items were of nominal character, they were not included in the process of the questionnaire reliability/item analysis.

At the ordinary items C1 – C13 the respondents expressed their opinions and assessments to the use of various interactive educational activities and digital means in teaching processes taking into consideration different aspects of the teaching process. The assessment was done through a four-point scale, i.e. by assessments from 1 to 4 point value (1 – *insignificant, unimportant, without influence*, 2 – *rather insignificant, rather unimportant, rather without influence*; 3 – *rather significant, rather important, rather with influence*, 4 – *significant, important, with influence*). A choice of the neutral, emotionally indifferent attitude towards the given questions/statements was not included because we wanted to force the respondents to express themselves clearly and exactly. Each respondent's response to the particular ordinary items were recorded, i.e. we re-corded the scale values by which the respondent evaluated impact of the interactive educational activities and digital means on the selected aspects of the teaching process (see list of aspects in the Fig. 1` Note).

Analogically in the questionnaire part D the respondents were asked to assess a level of their knowledge and skills to work with various selected software applications and digital means and to use them in frame of their teaching practice. Also here the assessment was done through a four-point Likert scale (1 – *my knowledge and skills are insufficient*, 2 – *my knowledge and skills are rather insufficient*, 3 – *my knowledge and skills are rather sufficient*, 4 – *my knowledge and skills are sufficient*).

As it has been above-mentioned, for a further use of the designed questionnaire as a tool for a broader research data collection we considered to be very important to verify its reliability. This was done in a pilot test.

3 Assessment of the reliability of the data collection tool

A basis of each measuring process is data collection. If the measurement is to be of an appropriate quality, the measuring procedure has to be objective, valid and reliable. In our case the reliability of the data collection tool was confirmed based on the identification of the suspicious items through the reliability/item analysis.

The reliability/item analysis belongs to multidimensional survey techniques and is used for quality assessment purposes. It can be used to assess reliability of the measuring process, in particular for example just to assess the questionnaire scale and to identify its suspicious items.

One of the direct estimations is Cronbach coefficient alpha – Cronbach's alpha

$$\hat{\alpha} = \frac{m}{m-1} \cdot \left(1 - \frac{\sum s_j^2}{s^2} \right), \quad (1)$$

where m refers to the number of questionnaire items, s^2 refers to the variance of the questionnaire scale (variance associated with the observed total scores) and s_j^2 refers to the variance associated with the item j scale.

Reliability estimation can be calculated also from the average correlation coefficient \bar{r} of the particular items, according the formula

$$\bar{\alpha} = \frac{m\bar{r}}{1 + (m-1)\bar{r}}, \quad (2)$$

where m is the number of items.

Standardized Cronbach's alpha can be calculated also through the previous formula (1), if all measurements were standardized in advance, what means each value of the variable to count off its mean and to divide it by its standard deviation.

If the two estimations differ, it indicates that the particular items have not the same variability [11].

4 Results of the questionnaire reliability assessment

Validation of the questionnaire was carried out at the beginning of the year 2017. The research sample of the pilot test consisted of 37 primary and secondary school teachers.

As it is above-indicated (see the part 2 *Design of the methodology of the CPD current state evaluation*), only 30 from the total number of 41 questionnaire items (13 ordinary items of the part C and 17 ordinary items of the part D) were included in the data collection tool evaluation and its suspicious items identification. The total reliabilities of the two relevant parts (questionnaire parts C and D) were assessed through Cronbach's alpha, Standardized alpha and the correlation. The calculated

values of Cronbach's alpha for the part C $\alpha_C = 0.8678$ and part D $\alpha_D = 0.9268$ indicate a high internal consistency of the designed research data collection tool [12].

At this point we would like to notice some attributes of the pilot research sample of the primary and secondary school teachers. Actually the respondents were only primary and lower secondary education teachers (ISCED 1 and ISCED 2), mostly females, with different length of their teaching practice. All respondents have already passed some continuing professional development courses, focused on enhancing their didactic technological competences (provided by different education institutions), i.e. the courses were devoted to improvement of teachers' skills to use computer applications and digital tools in their teaching practice and professional development. That is why the respondents' statements to the observed issues can be taken as relevant ones and creating a platform for the improvement of the pre-graduate teacher training study programs.

The main goal of the pilot validation of the questionnaire tool was to find out from the respondents' point of view, which components were causing problems, to be able to relieve eventual shortages, whether of the formal, technical, contentual or methodological character. From the statistical point of view, the size of the pilot research sample was large enough to use the statistic methods to assess the questionnaire reliability and to identify its suspicious items. Following the obtained results the questionnaire was modified into its final version.

Thereinafter, we present a deeper analysis of the results of the questionnaire part C verification.

4.1 Analysis of the suspicious items of the questionnaire part C

In the questionnaire part C the respondents, primary and secondary school teachers, were asked to express their opinion on incorporation interactive education activities into the teaching process. They were asked to evaluate a level of significance of their use in the teaching process from the point of view of different aspects of education (list of the aspects see in the note at Fig. 1).

On the basis of the reliability/item analysis, the suspicious items, which decrease the total questionnaire reliability and have the most serious influence on the mean value and variability of the total score, were identified.

The value of the correlation coefficient 0.86 expresses a ratio of the sum of the particular questionnaire item variability and the questionnaire total variability. Both estimations (Cronbach's alpha and standardized alpha) do not differ very much, what means that the particular items of the questionnaire part C are of the same variability (Table 1).

From the point of view of the given item group, the questionnaire shows to be reliable, however the low value of the average correlation between the items (0.3377) indicates that some items elimination (their removing) could even increase the questionnaire reliability.

Table 1. Overall questionnaire statistics

Number of the questionnaire items	13
Number of valid responses	37
Mean	42.1081
Standard deviation	5.6852
Average correlation between the items	0.3377
Cronbach's alpha	0.8613
Standardized alpha	0.8613

The graph in Fig. 1 shows how the elimination of each particular item decreases the given Cronbach's alpha (0.8613). The only exception is the item C13, limitation of which causes an increase of the given Cronbach's alpha (to the value 0.8787). This means that the item C13 decreases the total reliability of the designed questionnaire.

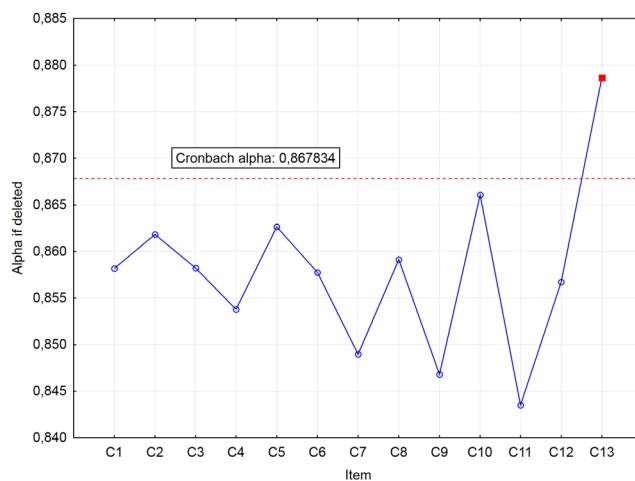


Fig. 1. Changes of the questionnaire reliability coefficient value after elimination of the relevant questionnaire item

Note to Fig. 1:

C1 – increase of pupils' motivation; C2 – increase of pupils' interest in the taught subject; C3 – increase of pupils' activity during the lesson; C4 – development of pupils' creativity; C5 – pupils' easier understanding of the presented new subject matter; C6 – longer-term retention of the presented subject matter; C7 – increase of the pupils' skills to apply the acquired knowledge in practical task solving; C8 – increase of the taught subject popularity (favour); C9 – increase of pupils' mutual co-operation; C10 – increase of pupils' "spirit of competitiveness"; C11 – positive influence on pupils' disciplined behaviour; C12 – increase of the positive classroom climate; C13 – development of pupils' digital literacy

The graph in Fig. 2 shows values of the coefficient of determination after elimination of each relevant item. The value of this coefficient indicates to how many percentages the other questionnaire items explain the relevant item (e.g. the questionnaire item C13 is explained by the other C items approximately only on 20 %).

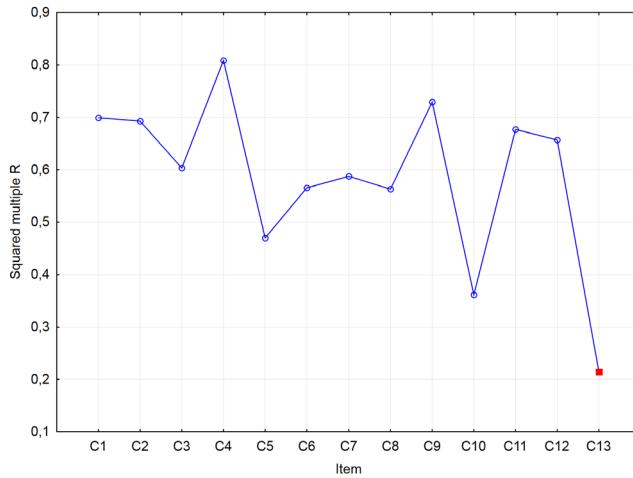


Fig. 2. Values of the coefficient of determination after elimination of the relevant item

From the graph presented in Fig. 3 it is clear that the total values of the standard deviation of the responses after the elimination of the relevant items are not changed significantly. This statistical indicator points out the most homogeneous responses recorded in case of the questionnaire item C13 (5.5615) at which the respondents stated their opinions on the influence of the use of interactive education tasks in teaching process on the pupils' digital literacy development. After this item elimination the vari-ability of the total questionnaire score (5.5615) was increased most significantly.

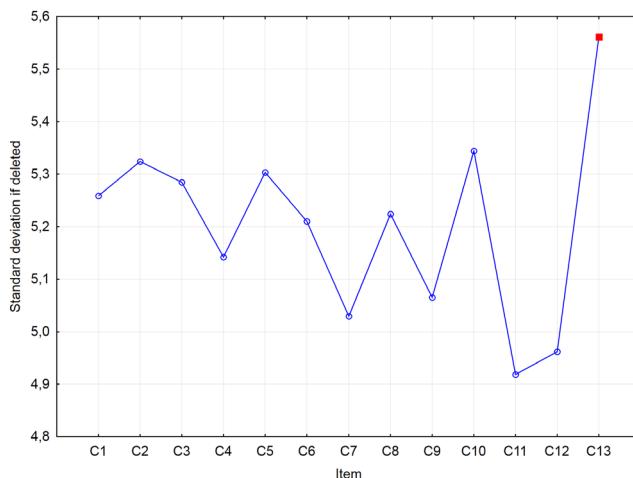


Fig. 3. Values of the total score standard deviation after the relevant item elimination

The graph in Fig. 4 presents correlations of the particular items with the total questionnaire score. A positive correlation, linear direct proportion, with the total ques-

tionnaire score was identified in case of all of the items with the exception of the item C13. This item does not correlate with the total score (0.014), what means that its values change independently. From this reason the item was identified as a suspicious one.

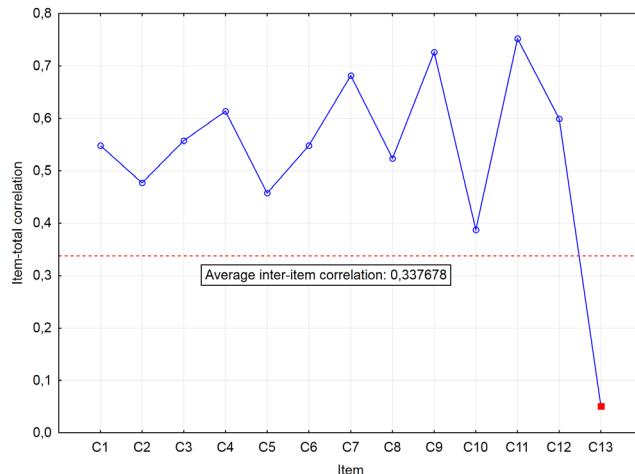


Fig. 4. Correlations of the particular items with the total questionnaire score

Based on the graphical visualization of the average value of the questionnaire total score after the relevant item elimination (the graph in Fig. 5) we state that just the item C13 was evaluated by the respondents very positively and after its elimination the decrease of the average questionnaire score was most marked.

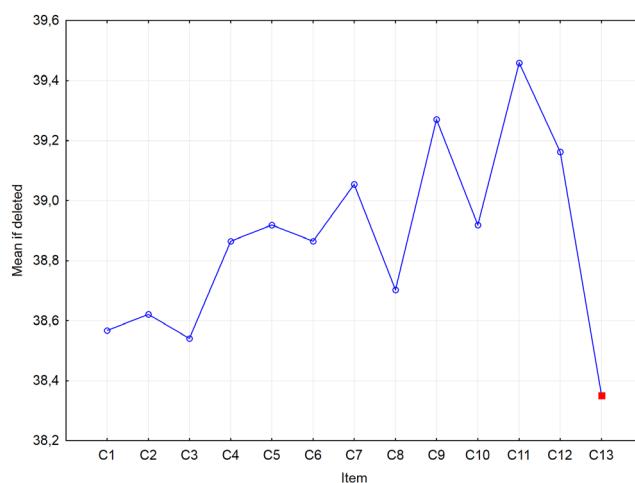


Fig. 5. Average values of the questionnaire total score after the relevant item elimination

4.2 Discussion of the achieved outcomes

Through the items included in the questionnaire part C, i.e. through the statements given in them, we want to find out teachers' opinions about how significant is to include interactive education activities into the teaching process to influence particular selected aspects of this process (list of the aspects see in the note to Fig. 1; 4 – *significant*, 3 – *rather significant*, 2 – *rather insignificant*, 1 – *insignificant*).

By the means of the reliability/item analysis the questionnaire item C13, in which the respondents assessed influence of the inclusion of interactive education activities into the teaching process on pupils' digital literacy, was identified as a suspicious one. As suggested by results from the recorded average value of the C13 score, this item belonged to those at which the respondents stated positive assessments, i.e. in the respondents' opinion inclusion of the interactive education activities into the teaching process is rather or even significant for the pupils' digital literacy development. From the C items (C1 – C13) this was the one with the most homogeneous responses of the respondents. At the other C items the standard deviations indicated a greater variability of the respondents' responses to them. This means that the influence of the inclusion of the interactive education activities into the teaching process on e.g. the pupils' behaviour (item C11) or increase of pupils' mutual co-operation (item C9) was assessed by the respondents not so exactly as it was in case of the development of the pupils' digital literacy (item C13).

Another reason why the respondents responded to the C13 item independently on the other items could be the fact that a conceptual inclusion of the interactive education activities into the teaching of the particular subjects has not so significant direct impact on the development of the pupils' digital literacy as it is in case of its influence on pupils' subjective attitudes to the taught subjects (e.g. C1 – increase of pupils' motivation; C2 – increase of pupils' interest in the taught subject; C6 – longer-term retention of the presented subject matter; C7 – increase of the pupils' skills to apply the acquired knowledge in solving practical tasks; C8 – increase of the taught subject popularity (favour)) or particular aspects of the teaching process realization (C3 – increase of pupils' activity during the lesson; C5 – pupils' easier understanding of the presented new subject matter; C9 – increase of pupils' mutual co-operation; C12 – increase of the positive classroom climate).

Untrustworthiness of the item C13 could result also from the used formulation, in meaning of uncleanness of the used term digital literacy. On the one hand this term is used very frequently but on the other hand its content is continually changing, shifted further, and so it is difficult to state how the term was taken by the respondents.

Following the presented discussion of the result achieved by the item C13 in the reliability/item analysis, a decision was made to keep this item among the others, although it was identified as a suspicious one and its elimination increased the questionnaire reliability from the value 0.8678 to the value 0.8787. But on the other hand there is an intention to reformulate it, to make it in its meaning more exact for the target group of the respondents of the further questionnaire survey.

5 Particular results of the identification of the requirements put on the designed curricula

In the questionnaire part C the respondents were asked to assess significance of the use of various interactive educational activities and digital teaching facilities in teaching process for selected specific aspects of education (questionnaire items C1 – C13). Processing of the respondents' responses to these questionnaire items indicates some requirements on the curricula of the teacher training in the area of didactic technological competences, which should be designed as the final output of the carried out research. Thereinafter the particular results of an analysis of the respondents' responses to these questionnaire items in dependence on the segmentation factor SUB-CATEGORY OF THE TEACHING STAFF are presented. In this analysis attention is not paid to the level of the significance of the use of various interactive educational activities and digital means in teaching process for the given specific aspects of education (and the differences among the identified significance levels for each of the given aspects). Attention is paid to the potential differences among the assessments of these significances stated by different sub-categories of teachers. These results reflect how important the teaching activities (staying behind the particular C items) are for the relevant age category of pupils and whether there are or there are not differences in the contributions of these activities applications into the teaching process in dependency on the age category of the pupils as recipients.

According Slovak legislation [13] teachers are classified in one of three teaching staff sub-categories: primary education teacher, lower secondary education teacher, upper secondary education teacher. The carried out analysis was carried out in dependence on this segmentation factor of the respondents. It means the divergence of the means – average values of the scores of the respondents' responses to the part C questionnaire items (focused on the assessment of the significance of the use of various interactive educational activities and digital teaching facilities to increase efficiency of the specified aspects of teaching) in dependency on the respondents' teaching staff sub-category (item A4).

In frame of the statistical processing of the results following null hypothesis, de facto presenting 13 particular null hypotheses (connected with the particular questionnaire items C1 – C13), was tested:

H0: Respondents' answers to the questionnaire item C do not depend on the level of the factor SUB-CATEGORY OF THE TEACHING STAFF.

Null hypotheses were tested on the 5% significance level. In the partial null hypotheses independence on the given factor was tested through both parametric and nonparametric tests.

Following results of on-way ANOVA as well as its nonparametric alternative Kruskal-Wallis ANOVA null hypotheses are not rejected in case of the variables C1 (*increase of pupils' motivation*), C2 (*increase of pupils' interest in the taught subject*), C3 (*increase of pupils' activity during the lesson*), C4 (*development of pupils' creativity*), C7 (*increase of the pupils' skills to apply the acquired knowledge in practical task solving*), C8 (*increase of the taught subject popularity / favour*), C9 (*increase of pupils' mutual co-operation*) C10 (*increase of pupils' "spirit of competitiveness"*) and

C13 (*development of pupils` digital literacy*), i.e. these variables do not depend on the factor SUB-CATEGORY OF THE TEACHING STAFF.

Within the questionnaire items C1 – C13 statistical dependence on the observed factor SUB-CATEGORY OF THE TEACHING STAFF was proved only for four of them and these are the items *C5 (pupils` easier understanding of the presented new subject matter)*, *C6 (longer-term retention of the presented subject matter)*, *C11 (positive influence on pupils` disciplined behaviour)* and *C12 (increase of the positive classroom climate)*.

Descriptive statistics of the final score of the responses to the items C5, C6, C11 and C12, i.e. items by which the statistical dependence on the observed factor SUB-CATEGORY OF THE TEACHING STAFF (TS-Cat) was proved, are presented in Table 2. The table comprises more detailed statistical view on the examined issues in dependency on the segmentation of the respondents – teachers into one of the four possible categories, which as it was already above-mentioned can be *primary education teacher* (a), *lower secondary education teacher* (b), *upper secondary education teacher* (c). Apart from the already mentioned in the table there are presented also descriptive statistics of the final score of the given items overall, i.e. for the whole research sample, without any segmentation of the respondents on the factor SUB-CATEGORY OF THE TEACHING STAFF (TS-Cat). There are presented values of the mean, standard deviation, standard error of the mean estimate and 95% confidence interval for the average value of the scale.

Results of the dot estimation of the average scores of the assessments of the particular factors show that the group of the respondents – *primary education teachers* (a) in comparison to other two group of the respondents, *lower secondary education teachers* (b) and *upper secondary education teachers* (c), responded to all of the four tested ordinary items (C5, C6, C11 a C12) more positively. Average values of the scores of the respondents` responses to the items C5, C6, C11 and C12 are from the scale range 2 (rather insignificant) – 4 (definitely significant) from the maximal scale value 4, while majoritarian part of these items was evaluated by the respondents on the level rather significant (scale value 3). The tabulation (Table 2) of the results of the respondents` assessments of the level of the influence of the use of interactive educational activities and digital means on the specific aspects of education (C5 – *pupils` easier understanding of the presented new subject matter*; C6 – *longer-term retention of the presented subject matter*; C11 – *positive influence on pupils` disciplined behaviour*; C12 – *increase of the positive classroom climate*) shows the lowest average score was recorded in case of the item C11 (2.42) at which the respondents expressed their opinions on the positive influence of the use of interactive educational activities and digital means on pupils` disciplined behaviour. According to the group of the respondents – *upper secondary education teachers* (c) the intervention of the interactive educational activities and digital means into the education process has not any adequate influence on the positive behaviour affecting at teaching time (item C11). The achieved results have been quite surprising as there were expected more positive opinions of the respondents in the context of the observed means influence on this aspect of education. A possible explanation of the achieved result may be the age category of the pupils and to this category more relevant other by the teachers used

methodological processes of the knowledge acquisition. We suppose that these „others“ ways of the new subject matter presentation/explanation have a proper positive impact on influencing pupils` behaviour within the teaching lessons.

On the contrary, the highest average score was recorded at the items C5 (3.45) and C6 (6.38) in case of the group of the respondents – *primary education teachers*. At these items the respondents assessed significance of the intervention of the didactically elaborated interactive educational activities in teaching process for *pupils` easier understanding of the presented new subject matter* (C5) and *longer-term retention of the presented subject matter* which is a part of the school curriculum (C6). The achieved more positive assessment of the tested items given by the primary education teachers (a) can be taken as a signing of the possibility to further applications of a broad scope of the interactive educational facilities into teaching (ISCED 1). The results indicate that the teaching has an object-lesson and attractive character for the pupils of the respective age category (based on the given possibility to enter actively into the object lesson teaching to both the teacher and the pupils).

In general quite satisfactory finding is the fact that the average score values achieved by the particular groups of the respondents for all the items did not occur bellow the scale value 2.

The final standard deviation values of the respondents` responses to the particular items C5, C6, C11 and C12 are not much different. Taking into consideration the confidence interval estimate for the mean score values of the particular items ranged from the value 1.99 even to the value 3.59. In frame of the used scale this means evaluation of the significance of the intervention of the interactive educational activities and digital didactic means in the teaching process in range from *rather insignificant* up to definitely *significant*.

The most heterogeneous responses were recorded at the item C12 in case of the group of the respondents – *upper secondary education teachers* (variability index 0.99). In case of this sub-group of the respondents, the highest heterogeneousness of the stated assessments regarding the significance of the implementation of the interactive educational activities and attractive electronic teaching materials into the upper secondary education (ISCED 3) to increase the positive classroom climate during the lesson was found out. All the same a higher heterogeneousness of the responses occurred also in case of the assessment of the items C12 (variability index 0.93) and C11 (variability index 0.92) by the *lower secondary education teachers*. Based on the interval estimate of the means, the score average values of the responses to these items ranged from the value 2.56 even to the value 3.21 (questionnaire item C12 assessed by the respondents – *upper secondary education teachers*), from 2.40 to 2.85 (item C12 assessed by the *lower secondary education teachers*), from 2.23 to 2.67 (item C11 assessed by *lower secondary education teachers*).

The lowest value of the standard deviation (0.52) was found out at the items C6 (range 3.26 – 3.52) and C5 (range 3.35 – 3.57) at the group of the respondents – *primary education teachers*. This means the lowest variability of the given statements given by the sub-category of the teaching staff *primary education teachers* to the specified teaching aspects. At the same time, at the items C5 and C6 assessments

done by the *primary education teachers* also the lowest value of the average score of the responses was recorded (C5 – 3.46; C6 – 3.39).

Table 2. Descriptive statistics of the items C5, C6, C11 and C12 of the questionnaire part C

Item C5	TS-Cat factor value	N	Mean	Standard deviation	Standard error	Confidence Interval for the Mean	
						-95.00%	+95.00%
Total		173	3.329480	0.611040	0.046457	3.237781	3.421178
"A4"	a	85	3.458824	0.524471	0.056887	3.345698	3.571949
"A4"	b	69	3.202899	0.631984	0.076082	3.051080	3.354718
"A4"	c	19	3.210526	0.787327	0.180625	2.831047	3.590006

Item C6	TS-Cat factor value	N	Mean	Standard deviation	Standard error	Confidence Interval for the Mean	
						-95.00%	+95.00%
Total		173	3.225434	0.674313	0.051267	3.124240	3.326627
"A4"	a	85	3.388235	0.599486	0.065023	3.258929	3.517541
"A4"	b	69	3.072464	0.648955	0.078125	2.916568	3.228360
"A4"	c	19	3.052632	0.911268	0.209059	2.613414	3.491849

Item C11	TS-Cat factor value	N	Mean	Standard deviation	Standard error	Confidence Interval for the Mean	
						-95.00%	+95.00%
Total		173	2.699422	0.909798	0.069171	2.562889	2.835955
"A4"	a	85	2.964706	0.837329	0.090821	2.784098	3.145314
"A4"	b	69	2.449275	0.916134	0.110290	2.229196	2.669355
"A4"	c	19	2.421053	0.901591	0.206839	1.986500	2.855605

Item C12	TS-Cat factor value	N	Mean	Standard deviation	Standard error	Confidence Interval for the Mean	
						-9.00%	+95.00%
Total		173	2.820809	0.919571	0.069914	2.682810	2.958809
"A4"	a	85	3.00	0.872872	0.094676	2.811726	3.188274
"A4"	b	69	2.623188	0.925162	0.111376	2.400940	2.845437
"A4"	c	19	2.736842	0.991189	0.227394	2.259104	3.214580

6 Conclusion

The achieved particular results indicate us some of the needs and requirements on the design of the curricula of the optimal model of the pre-gradual teacher training in the area of didactic technological competences which should be the main output of the solved research project. The needs and requirements of the teaching practice, level of their intensity, are reflected in the achieved scores of the observed questionnaire items (their average values). These scores show us primarily in connection to which aspects of the teaching process the use of the digital didactic means and interactive educational activities should be incorporated into the prepared curriculum. And secondarily the

identified significant differences between the responses of the sub-groups of the respondents to the particular observed questionnaire items (results of the analysis of the respondents' responses to the questionnaire items in dependence on the segmentation factor SUB-CATEGORY OF THE TEACHING STAFF, i.e. on the respondents' affiliation to one of the three teaching staff sub-categories: primary education teachers, lower secondary education teachers or upper secondary education teachers) point at some cases of the use of the digital didactic means and interactive educational activities in which the age category of the pupils (in teaching of which these means and activities are used) proved to be very important (different perception of the used means and activities by the younger and elder learners).

Currently the research continues in preparation of an analysis of the inclusion of different subject and courses focussed on the use of modern digital technologies in primary and secondary education (ISCED 1, ISCED 2 and ISCED 3) in teacher training study programs at various Slovak higher education institutions. Assessment of the observed subjects (courses) content (syllabi) will be done from the students – teacher trainees' point of view. Results of the presented first phase of the research together with the results of this second phase of the research will be used to design a proposal of a draft of measures to innovate and modernize the corresponding parts of the pre-graduate teacher training.

7 Acknowledgment

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Student’s Characteristics as a Basis for Competency Development in Engineering Informatics Education

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Abstract—Current technological innovations and continuous change in the labor market have generated new challenges for higher education, and thrown new light upon the importance of competency development in engineering education. Responsibility, flexibility, communication and collaborative skills, self-motivation, problem-solving and innovation are the most required skills by employers. However, individual differences like personality traits or interpersonal skills of students can also be considered relevant factors influencing teachers’ attitudes towards integration of effective methods into engineering education. The purpose of this paper is to examine the competencies of undergraduates attending Engineering Informatics education, and to identify their personal needs for development in the light of workplace demands. Personality characteristics of Engineering Informatics students are also addressed in this research in order to reveal possible ways of involving them into the teaching and learning process by implementing new methods or approaches in Engineering Informatics education in Hungary.

Keywords—Engineering Education, Competency Development, Students’ Characteristics

1 Introduction

The competency development has become one of the main areas of research in engineering education in the last decade and it was recognized that non-technical and interpersonal skills are crucial for engineers [1,2]. Solid evidence indicates significant differences between the competencies developed by institutions of higher education, perceived by graduates and expected by employers. Competence has become a key concept in higher education, regarding the combination of knowledge, skills, abilities and personal attributes that contribute to enhanced academic performance and success in the workplace [3]. Higher education in engineering primarily focuses on the development of professional competencies and technical skills, and students are not appropriately prepared for the demands of the workplace and lack social, communicative or personal competencies [4].

There is a growing interest in the attributes and skills required by engineers in our rapidly changing information society [5-8], with particular regard to examining the characteristics of engineering undergraduates from different perspectives [1,9,10].

Globalization has intensified the demands for flexible, socially adept and communicative engineers [8]. The engineers’ weaknesses in soft skills such as effective communication, cooperation, teamwork, project management, lifelong learning have been noted by industry and various professional organizations [1,7]. Other studies highlight the wider social context of engineers’ work, arguing that there is a need for new engineers who are not only equipped with employability skills but who are also socially and environmentally responsible [6]. It is also reported in the literature that personality traits are important predictors of job performance and satisfaction, and are also key characteristics for the engineering profession. Engineers differ from members of other occupations as they are less likely to be assertive, extravert, emotionally stable and optimistic, yet they show more intrinsic motivation and tough-mindedness [10]. Nonetheless, employers of engineering organizations require for new engineering graduates to possess both technical and non-technical skills such as communication, people and team management, motivation, problem solving, etc. [11].

Several studies emphasize that along with changes in technology and work organization, traditional methods of engineering education should be re-evaluated and non-technical, generic competencies, including the interpersonal skills of the future engineers also need to be developed in order to reflect the changing demands of working life and industry [1]. However, developing competencies is different from teaching academic topics, which implies that significant change is needed in how teachers teach and students learn. Teachers should reconsider their instructional practices and their role in the learning process [12].

Many universities make attempts to integrate soft skills into engineering curriculum, and positive impacts of different teaching methods have been reported on the students’ involvement in learning and personal development. Research results demonstrated that using the cooperative learning techniques, training and practice in social skills improved work cooperation and personal relationships with others [13]. Other study reported that a project-based learning approach was undertaken through a project work in a real workplace setting, which facilitated the students’ employability skills such as teamwork, communication, problem solving, managing interpersonal conflicts [2]. A 2-years course was created in the area of computer science at a Swedish university with the aim to improve a wide range of personal and social competencies of engineering students using a dialogue method developed for learning from experience and through reflection. As a result of the first year program the students’ awareness on the importance of soft skills and their own behavior was improved, and the drop-out rate decreased [14].

2 Method

The study was designed to measure a wide range of attributes and competencies (e.g. learning style, logical thinking, emotional intelligence, personality traits, achievement motivation and self-efficacy) at three time points among engineering informatics students during their academic careers. This paper focuses on the perceived workplace competencies of students, and on the personality aspects of competency development based on the first measurement.

The following research questions are addressed in the study:

1. How do undergraduates rate their proficiency in a range of competencies at the beginning of their academic career?
2. How do they rate the importance of these competencies for future employment?
3. What is the profile of Engineering Informatics students' personalities?

2.1 Sample

A sample of 188 first-year undergraduate Engineering Informatics students attending a Hungarian university participated in the study, of whom 166 males (88.3%) and 22 were females (11.7%). The ages of participants ranged from 18 to 26 years (Mean=20.07, SD=1.459). Sixty percent of the participants took their final secondary school examinations in 2016, 30% of them in vocational schools, 28% in high schools. Most of the participants (76%) have work experience, including summer work or student work, and 7 percent of them are working students.

2.2 Instruments

A set of questionnaires was used to assess different attributes and preferences of Engineering Informatics students before starting their academic career. The data was collected in September 2016.

The competencies of Engineering Informatics students were measured with a self-rating list of competencies consisting of 24 items which was constructed by using job vacancy advertisements and the results of previous competency assessments in higher education in Hungary. We examined, on the one hand, the extent to which these competencies are required for future employment according to the opinion of Engineering Informatics students, and, on the other hand, to the extent to which they possess these competencies at the beginning of their studies. Participants were asked to rate the importance of each competency in future employment using a 5-point Likert scale rating from (1) of minimum importance to (5) of maximum importance, and to self-evaluate their level of proficiency in the same competencies at the present moment rating from (1) at a minimum level to (5) at a maximum level.

The personality traits of Engineering Informatics students were assessed with the Hungarian version of Big Five Questionnaire [15,16]. The BFQ measures five personality factors, namely energy, friendliness, conscientiousness, emotional stability and openness. The questionnaire consists of 132 items, with five dimensions and ten

sub-scales, and a social desirability scale. Each BFQ factor is measured by 24 items, 12 of which are positively phrased and 12 of which are negatively phrased. Table 1 shows the factors and sub-scales with examples of items. Participants were asked to rate their responses on a 5-point Likert scale, (1) meaning ‘does not apply at all’ and (5) meaning ‘does apply entirely’. For the BFQ, norm data of a representative sample of Hungarian population was available [16].

Table 1. Factors, sub-scales and sample items of the BFQ, based on [15]

Factors	Sub-scales	Sample items
Energy	Dynamism Dominance	I am an active and vigorous person.
Friendliness	Cooperativeness Politeness	I hold that there's something good in everyone.
Conscientiousness	Scrupulousness Perseverance	I always pursue the decisions I've made through to the end.
Emotional Stability	Emotion control Impulse control	Usually I don't lose my calm.
Openness	Openness to culture Openness to experience	I'm fascinated by novelties.

3 Results

3.1 Perceived Competencies

Table 2 presents means and standard deviations of all 24 competencies, and the discrepancies between the self-reported proficiency and the importance level of competencies perceived by the Engineering Informatics students. As the distributional assumptions of parametric statistics were not met for the competency list, the Wilcoxon test was used to determine whether there is an association between the two set of variables. The two sets of competencies show acceptable internal consistency (Cronbach’s alpha: 0.863 and 0.871).

The findings regarding the importance of competencies indicate that in the opinion of Engineering Informatics students the most necessary skills for their future profession are problem-solving skill ($M=4.87$, $SD=.407$), the ability to work precisely ($M=4.78$, $SD=.496$), understanding causal relationships ($M=4.84$, $SD=.386$), and the ability to apply knowledge ($M=4.81$, $SD=.417$). The students attributed less importance to self-expression and writing ability ($M=3.01$, $SD=1.065$), conflict management ($M=3.24$, $SD=1.046$) and self-knowledge ($M=3.27$, $SD=1.212$). Furthermore, four other competencies did not receive a 4.00 rating, namely self-evaluation, openness, the ability to organize, and the ability to connect and communicate effectively with others. These results show that first-year students consider cognitive skills and profession-related competencies much more important for employment than soft skills.

Table 2. Means, standard deviations (SD) and differences between the perceived importance and self-reported proficiency level of competencies

	Importance Mean (SD)	Own level Mean (SD)	Difference	Wilcoxon (Z)
Oral communication	3.87 (.752)	3.24 (.989)	.622	-6.523**
Problem solving	4.87 (.407)	3.79 (.674)	1.080	-11.213**
Ability to work precisely	4.78 (.496)	3.73 (.798)	1.053	-10.495**
Cooperation	4.17 (.733)	3.87 (.883)	.303	-3.866**
Teamwork ability	4.23 (.792)	3.84 (.973)	.388	-4.780**
Working independently	4.56 (.568)	3.87 (.811)	.691	-8.489**
Analytical thinking	4.68 (.589)	3.73 (.810)	.947	-9.542**
Learning ability	4.66 (.567)	3.58 (.871)	1.080	-10.163**
Innovation	4.66 (.575)	3.70 (.905)	.963	-10.125**
Conflict resolution	3.24 (1.046)	3.49 (.989)	-.250	-2.169*
Organization	3.48 (.967)	3.18 (.951)	.309	-3.863**
Persistence	4.20 (.885)	3.64 (.831)	.559	-6.171**
Written communication	3.01 (1.065)	3.29 (1.015)	-.277	-3.237**
Openness	3.94 (1.048)	3.82 (.986)	.117	-1.768
Goal orientation	4.62 (.614)	3.97 (.824)	.644	-7.863**
Self-knowledge	3.27 (1.212)	3.61 (.973)	-.340	-3.376**
Stress tolerance	4.27 (.892)	3.55 (1.046)	.713	-7.123**
Responsibility	4.36 (.779)	3.92 (.820)	.441	-5.889**
Adaptation to change	4.39 (.734)	3.98 (.821)	.415	-5.561**
Concentration	4.80 (.464)	3.64 (.824)	1.154	-10.710**
Understanding causal relationships	4.84 (.386)	3.87 (.690)	.963	-10.586**
Appling knowledge	4.81 (.417)	3.97 (.701)	.846	-10.241**
Flexibility	4.31 (.739)	3.85 (.807)	.457	-5.853**
Evaluation and self-evaluation	3.59 (1.033)	3.57 (.865)	.016	-.129

* Significant at the 0.05 level.

** Significant at the 0.01 level.

Regarding the proficiency level of these competencies, higher ratings were revealed for adaptation to change ($M=3.98$, $SD=.821$), goal orientation ($M=3.97$, $SD=.824$), applying knowledge ($M=3.97$, $SD=.701$) and taking responsibility ($M=3.92$, $SD=.820$). Lower ratings were found for organization ($M=3.18$, $SD=.951$), oral communication ($M=3.24$, $SD=.989$) and written communication ($M=3.29$, $SD=1.015$). The mean ratings of the self-reported levels of competencies ranged from 3.18 to 3.98, indicating that development of these competencies would be necessary during academic courses.

In accordance with previous studies (e.g. [1]), students rated the importance of the competencies higher than their actual level of proficiency in most cases. The Wilcoxon signed rank test was used to analyze the median difference. Significant differences were found between ratings of all competencies, except for “openness” and “self-evaluation”, so there is a gap in 22 of the 24 analyzed competencies. The most evident

differences were found for concentration, learning ability, problem-solving skill, working precisely and innovation, and the following eight other competencies obtained mean differences greater than 0.50: analytical thinking, understanding causal relationships, working independently, ability to apply knowledge, stress tolerance, goal orientation, oral communication, and persistence.

There are three competencies for which the Engineering Informatics students estimated their proficiency higher than the perceived importance for future work, namely self-knowledge, written communication and conflict resolution. However these skills also received lowest ratings regarding the importance of competencies.

Comparing these results with studies previously conducted in Hungary regarding student competencies, some differences have been revealed. In the opinion of new graduates the most important competencies in the labor market are related to working ability like precise, autonomous and hard working, while employers seek graduates who are enterprising, have knowledge of foreign languages and analytical thinking [17]. Although the competency list used in the mentioned study was not the same as the one applied in our research, there was a conspicuous difference between the opinions of the two samples regarding the communication skills. Kiss [17] reported that graduates ranked the communication skills as the fourth most important skill ($M=4.63$ on a 5-point scale), however Engineer Informatics students positioned this skill at the bottom of the list with a nineteenth place rating ($M=3.87$ on a 5-point scale).

These results show that engineering undergraduates lack of awareness of skills acquired by engineering profession and they underestimate the importance of communication skills in their future work. Several studies demonstrated that communication skills, problem solving and interpersonal skills are among the most valued employability skills or generic competencies and considered more important than hard skills in engineering profession [5,18].

Principal component analysis was used for further examination, and four components were derived for both the perceived importance of the workplace competencies and the level of proficiency of these competencies estimated by the students ($KMO=0.824$ and 0.839). Regarding the competencies required for the future work based on the opinion of the Engineering Informatics undergraduates the first principal component was the “personal efficacy” including self-awareness, self-evaluation and self-control, and it was revealed that the women were characterized markedly by this component (the mean of principal component scores is 0.477). The second component was connected to learning, thinking, in other words to “cognitive function”. The third component was labeled “initiative” in which adaptation, flexibility and openness were the dominant competencies. This component was found mostly in the case of younger students (the mean of principal component scores is 0.131). Finally, the fourth component was related to the management of relationships with people which was denominated “cooperation”. These interpersonal skills along with openness and flexibility were more important for elder students or who had some work experience previously.

3.2 Personality traits

Table 3 contains the means and standard deviations of the participants on the five personality dimensions and the social desirability scale. For comparison, average scores of the Hungarian norm group [16] are also provided. Note that the scores of the BFQ scales are represented in raw scores although standardized T scores were used for further analysis.

Table 3. Means and standard deviations (SD) of Engineering Informatics students in five personality factors and social desirability scale compared with the Hungarian norm group (raw scores)

	Engineering informatics students Mean (SD)	Hungarian norm group (N=774) Mean (SD)
Energy	74.74 (12.20)	77.51 (11.85)
Friendliness	79.22 (10.43)	82.25 (10.09)
Conscientiousness	82.65 (10.43)	81.34 (11.11)
Emotional stability	74.12 (12.39)	68.60 (15.83)
Openness	79.83 (10.78)	85.52 (6.88)
Social desirability	34.49 (5.00)	29.54 (6.88)

Engineering Informatics students obtained lower scores on energy, friendliness and openness dimensions, but higher scores on conscientiousness and emotional stability than Hungarian norm group.

Higher scores were found on the lie (validation) scale indicating that the participants tend to distort their profile in a positive way, and to present themselves in a better light than in reality.

Regarding factor scales, gender differences were revealed using an independent samples t-test (the normal distribution of the data was confirmed by the Kolmogorov-Smirnov test).

Its result shows that men obtained significantly higher scores on emotional stability compared with women ($M_{men}=75.23$, $SD=11.92$, $M_{women}=65.73$, $SD=12.86$, $t=3.479$, $p=0.001$), but lower scores on openness ($M_{men}=79.15$, $SD=10.53$, $M_{women}=84.95$, $SD=11.52$, $t=-2.401$, $p=0.017$).

The internal consistency coefficients of the dimensions ranged from .78 (openness) to .84 (energy), and .621 for the lie scale (social desirability) which is also feasible.

Based on the standardized T scores (provided in the BFQ Manual, [15]) personality profiles may be portrayed. T scores for each factors and sub-scales may be categorized as low (below 45), average (between 45 and 55) and high (above 55).

Engineering Informatics undergraduates in general achieve average scores for energy ($M=48.26$), friendliness ($M=48.88$), conscientiousness ($M=52.6$) and emotional stability ($M=52.81$), but low scores for openness ($M=44.01$), although they achieve high scores for social desirability ($M=54.8$).

4 Discussion

Our findings based on perceived competencies and personality traits suggest that Engineering Informatics students have several attributes, skills and competencies before starting their academic career which are relevant to the selected specialty in the university and crucial for their future profession as Engineering Informatics, for example they are capable of working both independently and dependably, meeting with high standards, controlling their emotions and showing consistent and coherent behavior without oscillating because of emotional states. However, they show a lack of social competencies such as effective communication, self-expression, organization, learning ability and cooperation which are important aspects for successful employment.

Based on the results related to the Big Five personality traits, the Engineering Informatics students display a low level of social skills, activity and dominance, implying that most of them are introvert and inactive, prefer working independently and tend to avoid interactions with others. They are characterized by moderate friendliness, helpfulness, tolerance and cooperation, but in contrast, they obtained higher than average scores for conscientiousness, meaning that they show accuracy and precision in various activities, have great respect for order and discipline, hence responsibility and reliability may be considered as their strengths. The participants also show emotional stability, indicating that they are rather calm and relaxed, and capable of controlling anxiety and impulses and coping with associated emotions.

These findings are in line with other studies that confirm existing evidence on emotional stability and conscientiousness among engineers together with lower levels of agreeableness compared with a norm population [9], and found that engineering students are more orderly, tough-minded and conventional than students in other disciplines [19].

Surprisingly, Engineering Informatics students obtained very low scores on the openness scale, indicating that they are neither interested in cultural and intellectual activities and events, nor open to change and to innovation, and that rather they have a traditional and conventional way of thinking.

These findings are in accordance with Holland's vocational personality types [20], which are based on the assumption that correspondence between key personality characteristics and work environments leads to important vocational outcomes (such as satisfaction, performance, etc.). Although it was not possible to identify clear types, 32 percent of the sample of Engineering Informatics undergraduates could be labeled as realistic or conventional types. Realistic individuals prefer to work with things rather than ideas or people, they enjoy physical activities, and they are skilled in mechanical and physical activities. Typical realistic careers include electrician and engineer (in their BFQ profile they score low in E and F, high in C, low in S and O factors). Conventional individuals are more likely to be conformist, they are organized and conscientious, they prefer organized, systematic activities and well-defined instructions, and are persistent and reliable in carrying out tasks. Typical conventional careers include secretary, accountant and banker (in their BFQ profile they score low in E, average in F, high in C, average in S and low in O factors). It seems that only a

third of the first-year Engineering Informatics students selected the university specialty in accordance with their personality traits.

The findings of the study suggest that many of the Engineering Informatics students are not aware of the expectations of the selected profession, and of a mismatch of the attributes required for the job and their personal needs and skills. Practical implication of our findings for engineering education would suggest that the competency development of engineering informatics students should include the development of self-knowledge and several personal and interpersonal skills which mainly contribute to the students’ academic career and future success in the workplace. The improvement of learning abilities, concentration and problem-solving skills are also crucial for preventing dropout among the students. Reforms in Engineering Informatics education are necessary, emphasizing the key role of the students’ activity in the learning process.

Considering the personality traits and perceived skills of the Engineering Informatics students, diverse learning organization methods and appropriate pedagogical techniques within the framework of student-centered learning approaches (e.g. problem-based learning, case studies, students’ presentations and projects) [21], need to be implemented in engineering education in order to motivate students and to prepare them for the employment challenges of today.

Some recommendations provided by Riemer [22] for improving a set of personal and interpersonal skills in the context of emotional intelligence of engineering undergraduates are in line with the student-centered teaching approach, and applicable for Engineering Informatics education as well. It is suggested to incorporate the development of non-technical competencies and soft skills across curricula [22]. For example, the students’ communication skills can be augmented by the delivery of oral communication and presentations in engineering studies. Opportunities for reflection are useful way to improve critical thinking and self-awareness (e.g. writing a reflective essay after fulfilling a task). Teamwork and collaboration in the context of cooperative learning help to form a proactive, rather than reactive attitude and support more active participation in learning.

It seems that not only the teaching methods need to be changed, but also the evaluation process of students’ achievement, and as Yorke [23] argued, formative assessment is critically important in higher education. The purpose of formative assessment is to contribute to student learning through the provision of information about performance [24]. Positive feedback from the teacher on student performance encourages the student and builds on strengths [22]. The constructively structured comments from peers also have a positive learning effect, as these encourage perspective-taking skill.

There are several possibilities for implementing new teaching methods and approaches into engineering higher education towards competency development of the students, however, it is essential for the teachers and instructors to create a new mindset and to develop their competencies that enable them to be prepared for teaching the new generation.

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Moray: Bridging an Ancient Culture of Innovation with Emerging Pedagogies in Engineering

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Abstract—From its inception, Universidad de Ingeniería y Tecnología (UTEC) has functioned under the mandate of causing a disruptive effect in society by educating a new generation of holistic engineers bound to become empowered change agents. The university has recently embarked on a radical transformation of its educational model, in order to deliver this promise. A flexible curriculum provides students not only with a strong STEAM backbone imparted in a student-centered active-learning format, but also exposes them to real engineering challenges and promotes the acquisition of professional skills from the onset. For this change to be implemented successfully, UTEC has decided to design and launch a Laboratory for Educational Innovation, called Moray. Conceived as an open platform, Moray sits at the intersection of physical and virtual spaces and is organized around flexible protocols that allow faculty, students, staff, and experts from top universities worldwide to work interdisciplinarily and collaboratively, towards the enhancement of teaching and learning dynamics in higher education.

Keywords—Educational Innovation, Engineering Education, Emerging Pedagogies, Student-Centered Teaching, T-Shaped Engineers

1 Introduction

The founders of Universidad de Ingeniería y Tecnología (UTEC) conferred one main mandate to its executive team: to cause a disruptive change in society by educating a new generation of holistic and global engineers. The university was launched in 2012 as a non-for-profit organization, under the premise of giving Peruvian youth access to a world-class and future-proof educational model in Engineering, regardless of each individual’s socioeconomic status, and only dependent on his or her talent, disposition, creativity and intellectual capacity.

To be able to live up to this vision and deliver its promise to students and society at large, the university has recently embarked on a radical transformation of its educational model. It has now instituted a more flexible and project-based curriculum, that provides students not only with a strong scientific, disciplinary and technical backbone, but also exposes them to “real life” engineering challenges, thus promoting the

acquisition of professional skills from the very first day. All of the content transmission and skill-building dynamics are carried out in student-centered, active-learning formats that promote student engagement, development of intrinsic motivation and deep learning. This structural change should create the conditions for the formation of the T-shaped professionals the world is in such high demand for.

Furthermore, in order to facilitate the “structural re-engineering” of the traditional engineering program and a successful implementation, UTEC has decided to implement a Laboratory for Educational Innovation named “Moray”, after an archaeological site in Cusco, Peru, which is considered to have been a controlled environment for hydraulic and agricultural experimentation for the Inca civilization. This paper describes the design and implementation process of this laboratory, whose main purpose is to provide faculty with the training and support before, throughout and beyond this change process.

2 Background and Motivation

The science behind learning has significantly evolved in the last few decades, highlighting the deficiencies of traditional models for Engineering Education[1]. Diverse entities have asked Engineering Schools across the globe to, on the one hand, strengthen and widen the scope of the fundamental sciences; and on the other hand, expose students to real-world engineering challenges, develop in them effective communication and teamwork skills, and also cultivate critical and ethical thinking[2]. All of this while reducing the number of hours in the curriculum, to allow most students to graduate in time. Traditional Engineering Education and its unrevised teaching methodologies cannot, as data shows, fulfill these great expectations[1]. Today we count on proven theories on the science of learning (i.e. how people learn in a pedagogically-sound and relevant manner) and on the science of instruction (i.e. how teachers or mentors should help students learn), based on cognitive theory and neuroscience[3]. There is now an almost unanimous agreement that people learn by doing, experiencing and reflecting on the results, whereas they absorb and retain a rather small fraction of what they see and hear in a lecture-heavy format[4].

In addition, the advances in telecommunications and digitalization of information have revolutionized the processes of knowledge production and transference. The mission of universities is to prepare their students for a modern professional career, encouraging them to actively engage with advanced technologies and develop functional skills in relation to new media, so that they can successfully integrate themselves into a society increasingly organized around these[5], [6]. Such developments have given rise to new scenarios of academic training, contents and processes of teaching and learning[7]. As a consequence, the adoption of a student-centered educational focus has led academic institutions to redefine the dynamics of teaching and learning that had previously been confined, predominantly, to the traditional classroom[8].

In view of these advancements in the learning sciences and the digital revolution, last year, and one year before graduating the first class, UTEC’s higher administration

and the Board of Directors decided to embark on a root-and-branch reform to be aligned with these changes and to ensure the preparation of holistic and T-shaped engineers. This disruptive change is embodied in what is now known as UTEC's Educational Model (UEM), which in turn aims at ensuring that our students attain five main competencies. We consider these competencies necessary to truly become the holistic engineers that Peru and the world require, in the face of the fourth industrial revolution:

1. Deep technical, disciplinary and interdisciplinary knowledge
2. Analytical reasoning and critical thinking for complex problem solving
3. Communication and collaboration skills across disciplines and cultures
4. Ability and will to lead the innovation and change processes
5. Ethical and socially responsible thinking and doing, both on a local and global basis

In short, UEM seeks to educate global professionals, able to understand, disaggregate and solve complex problems in a creative and ethical way; and communicate these solutions effectively. The model is highly student-centered and aims at awakening students' intrinsic motivation to deeply learn and ideate new solutions to the world's most pressing challenges. At UTEC, we believe that learning in a transdisciplinary and contextualized fashion and in connection with the real world, alongside the most important local and global industries, are richer and more effective means for developing our students into adaptable, lifelong, flexible learners and change agents.

In this context, Moray has been thought out as an open platform, consisting of both a physical and virtual space as well as a set of flexible protocols through which faculty, students, staff and experts from top universities around the world can work interdisciplinarily and in a collaborative manner. The main goal is to enhance teaching and learning dynamics and experiences both inside and out of UTEC's classrooms, fully embracing and harnessing the digitalization of the educational world. Moray crystallizes the innovative culture embedded in UTEC's DNA; such directive for radical innovation was, as mentioned before, first given as a mandate by its founders and later incorporated as one of three constitutive pillars – research, entrepreneurship, and educational innovation- during the university's design phase. Currently, it lies at the very core of the new educational model. This culture promotes experimentation, fosters a code of radical openness, is data-driven, and understands "failure" as something to be learned from and as an important step towards continuous improvement. Just like the Incas utilized Moray and its terraced depressions in concentric circles as an experimentation and testing station, the new curricular reform within UTEC has in the Educational Innovation Laboratory a platform from which to design, launch and monitor new initiatives. These initiatives can range from implementing technology-enhanced learning experiences to redesigning the underlying skill-building and knowledge-transfer activities, all of these with the objective of creating deep learning experiences in our students.

3 Design Process

The first step in the design process consisted of an initial (and mostly theoretical) benchmarking analysis, which allowed us to determine the key success factors for constituting an Educational Innovation Laboratory. Different laboratories and centers in ten countries -USA, UK, Finland, Australia, Singapore, Korea, Uruguay, Colombia, Chile and Mexico- were covered in this analysis. From the observations, it soon became clear that Moray had to become an overlay of physical and virtual spaces, serving as a focal point for the different actors and stakeholders of UEM. It had to be based on the following principles:

1. Be founded on a co-working and collaboration philosophy, a “radical openness” code of conduct and be staffed with a multidisciplinary team. In order to avoid blind spots and to be able to create communities and networks beyond the physical space or the confinement of the university, teamwork becomes essential.
2. Be student-centered and ensure the engagement of all stakeholders within the ecosystem. Students should be co-creators of UEM’s deliberate practices and changes.
3. Behave as an incubator and/or accelerator of educational projects. By fostering a culture of rapid prototyping, testing, iteration and continuous improvement; we aim to scale and replicate successful projects in other and larger contexts.
4. Be research-based and data-driven, as well as prone to incorporating new technologies and digital media into projects. In order to guide decision-making processes and to communicate them efficiently, we intend to catalyze otherwise tedious processes, capture as much data as possible and produce relevant information models.
5. Provide constant mentoring and feedback to establish best practices that could later be effectively communicated to and shared with diverse audiences.

Taking these key principles into account, the following sequence of steps was pursued for the implementation of Moray:

1. Identification of main stakeholders and possible contributors, participants and collaborators. In addition to the permanent staff, the champions (i.e. change leaders) and ambassadors within the organization were identified early on in the curricular transformation process, sent to specific “train-the-trainers” workshops and are now an integral part of the Laboratory. Furthermore, UTEC’s Provost and the Heads of Department have contributed to the design and launch phase, and now collaborate with Moray on a regular basis.
2. In-situ contrasting of benchmarking analysis. After carrying out the benchmarking analysis based on available literature, an important step was to corroborate our theoretical findings on-site. Thus, Moray’s Director and UTEC’s Provost embarked on a journey that allowed for the exchange of ideas with the leaders of the most reputable Teaching and Learning Laboratories around the world and also hosted such leaders at UTEC. The main goal of these visits was to procure intensive knowledge-transfer dynamics and a bi-directional sharing of good practices with these experts.

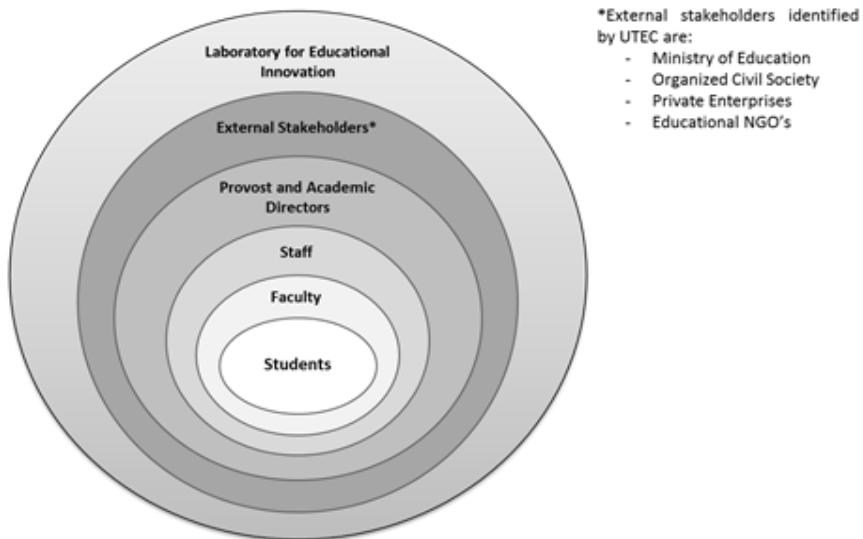


Fig. 1. Stakeholders' map showing the different players that are being brought together by the Laboratory for Educational Innovation. At the heart of the map are UTEC students, whose experience of the new UEM is critical when it comes to orienting the Laboratory's efforts.

3. Development of a strategic plan (Figure 2). This strategic planning process had to take into account the following aspects:
 - (a) Main activities: the initial focus areas would determine the activities to be developed and would take into account existing gaps and available resources. These would range from pedagogical workshops, rapid prototyping with share-backs, presentations, one-on-one sessions, co-teaching dynamics, peer reviews, faculty exchange programs, content production, portfolio building, among others.
 - (b) Personnel: the people hired for the laboratory should have focus areas aligned with the main educational themes and problems that the Laboratory would be focusing on with the option of calling in external talent for pedagogical consultancies.
 - (c) Space: the main functions and actions of the Laboratory would also determine the type of space needed. Aspects to take into consideration here include location, flexibility of the given space, and the atmosphere to be created with the furniture, equipment and lighting.
 - (d) Budget: the budget should be divided into four main pillars: personnel, space, equipment and operating costs by project.
4. Selecting and launching pilot project(s) that should evaluate the possible benefit to the final user and describe the concrete strategy to attain an objective. In this phase, it was important to ensure that the initiative served as enough of a proof of concept to merit the scale-up; otherwise, more pilot projects or prototypes would be necessary.

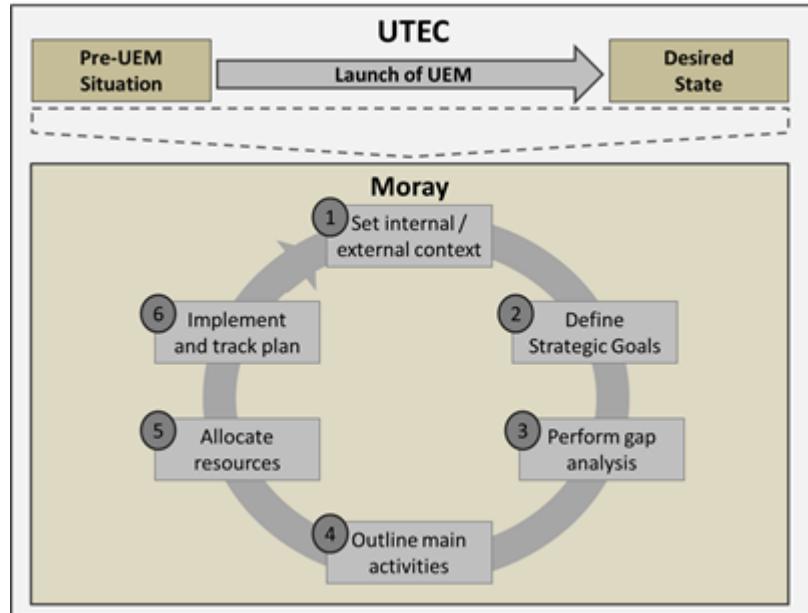


Fig. 2. Moray's strategic planning process for the successful implementation of UEM. The benchmarking analysis and internal diagnosis (step 1) led to the definition of goals (step 2) and a follow-on gap analysis (step 3). The initial main activities (i.e. pilot projects) were focused on bridging these gaps (step 4) and were planned carefully by allocating the necessary resources to attain quick wins (step 5). The final step (6) consisted of implementing the initial plan and tracking the impact and results on the implementation of UEM. The process is iterative for continuous improvement of Moray and UEM at large.

4 Preliminary Results

For the first pilot project, each coordinator of the common core humanities and science courses was tasked with revising and redesigning his/her course, to guarantee the development of UEM's five core competencies and to ensure consistency across the curriculum. These faculty members now gather at Moray every Friday for the "F3 - Faculty Feedback Fridays" meetings, a roundtable discussion and feedback session that aims at aligning on the overall objectives, iterating and improving these critical courses on the go. The preliminary effects of this course overhaul on the development of critical competencies are shown in Figure 3.

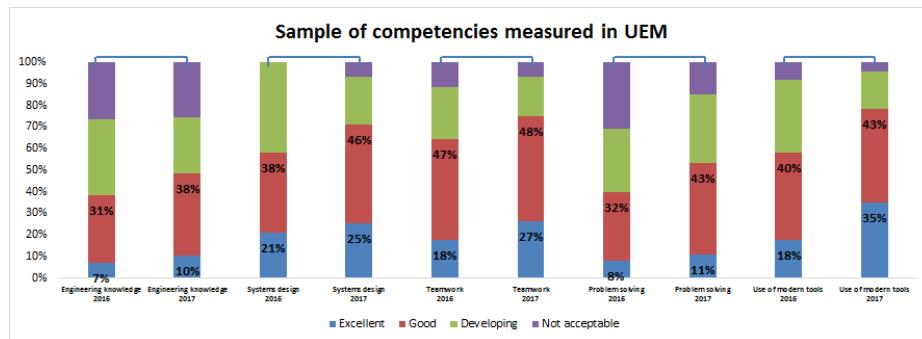


Fig. 3. Comparison of levels of achievement in UEM-related competencies in UTEC's previous vs. present education models. Faculty members were asked to fill-out detailed rubrics for each student in every course and in relation to specific competencies. The bar graphs show a significant increase of "good" (in red) and "excellent" (in blue) scores in 2017 vs. 2016, which coincides with the launch of the new educational model.

The Laboratory has also launched a "Fellows Program" that chooses and supports three to four faculty members throughout a semester to backwards-design and innovate either the entirety of their courses or a significant portion of them, based on hand-picked literature that is read and discussed in an applied and reflective manner. This course expects to enhance teachers' competencies when designing and implementing a student-centered course. By training the teachers, they will be in the capacity to rework their course so as to have better teaching and learning dynamics, consistent competency-building practices, and continuous formative assessment. The basis of this course was adapted from Richard Felder's framework for Teaching and Learning STEM[9] and is shown in Figure 4.

Additionally, Moray is conducting several data-gathering assessments and surveys with both students and faculty. For instance, a rigorous classroom observation protocol -an adaptation of The Classroom Observation Protocol for Undergraduate STEM (COPUS) [10] -has been administered to students in order to capture the level of student engagement during classes, which is regarded as a direct reflection of the teacher's ability to implement emerging pedagogies successfully (Figure 5a). The laboratory is also disseminating a student survey at two points during the term, to measure motivation, relatedness, autonomy, perception of competence and overall satisfaction with each course (Figure 5b). The results from these two studies suggest that having a more student-centered class, as well as other critical factors, should have a positive effect on students' academic performance.

Moray has also already organized three main faculty-wide, week-long teaching and learning workshops to prepare each and every member of the academic department for the new educational approach. The faculty will continue to have several capacity building / training opportunities offered by external experts in the field of emerging pedagogies. Faculty will also receive scientific literature, research papers and other tools and resources each week, which can be reviewed individually and later discussed at Moray's Journal Club. Finally, UTEC's faculty is also encouraged to work

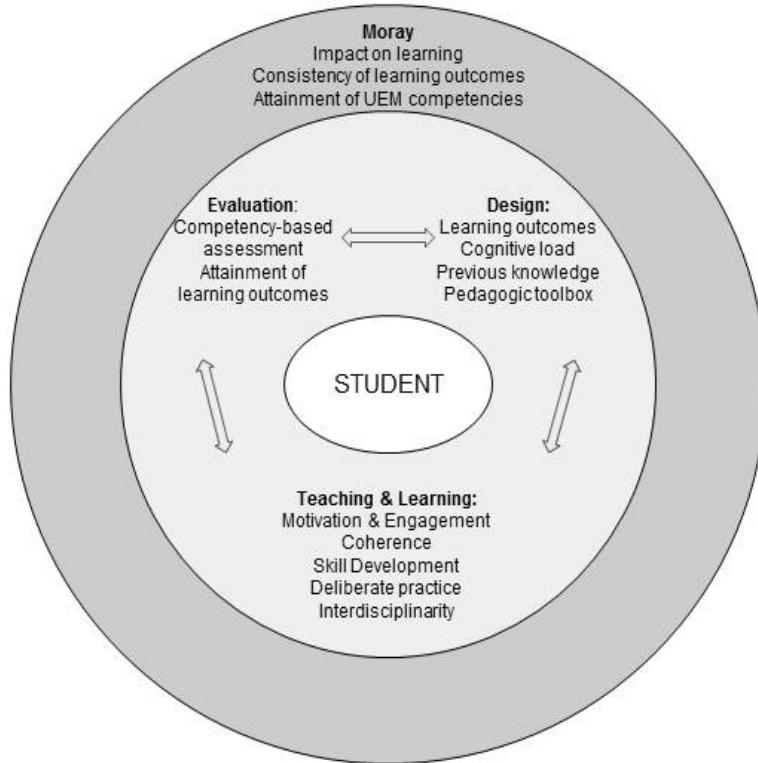


Fig. 4. Structural model for the design of faculty workshops. The semester-long course for selected faculty members follows the same structure as they should follow when designing a new course under UEM guidelines. Since the student lies at the center of the process, the initial design is shaped by the desired learning outcomes, his/ her preconceptions, prior knowledge, and cognitive capacities. The teaching and learning process has to motivate and engage the student in such a way that skills are developed through experimentation and active learning. Finally, the evaluation phase tests whether the desired skills have been developed and the learning outcomes attained. Moray has the overarching task of ensuring coherence and consistency for the development of UEM competencies.

across-fields at Moray in order to devise new transdisciplinary content and explore co-teaching opportunities. Some of these initiatives have already been rolled out; examples include courses like *Art and Technology*, *Geopolitics of Water*, and *Global Challenges*. These courses are meant to be a platform for students to approach a specific topic from different disciplinary perspectives while making sense of these diverse approaches as a whole.

The Laboratory is also designing new spaces that are more suited to promoting collaboration and creative thinking than a traditional classroom format does. By replacing the layout, equipment, and furniture corresponding to the “sage on the stage”

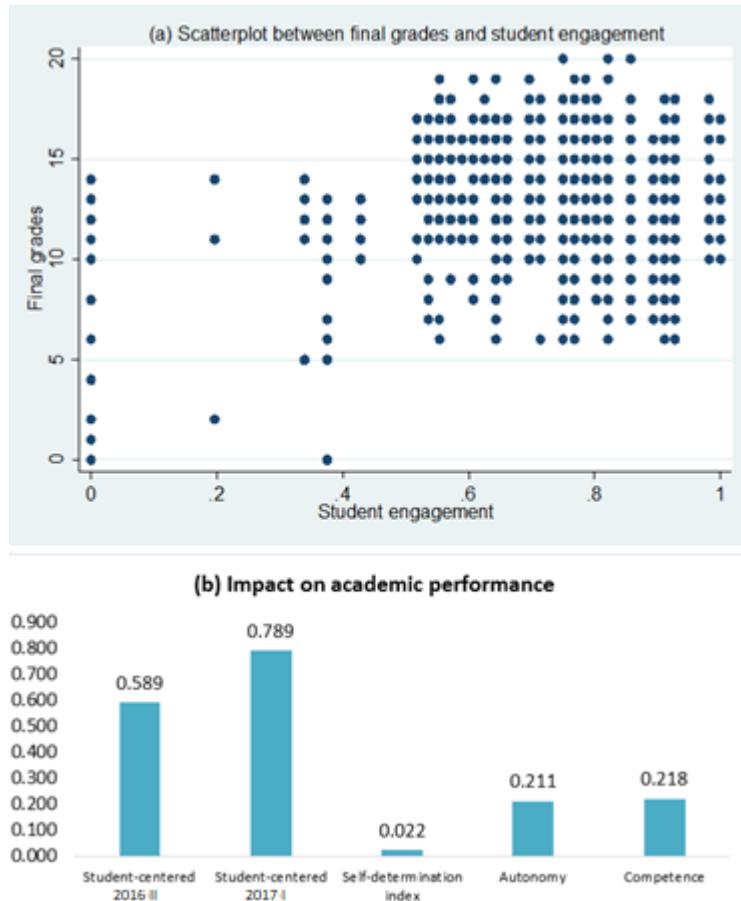


Fig. 5. Samples of data dashboards illustrating the level of achievement of two UEM-specific goals: (a) student engagement (as accounted by an adaptation of The Classroom Observation Protocol for Undergraduate in STEM[10]) and its correlation with final grades. Using a Tobit regression model, the data shows a positive and statistically significant effect ($p<0.05$) of 0.803, meaning that a one point higher level of engagement could improve a student's final grade by 0.803 points. (b) the impact on academic performance of a perception of student-centeredness, self-determination, autonomy and competence. The graph exhibits the positive effect of these variables, with student-centeredness showing the strongest and most statistically significant ($p<0.01$) effect on academic performance.

model, with a new set-up that instead sparks a “guide on the side” take on didactic practices [11], we expect to trigger changes in students’ behavior in line with 21st century skills such as teamwork, communication and collaboration. In addition, Moray has also been involved in the re-shaping and re-tasking of some areas within our campus to facilitate the “design-build-implement-test” process in proper engineering workspaces [12]. Accordingly, UTEC now has a large workspace, called UTEC Gar-

age, where students gather, exchange ideas, think them through in a hands-on approach and test them in a safe environment (Figure 6). Likewise, UTEC's FabLab allows students to 3D-print and prototype any idea quickly, under the guidance of experts in relevant fields. More advanced ideas that have been matured over several semesters will have the chance to be advanced in UTEC's very own business incubator/accelerator, UTEC Ventures. The university also holds over 30 laboratories with different field-specific resources and equipment that are open to students and faculty for research projects or prototyping exercises. All these spaces are thought to be spatial extensions of Moray where students can gather to develop their engineering and design projects.



Fig. 6. UTEC Garage as a MakerSpace lying at the heart of Moray. This 250 m²-large space is open around the clock to allow students, faculty and external stakeholders to gather in groups and develop prototypes of different levels of fidelity for their diverse projects. It is also a space for transdisciplinary workshops and roundtable discussions.

Finally, and as an umbrella program to all these initiatives, Moray has adapted and is now piloting a framework for the evaluation of teaching achievement. Such framework has been put forth as part of a study commissioned by the Royal Academy of Engineering (RAE) to a leading pedagogical consultancy. This Career Framework for University Teaching[13], proposes a standardized and transparent -therefore, portable- method for evaluating and evidencing teaching achievement. The metrics proposed by the Framework have been designed after gathering input from sixteen universities from around the globe -one of them being UTEC- and is already being used here to evaluate teaching performance at different stages: appointment, promotion and professional development. At Moray (and UTEC at large), we view this change in mindset and focus on teaching and learning (as opposed to mainly on research performance) as instrumental for the success of the new educational model.

5 Conclusions and Future Work

UTEC has embarked on a major transformation of its education model, to fulfill its promise of causing a disruptive change in society through the education of a new generation of engineers. This new model is based on two main, interrelated pillars: a novel curricular structure and a teaching and learning–focused Faculty Development Model. We truly believe that the early adoption, enthusiasm and active participation of the faculty in this transformation have all been catalyzed by the fact that the Faculty Development Model was designed and is being launched simultaneously with UEM. It helped faculty understand the undergoing process in a way that allowed them to grasp the need and the sense of urgency for a shift from a highly research-focused to a holistic perspective. Such change is not only more in line with the current trends in higher education around the world, but also truly values teaching/mentoring – and rewards them accordingly. One of the main early findings from our design and implementation process was that faculty need to be involved from the initial stages: they need to be part of the change process and be supported throughout. That is how the idea of Moray, UTEC’s own Educational Innovation Laboratory, was born. Having both a physical and digital space, dedicated personnel and a clear strategic plan for the implementation and change management process underlying the UEM, clearly helped all the involved parties align with the overall goal.

Today, Moray is already fulfilling the promise of serving as an open platform for UTEC and the higher education community to design and test innovative pedagogical initiatives in order to improve engineering education in Peru. There are five foundational competencies that have shaped the new educational model at the university. How to help students develop these throughout their experience at UTEC has been the guiding question and the connecting thread to which this model is the answer. Our initial pilot projects have shown a significant increase in the development of these critical competencies since the launch of UEM. Furthermore, the perception of student-centeredness within UTEC courses has had a noticeable impact on student performance in class. Every course now targets specific skills that are meant to percolate into a variety of fields. Therefore, we expect students to be able to connect the dots between their engineering education and the complexity of the world they will face as professionals. We count on educating students to propitiously navigate scenarios where leadership, ethical behavior, and teamwork, among other skills, will be crucial. As mentioned above, faculty at UTEC are the key players for this model to be implemented successfully. According to this line of reasoning, Moray should continue its path toward becoming the underlying support system for them to feel backed, motivated and empowered throughout and beyond this process.

A challenge faced at the early stages that is now being addressed, was finding the appropriate physical location for Moray. For a short period of time, the laboratory had to share space with other academic departments at UTEC, but it has now been assigned with a spacious area on a very visible and well-transited spot of the university. It will also be adjacent to a faculty lounge, so that teachers can freely navigate from a more relaxed and social atmosphere to a more “academic” space at Moray. This location communicates accessibility and divergent thinking at the same time. Additional

work still remains to be done regarding metrics to measure Moray's impact on the change management process and on the implementation of the educational model. To this means, the Laboratory needs to continue conducting focus groups, interviews and surveys with both students and faculty. Such research tools will be crucial in order to assess the level of satisfaction with and support perceived from Moray through the preparation, launch and implementation of UEM. Also, other ICT-driven processes, such as the integration of additional tools and resources, the path toward a blended or inverted model of instruction, and a more powerful drill-down on Business Intelligence tools to increase student retention rates, still need to be launched by Moray. All of this in order to make sure technology is properly leveraged so as to enable student-centered learning.

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The Personalized Computer Support of Teaching

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Abstract—In comparison with the traditional learning, the computer support of teaching represents a combination of didactics and informatics approaches. This requires researchers to solve an additional design of specific educational software and suitable ICT infrastructure. This contribution describes a continuous progress under the umbrella of the research on technology-enhanced learning; and how the ICT integration is modelled for the collaborative teaching and appropriated activities when using an in-house educational beta-software BIKE(E)/WPad. The practical experiences are demonstrated with some examples of how it is applied within the teaching bachelors students and from the related research on computer support from a teacher point of view.

Keywords—technology-enhanced learning, computer supported teaching, CSCL, educational software, database applications

1 Introduction

Technology-enhanced learning (TEL) represents an interdisciplinary issue. As the key-term, TEL was used within the project calls of the FP7 EU funded research program. The research focus was more on the informatics aspects of computer support of teaching and learning than the didactics ones. There are many literature sources related to the TEL. One can find useful information especially in the “basic” books on TEL [1-3]. A specific computer support of academic teaching is described in [4], including the CSCL (Computer Supported Collaborative Learning), which is presented from a historical perspective in [5].

Nowadays, the computer supported teaching and learning covers many specific areas of education. The global goal of authors' research is to computerize teaching processes on a personalized level with focus on the complex computer support without a need to use global software solutions (see e.g. [6-8]- interdisciplinary approach, or [9,10]-CSCL/ICL Conferences). So, the educational software WPad was continually developed in the period of 2007-2016 (by one of authors). The specific goal is to test and modify the pilot version of the WPad also for collaborative teaching (WPad is a part of the beta in-house software BIKE(E)-Batch Information and Knowledge Editor and Environment). It supports various collaborative activities in engineering education, e.g. in the framework of the courses of study: Background of environmental

protection; Occupational health and safety; Basics of Chemistry; Programming languages.

Fig. 1 illustrates the actual approach of authors to the ICT integration into the teaching and learning.

The education issues cover not only the educational content but also the teaching processes. The digital technology issues cover the technology infrastructure and the ICT tools. In this context, the pedagogical-didactic approach relates to the content and activities, and the ICT approach to the content and communication issues. This general approach more clearly illustrates the CSCL infrastructure in Fig. 2.

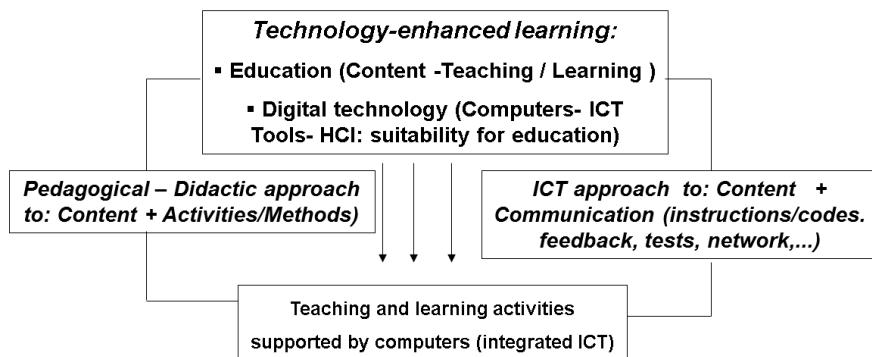


Fig. 1. Schema of the actual approach to the ICT integration into teaching and learning

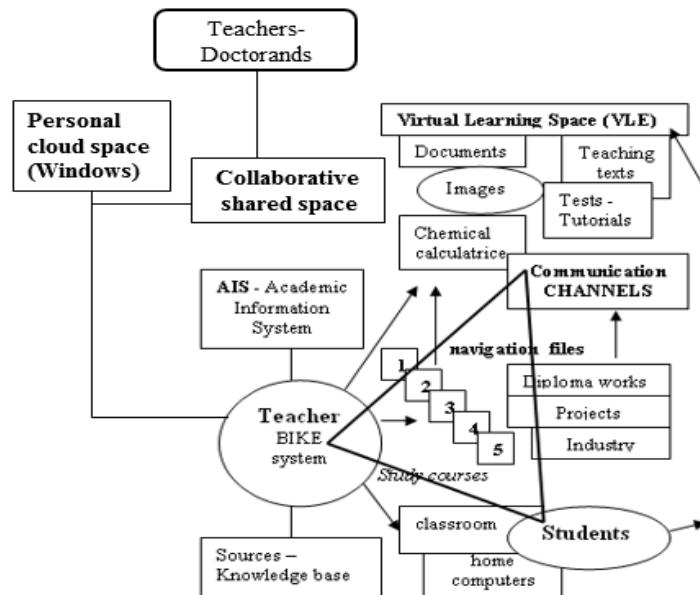


Fig. 2. CSCL infrastructure for the automation of teaching processes

In comparison with previous research presented in [7, 9, 10], the collaborative shared space and personal cloud space were implemented. The actual approach of authors' research on TEL is presented as the "automation" of educational processes" [11]. It should be understood as the integration of three key areas: (1) didactics processes running in classrooms, (2) informatics processes running during teaching, and (3) the adaptation of individual's activities related to using the Windows operation system, Internet browsers, software, hardware, clouds, networks (this affects the Human-Computer-Interaction). Authors' long-term research showed that the computer support must be strictly tailor made to the teaching activities, so not vice versa (teachers usually applied only a general software, e.g. office packages).

2 Examples of using WPad - Teaching

Any integration of ICT into education requires one to use an interdisciplinary approach. The issue belongs to the applied informatics, or applications in the field of cognitive science. This should be clear from the introduction, especially from the schemas in the Fig. 1 and Fig 2. In the context of this, the authors published their approach both from the didactics and informatics point of view (especially because one of them writes the educational software BIKE(E)/WPad).

For example, their actual IT approach is based on a theoretic background which was derived from Cybernetics approaches for automation of mental processes (teaching is considered as a knowledge based process). In our case, the WPad uses a so-called "virtual knowledge unit" which is both human and machine readable and isomorphically bridges mental processes with physical-computer processes [11]. So, the basic CSCL problems are solved by using the WPad in the framework of the combined off-line/online infrastructure (computers in classrooms/faculty's servers and open domain). This is illustrated by Fig. 3, i.e. the WPad, which is installed on computers in the classroom, virtual faculty's spaces and teacher's computers, represents a key IT tool for CSCL.

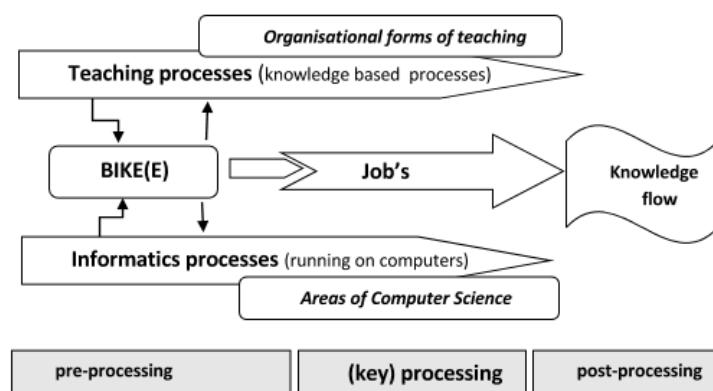


Fig. 3. The schema of the BIKE(E)/ (WPad) function within the research on CSCL

As was mentioned above, the supporting ICT infrastructure was implemented for modelling CSCL. The outcomes represent both the implemented collaborative methods (e.g. collaborative writing semester works) and the supporting IT background infrastructure (database application WPad, virtual learning space). It should be emphasized that the WPad tables are used by authors, teachers and students as the platform for sharing the same domain knowledge and to manage and move it via informatics paths (i.e. between classroom or home computers and faculty's server or internet).

Fig. 4 shows a screenshot of the WPad table. It represents an information exchange among teachers (see e.g. the note about Hopper's "Human are allergic to change", which was made from an e-mail).

One can also imagine the system BIKE(E)/WPad as a personal knowledge system or base which is empty at the beginning. Success in the processing of knowledge depends on the methods used for recording human or non-human knowledge into the knowledge tables. Fig. 5 illustrates examples of how various educational content is stored in the knowledge table. It can consist from strings and texts, e.g. personal notes, ASCII characters (e.g. a stored jpg- or mp3-file), or programming code which can be edited and launched directly from BIKE (here C++). The content and linked metadata are in one row of the knowledge table (see also output to html format).

Table Data:

03.03.2016	Wpad MIX Linky - M. Hopper lúdia sú alergickí n
03.03.2016	Wpad AIS Modul Diplomová práca ICT 22
03.03.2016	Wpad Multi rešér
03.03.2016	Wpad WILLEY BJET IF=1.3 Edukačná technológ
03.03.2016	PROJ Personálna matika
02.03.2016	64 :: PIESNE
02.03.2016	64 :: Studenti ZE 2015
02.03.2016	64 :: PDF
02.03.2016	WILLEY BJET IF=1.3 Edukačná technológia
01.03.2016	MIX Linky
01.03.2016	MIX Linky

Right Window Content:

```

[Admiral Grace Murray Hopper]
: https://en.wikiquote.org/wiki/Grace\_Hopper :: zaslala 1.
Markechová - ... Humans are allergic to change. They love to
say, "We've always done it this way." It's easier to ask
forgiveness than it is to get permission

Rear Admiral Grace Murray Hopper (9 December 1906 – 1
January 1992) was a U.S. Naval officer, and an early computer
programmer. She was the developer of the first compiler for a
computer programming language;

```

Fig. 4. Screenshot of the collaborative knowledge table for information exchange

Table Data:

* http://www.isc-conf.org/cfp.htm :: Call for Papers American Applied Sciences Research Institute Confe	1. Intelligentní AI 2. Signal ai 3. Commu 4. Network 5. Data Mi	French "ù@61 //Kd& //include "tj class Vozidlo private: int PocetK public: void nastav	TCHEMIA Schéma Virtuálna kemička Voda - Výpočet potenciálu elektro energie Hustota prachoviny a roviny 2 Periodická tabuľka MEROX Síra pridaná ZE - MI Atomy a krestové řetězce Chemická reakce a výpočet zmeny Tlakový efekt na zmenu	DEPLN Starovia novica VCHEMIA DEPLN Tipovat R R = $\rho V = \rho RT$ $R = \frac{p}{\rho T} = \frac{p}{\rho RT}$ $R = \frac{p}{\rho T} = \frac{p}{\rho RT}$ $T = \frac{p}{\rho RT}$
--	---	--	--	--

Fig. 5. Examples of content categories in a row of the knowledge table

Within the programming of WPad, an internet application was designed (the personalized TEL system) and placed on the virtual learning space. It functions as a communication channel for feedback and collaborative activities. So the collaborative teaching is performed in combination with the communication channels which connect the virtual learning space at the faculty's server with classrooms' computers, notebooks or mobiles. The communication channels work as a personal network where information, knowledge and instructions "travel" between teacher and students to be shared. They represent a sophisticated analogy to the Internet forums.

Fig. 6 illustrates how the teacher or students write information (ASCII-data) into the channel (on the left). It can be written by using keyboard or teacher can use a simple HTML text. For example, there is a comparison of emission and absorption spectrum of hydrogen from Wikipedia in the screenshot on the right.

While Fig. 6 represents one record (information) of the communication channel, while as one can see, the screenshot in the Fig. 7 represents the more complex communication content - in this case, an example of seven rows with instructions for students and links to an educational material (e.g. Windows 7 manual - created within a diploma work; computer speaks training material for photosynthesis – made by students).

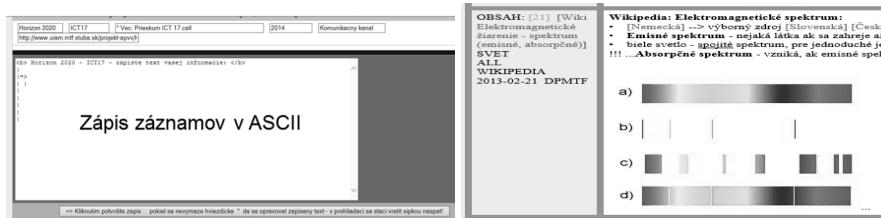


Fig. 6. Examples of screenshots of the communicational channel for Chemistry

Komunikačný kanál: ZE	
Diplomovka	INFO: [Manuál pre Windows 7] [Viacej...More]
Diplpraca	Diplomat Široký pre vás urobil špecifický manuál pre prácu s PC [Viacej...More]
SemPraca	[PHOTOSYNTHESIS - mp3] [Viacej...More]
SemPraca	[REVI - mp3] <ul style="list-style-type: none"> The dark phase produces glucose - sugar, which has six carbons. In the cell is already present ribulose-biphosphate-1,5 - sugar, which has five carbons. This fixes CO₂ from the air and creates a six carbon compound (carboxylation). The ribulose breaks up three carbon compounds that are involved in a series of chemical reactions in the Calvin cycle. The energy for this reaction comes from the comp [Viacej...More]
SemPraca AUDIO	INFO: [I am Translator prehrá text /Say It/ a link naň sa dá poslat!] - nemusí sa teda nahrávať!
ZE	Nezabúdajte, že zápočtový týždeň končí s prizmúrením očí v nedele u 24.00!
ZE	Vypíšem termíny skúšky na štvrtok, piatok a sobotu okolo obeda

Fig. 7. Communicational channel containing educational content and instructions

3 Examples of using WPad - Research

In general, university teachers must perform such complex activities as education, training, formative and summative assessment, publishing (writing papers or conference contributions), even project solving, expertises, or other specific activities (international cooperation, partner search). To meet the mentioned drivers pressure in the workplace, where everything is focused on performance and performance is everything, a permanently formal and informal learning, and self-study of the teachers is required. To be sustainable it requires particularly for senior teachers to use:

- personal expert knowledge base with the huge amount of steadily updated educational information (in a computer-readable and human-readable form),
- generic information flow (e.g. from CORDIS, Wikipedia or other EU/Regional portals and databases),
- specialized expert information flow (e.g. concerning technology, standards, expertises, patents, case studies, information exchange, international collaboration,...),
- various information types and formats within their knowledge base (electronic, printed, audio, video, hand-written),
- various information sources (WEB-databases, online libraries, journals, books, standards, personal correspondence or records, educational portals, etc.).

In this context, the research performed under the umbrella of TEL is considered by the authors to be an automation of traditional "face to face" teaching. The software, a database application BIKE(E)/WPad, was written by one of the authors (Svetsky) who is both teacher, designer and researcher. Case studies on BIKE(E) implementation within traditional teaching were presented in [6-11]. Basically, it works as an all-in-one tool used by him for producing a set of teaching aid tools, i.e. from simple off-line tutorials to the complex virtual learning environment functioning online on the faculty's server. It is not simple to explain it in details because an atypical approach is used, which was patented as an utility model [12]. The database application is also unique, however it could not be patented because in the EU it is not possible to patent any software (only technical solutions).

The BIKE(E)/WPad as a multipurpose, "all-in-one" personal tool is also used for modelling interactive collaborative teaching as was mentioned above. However, it is possible to perform only a limited number of collaborative activities during the teaching hours (due to lack of time, when one teaches ten to fifty students). So under the "automation of traditional teaching" one should understand that computer support - with BIKE(E)/WPad as teaching tool - enables a teacher to solve new methodological approaches that could not otherwise be solved within regular teaching time. One can imagine simply that the computer works as a teacher's assistant. For example, the content from a computer - as illustrated on Fig. 4-7 - can be shared, evaluated, managed, i.e. used by the teacher for didactical purposes, summative or formative assessment, writing collaborative works etc.

To the best knowledge of authors, no such solution has been described in the literature. For example, several years ago, the learning management system Moodle was evaluated as the most frequent technology-enhanced learning tool used at European universities [13]. However, in contrast to Moodle, BIKE(E) works both off-line and online, allows the teacher to produce eLearning materials, perform internet retrievals or launch external applications in Windows operation system. Being a personal knowledge management tool, as published previously by authors [13], BIKE(E) could even be used to build a Moodle-like personal learning management system. For example, Fig. 8 illustrates integrating the in-house software BIKE/WPad within educational knowledge management processes.

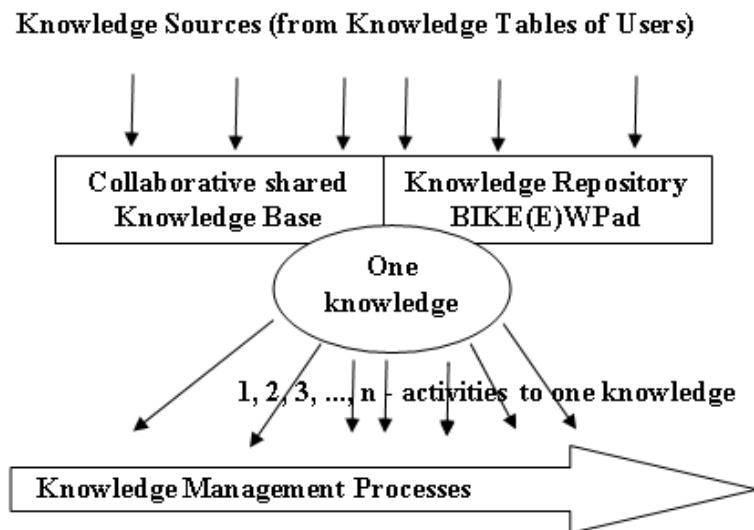


Fig. 8. Relationship between knowledge (content) and activities (knowledge flow within knowledge management processes)

In principle, a systematic research on technology enhanced learning started within the FP7- ICT proposal KEPLER (Knowledge-Enhanced Proactive Library Learning) [14]. The focus was on the ICT Objective ICT-2007.4.1-Digital libraries and technology-enhanced learning, and aimed at the crucial processes of the selective capture, preservation, accessibility and usability of multilingual, multimedia websites. The virtual federated grid services should have been used on the basis of the elaborated use cases, and the R&D innovations demonstrated within a new kind of grid-based Federated Digital Library. Basically, this grid-based Federated Digital Library would had been a source of learning content for engineering teaching and learning. This required, inter alia, to design a system of keywords for multilingual content indexing and retrieval.

The following text illustrated a planned content of such work-package (Slovak University of Technology was a leader of this task) as was in [14]:

Work-package title: MULTILINGUAL CONTENT INDEXING AND RETRIEVAL

[STATE OF THE ART]

1 WEB-Monitoring (investigation and testing of content sources for indexing and retrieval, multilingual tools and services, testing of on-line applications)

2 State-of-the-art Study

[SUBTASK 1] : KEYWORDS STRUCTURATION FOR M-CONTENT INDEXING

1.1 GENERIC meta content keywords

Deliverable: M-Database 1

1.2 SPECIFIC R&D meta content keywords

Deliverable: M-Database 2

1.3 DEFAULT R&D content keywords (standards or international classification)

Deliverable: M-Database 3

1.4 Keyword based BATH SEARCHING SYSTEM modelling

Deliverables: Set of retrieval templates

1.5 Reporting

Deliverable: Report

[SUBTASK 2] : MULTILINGUAL RETRIEVAL MODELLING

2.1 Mono- and multilingual RETRIEVAL with refining

Deliverables: Set of databases

2.2 Knowledge based RETRIEVAL LIBRARY BUILDING

Deliverables: Partial libraries

Another focus on the Learning Analytics field was within the FP7 ICT proposal L³-Pulse (L³-Pulse: a Scalable Cloud Platform for Interactive LongLife Learning Data Mining for a Sustainable Future). The topic of the proposal aimed to develop an innovative eLearning toolkit for collecting, storing, exploring and reasoning on large-scale educational data to better understand learners' knowledge, assess their progress and evaluate environments in which they learn. This toolkit should have been equipped with intuitive interfaces for visualizing and interacting with the data in order to ease their integration into the practice of teaching and learning. L³-Pulse would have been research new techniques for automated improvement of learners models, assembling a technology platform to support a free and open source learning analytics toolkit for sharing hypotheses and integrating, analysing and visualizing data creating innovative training scenarios for such developments that are supported by the toolkit to be constructed. Expected Impact was: more efficient use of ICT for learning through the exploitation of learning analytics tools, and increased awareness on the benefit of the adoption of learning technologies.

Fig. 9 illustrates a schema of modelling the learning analytics by using the in-house software BIKE(E). In this case, the objective intended to be attained is the modelling learning analytics in the classroom conditions. However, in comparison with state-of-the-art in the field of Learning Analytics this approach is focused directly on "human knowledge", i.e. educational knowledge flow during real teaching, not only on monitoring of activities of students in online learning environments.

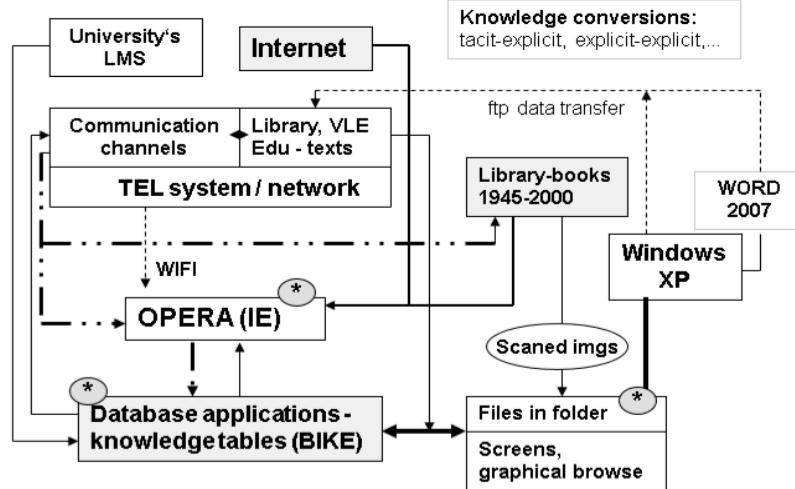


Fig. 9. Schema of modelling Learning Analytics by using the in-house software BIKE[15]

In the Cybernetics, it is common that some thought problems and processes can be investigated by their physical representatives. A necessary condition is that isomorphic relationships exist between the specific system abstractions and real physical systems [16]. Due to this isomorphism, the result of physical processes can be translated into mental operations, i.e. into the "intellectual" result. Because the mental processes are knowledge based, one can design a physical model based on the isomorphism in order to transfer some mental (thought) tasks into the physical area and vice versa.

Fig. 10 illustrates such isomorphic relationship between the mental and physical processes, which is represented by the "virtual knowledge unit" as the key element of the presented approach. A concept of this "virtual knowledge unit" is explained in [17]. In our case, just this can be used for monitoring the "educational" knowledge flow when solving learning analytics issues as was mentioned above (it is also used within the registered utility model for processing unstructured data in the Slovak Patent Office).

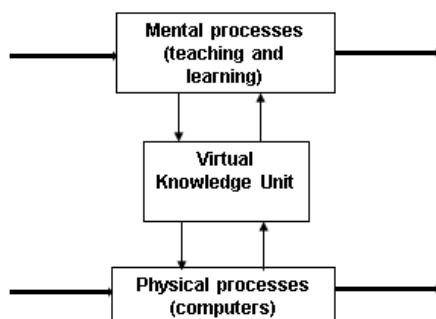


Fig. 10. Isomorphic relationship via the "virtual knowledge unit"

4 History of the in-house research on TEL

Within a period of around ten years of empirical research on Technology Enhanced Learning (TEL) implementation in teaching at the Faculty of Materials Science and Technology of the Slovak University of Technology, a pre-programmed environment for “batch knowledge processing”, was developed. This includes the about mentioned in-house educational software BIKE(E), a personalized Virtual Learning Environment and a set of tailored WEB-pages for several engineering courses of study. This was tested and directly applied in the teaching of bachelor students. The field of TEL was a part of the calls put forward by the 7th Framework Programme (ICT research in FP7), where the research priority was focused on “how information and communication technologies can be used to support learning and teaching“.

At the beginning, there was an idea to equip research and development staff (knowledge workers) with informatics tools for personalised working with huge amount of information, e.g., for “self-eLearning”. Thus, a knowledge base and information sources structure, associated activities and outputs were designed to be solved. For this purpose, the database application BIKE(E) was developed as an “all-in-one” support tool for generating browser-based eLearning applications, performing personal internet retrieval, creating a combined virtual online / offline learning environment and the support of content management, etc.

In this context, the introduction of an entirely new paradigm of batch processing of information and knowledge was needed, because in a conventional DBMS (Database Management System) the data are processed in another way based on a relational E/R model. This gradually resulted in the development of the pre-programmed environment of the BIKE (Batch Information and Knowledge Processing) that was used for support of the engineering education of bachelors. For students and other teachers it is available as a standalone WPad (Writing Pad), which is installed on computers in a classroom. The existence of such an informatics tool allowed for teachers to solve the first stage of processing the knowledge flow between information sources and the “knowledge” database tables. In this stage various types of learning materials and libraries with browsable pages and documents were produced to support daily teaching.

However, the creation of tools and solutions only for processing the content was not sufficient for the needs of teaching, because this technology - driven approach, did not take into account the pedagogical aspects of education and the key role of the teacher. It was found that the processing of knowledge (engineering content) also needs to address the flow of knowledge between the produced learning materials (tailored for courses of study) and between individual educational activities. This required more education - driven TEL approach than the previous technology driven one. In other words, the technology-driven approach for TEL was expanded with educational aspects. From an informatics point of view, the next solution showed a need to understand the information and knowledge processing in order to support teaching and learning activities such as "automation." When programming is focused in this direction, it became clear that when dealing even with the simplest of activities

a large amount of alternatives are available. If one takes “the automation of teaching and learning activities” into account as an individual interdisciplinary issue, the solving represents a “never-ending story”. In this paper, some examples, i.e. applications of personalized support of teaching, were presented.

Currently the BIKE environment allows individuals (teachers, students and researchers)]:

- to design and produce a large amount e-Learning of training materials from one's own personal know-how, such as, printed materials, electronic media and also the multilingual Web environment by the use of educational content and internet services,
- to solve the support of teachers in developing their personal preparation for teaching and related e-Learning tools (tutorials, self-evaluation tests, interpretation of the scheme, a personal information system, the digitization of printed books and the transfer in teaching material for a given study program),
- to automate all kinds of educational activities - teaching, testing, evaluating and grading of students, publishing, making retrieval, administrative activities, the data transfer from Academic Information System,
- to create a personal Virtual Learning Environment and use a communication forum that acts as a personal social networking among students and teacher for feedback, sharing information, instructions, but also for a common research space where participants can store information from the survey of literature (particularly students working on diploma theses),
- to automate, i.e. streamline the activities of individuals in the Windows environment (the additional features to the operating system, searching in the database, directories and files, to archive files by incorporating certain features of the File Manager and editing programming languages – HTML, PHP / MySQL).

With the multi-purpose environment of BIKE (it is only on the author's computers), or its part WPad, which is installed on personal computers, teachers and students can use all five categories and all possible types of learning (face to face, blended learning, informal learning to life-long self-study). For these reasons, it can be understood as a specific type of personal "Mindware" (personal external memory), but also as a supplement to the operating system of Windows.

It may be noted that despite several years of intensive research, there could not be found in the literature and on the Internet described, a similar paradigm of batch knowledge processing when working with conventional RDBMS (relational database). No identical or similar multi-purpose software package that provides many activities at once, such as dozens of dedicated software routines, can be found. This multifunctional environment of BIKE(E) gives added value to traditional teaching, which brings a synergic power factor in terms of educational materials for the creation of new materials, new innovative ways of teaching and self-study. By BIKE(E) from beyond the established computer and pedagogical practices, it is quite difficult to explain its function. This is one of the reasons for the differences of evaluators when peer-reviewing, where someone classified it as a tool for knowledge management, eLearning, and even soft-computing.

5 Conclusions

The real computer support of teaching represents always a mix of various kinds of teaching and learning processes and areas of ICT. Some practical experiences with the in-house developed educational software BIKE(E)/WPad for modelling the interactive collaborative teaching were briefly described via examples from teaching bachelors students (e.g. how communication channels "teacher-students" function and how the computer support of collaborative writing is solved by using the WPad tables). From the collaborative teaching point of view, both teacher and students can use the same knowledge, including transfer of the domain knowledge flow via digital paths. The teacher designs collaborative methods, in addition, the described informatics background infrastructure is hierarchically subordinated to those methods. The communication channels were also tested when examining bachelors students (on their classroom or home computers they see the communication channels, located on the faculty's shared virtual space).

The interdisciplinary research on CSCL actually continues in the framework of an institutional project. For instance, teachers and PhD students test collaborative methods for sharing their personal data (in their WPad tables on their devices) with the shared central WPad table (localized on the faculty's server). A future work is aimed at the design of database applications for modelling the automation of mental processes (based on the utility model), including solving the CSCL visualisations. It should be also emphasized that modelling the computer supported collaborative teaching and learning requires in parallel a combined pedagogic (didactic) and informatics research (because it is not possible to write programing codes if no teaching steps exist).

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Managing Human Factors Related Risks

The Advanced Training Model in Dangerous Goods Transport on Roads

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Abstract—This paper studies the methodological essence of dangerous goods (DG) training courses for drivers and dangerous goods safety advisers (DGSA). The research aims to advance existing teacher-centered course model in Estonia with learner-centered methods that best suit specific objectives and meet expected learning outcomes, as well as to improve DG training model with the integrated use of interactive teaching methods.

The paper presents a qualitative development research strategy based on studies regarding ADR regulations training courses in Estonia as well as on the analysis of teaching methods applied in the professional training of adults. The data is collected in two steps: firstly by implementing questionnaires for consignors/ consignees, freight forwarders carrier companies and drivers, secondly during in-depth interviews/ focus group meeting with DG regulations training companies' providers. Implementing methodology of qualitative comparison analysis (QCA) combination of best suitable teaching methods is identified. After following in-depth interviews and performing a focus group, these combinations are further used as input for developing existing course model with integrated use of blended learning alternatives, where digital media meets with traditional classroom methods. Results of this research contribute coming up with interactive methodological approach within ADR regulations training courses that meet the best trainees' expectations and fulfills the risk management aim.

Keywords—DG training courses, teaching methods, qualitative comparison analysis, blended learning

1 Introduction

The transportation of DG on the road always involves risks. If substances are mishandled, injury and property damage risks are increased. From the perspective of road transport, this concerns primarily main parties of a transportation chain, *i.e.*, consignors/ consignees and carrier companies (including drivers), but also freight forwarders, and third parties. A transport containing DG can have an impact on the environment if an accident occurs and these often incur a higher cost for the society than non-dangerous goods accidents. This is one reason why it is essential to focus on

improving the efficiency and security of DG transport and avoid potential accidents [41].

Training courses for drivers and DGSA involved into dangerous goods transport (DGT) are based accordingly to the European Agreement concerning the International Carriage of Dangerous Goods by Road (*i.e.* ADR, Chapter 8.2) and the European Commission Directive (96/35/EC) on the appointment and qualification of Safety Advisers for the transport of dangerous goods by road, rail and inland waterways [43, 45]. In addition to these documents, there is the Adult Education Act that sets additional requirements for adult education in Estonia on a national level [31]. The role of DG training courses has an essential impact on the human factors aspect that reveals during DG handling and transportation processes as the human factors are crucial why accidents occur within a transportation chain.

The role of educational technology in teaching today has importance due to combining the amount of information and communication technologies [41]. What comes to in-service training with the focus on practice, it is complicated to implement suitable interactive teaching methods and techniques effectively. In the scope DGT by roads, there is no doubt that adequate training of drivers and DGSA may affect the safety aspects in peculiar transports, such as the one of DG. Training may not only include regulations, technical and procedural elements, but also important psychophysical aspects such as how to manage fatigue [3, 33].

The provider of training may be different according to national legislation. It can be the role of the employer (in the US and Canada) to ensure appropriate truck-driver training for the transportation of DG. In Sweden and the Netherlands, as well as in Estonia, a competent national authority must accredit training institutions or trainers and monitor the examination of truck drivers [20]. However, all training system approaches to pursue the same goal: to ensure appropriate training and prevent the accidental release of DG during transportation. By implementing specific interactive teaching methods, remarkable improvement of course participants' learning can be achieved. Moreover, operational risks related to human factors' issues can be reduced within entire transportation chain of DG.

When considering an approach to instruction, teachers are aspired to use methods that are most beneficial for all of their students. Using both approaches, teacher-centered as well as student-centered together, learners can sense the positives of both types of education. By implementing interactive teaching methods to support existing teacher-centered ADR training course model in Estonia remarkable improvement of course participants' learning can be achieved. To implement the procedural approach, a designer has to understand the contents of the whole system, its structure, the principle of operation and behaviour [21] fully. It becomes very difficult to describe complex systems using only procedural techniques. The reason lies in the nature of a modeled object because any procedural model implies a one-sided, incomplete, and prejudiced glance on the original [27]. In the scope of this paper relation between concepts of a training system, training model, training process and training requirements is visualized as shown in Figure 1.

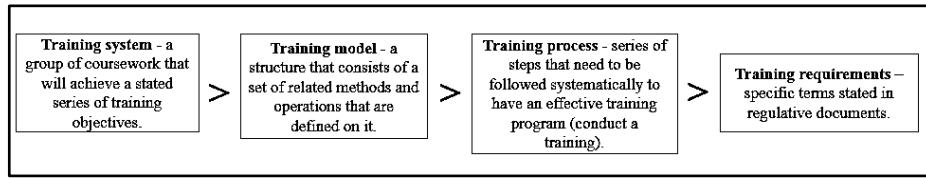


Fig. 1. Conceptual relation. Source: Authors.

In Estonia, ADR regulations training courses are formed based on teacher-centered course design mainly. This methodological approach is outdated as the concept of the learner is changing rapidly. The problem discussed in the scope of this paper is a part of a broader study and refers to an outdated methodological approach in carrying out DG training in Estonia, both for drivers and safety advisers. Based on conducted survey research among representatives of different parties of a DG transportation chain in Estonia, best suitable interactive teaching methods are studied. From developed combinations of techniques, advanced training course models are created with the implementation of blended learning elements. As this methodological approach is in the scope for discussion of a focus group with DG training provider companies and the representative of Estonian Road Administration, it finally represents a comprehensive training model that considers human factor risk managing elements of all parties. Results present readily handled ADR regulations training course model that could be implemented by DG training provider companies of Estonia in the coming years. All this will contribute to improved human risk management of DGT by road.

2 Background

2.1 Literature review

The global trend of increasing traffic due to globalisation leads to a higher number of DGT [11]. Several studies have focused primarily on the critical analysis of ADR implementation concepts in European countries [*Ibid.*]. What comes to performance indicators supplemented regarding the transport and handling of dangerous goods, the number of DGSA as well as the number of ADR training certificates, are critical controlling the performance of handling dangerous goods in green transport corridor [36]. Chances and challenges coming along with the ADR ratification were illustrated, and the concept / recommended procedures of how to train involved people in the framework of DG was developed from in-depth analysis and critics of current training methods.

The broader approach with regards to blended learning issues within in-service training, in general, has been studied a lot. These studies focus mainly on training school teachers with implementing different types of blended (mixed) learning scenarios of information and communication technology (ICT) related subjects. When modeling practical scenarios based on a combination of different face-to-face interactive approaches (such as problem-based learning, collaborative and project-based approaches, and diversity of e-learning activities and resources within), it is funda-

mental to take into account learner's previous experience and ICT skills. Better results in acquiring the content of the course are in a healthy relationship with learner's previous experience in ICT [22].

Specific models, methods, and technologies have also been studied in the scope of support the training of drivers involved in the transport of DG [5]. Italian developed online training environment (TIP – Transport Integrated Platform) is addressed to operators in the transport sector and combines classroom-based training with online self-learning possibilities on a distance. The platform has been continuously upgraded with innovative tools and presents a component of blended learning model where online digital media meets with traditional classroom methods [5, 39, 40]. Implementing blended learning methodology within classes keeps students active not allowing them to disconnect from the subject. This leads to a better attitude to improve learners' thinking and writing, motivating them for further study and development of new thinking skills [13, 22].

Training of safety and DG topics is essential for a risk and accident minimisation in the handling of DG and their transports. According to previous research studies on DGT the awareness of different parties of transportation chain in Estonia, there is a lack of professional knowledge among personnel on the national level [17]. According to a comparative analysis of teaching methods of ADR driver training courses of France, the Netherlands, and Estonia, remarkable differences were identified [18]. In Estonia, a significant lack of learning tools and no ARD based activities to endorse training courses and to increase the proportion of practice are so far in use [*Ibid.*].

Human-related risk preventive mean lies in efficient staff training. In following parts of this paper, the methodology of QCA is implemented in to analyse specific methods as cases due a set of relations and assess of their consistency. Existing teacher-centered DG training model will be completed with blended learning approach and evaluated within focus group meeting to define its' relevance toward risk management of human factors related risks when transporting DG by roads.

2.2 Dangerous goods regulations training courses

As DG and their transport need special handling and attention due to their risk for the environment and health of people, the training of any persons having to deal with those goods is essential for safe processing [15]. Common legal requirements (ADR) states in details that drivers when transporting DG (with small exceptions) shall undergo training in the form of a course approved by the competent authority. Concerning chapter 1.3 of the ADR, every employee, which has to commit the duties of DG regulations, needs to be specially trained [1]. Other parties involved within operations with DG can be: manufacturer or owner of DG, owner of tank containers, persons carrying out forwarder duties, persons writing and preparing transport documents, persons working for the DG receiving, persons committing packaging procedures, filling personnel of tanks, vehicle drivers, who do not need an ADR certificate, persons carrying out carrier and vehicle owner duties [2, 23].

Persons mentioned above often carry obligations of DGSA as they are involved in operations with DG in road transportation. A DGSA is a consultant or an owner or

employee of an organisation appointed by a company that transports, loads or unloads DG in the European Union and other countries [38]. There is no specific classification regarding DGSA courses. However, ADR driver training courses can be classified according to two aspects. Figure 2 visualises the content of training programs and training courses, highlighting common and distinctive elements of ADR driver training courses.

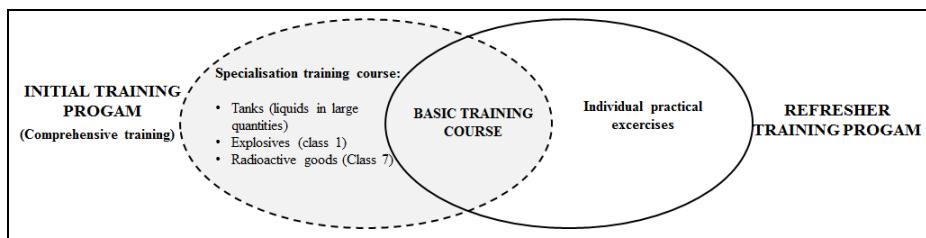


Fig. 2. The content of ADR driver training programs. Source: [18]; adapted by authors.

Firstly, training programs are identified by the level of the training program (initial or refresher training program), and secondly, training courses within programs are divided according to specificity (basic or specialisation training course). The minimum duration of the theoretical element of each initial training course or part of the comprehensive training course is set according to common legal requirements. The overall length of the comprehensive training course may be determined by the competent authority, which shall maintain the duration of the basic training course and the specialisation training course for tanks, but may supplement it with shortened specialisation training courses for Class 1 (explosives) and Class 7 (radioactive materials) [25]. Refresher training has to be undertaken by drivers (as well as by DGSAs) at regular intervals in every five years. As the form of a training program is defined by compulsory topics and minimum learning hours only (according to ADR), it is free to choose the methodological approach to conduct the training itself [18].

2.3 Interactive teaching in adult training

Today classrooms challenge traditional, teacher-centered curriculum to meet the increasingly diverse needs of students and make the required increases in achievement gains [7]. The fact that the adult teaching method is to a great extent different from the system in which students of various ages are schooled is felt in the assimilation of knowledge, in the means which they put into practice and understanding at a conceptual level of the theories and models proposed in the course program. Moreover, what comes to in-service training with a focus on practice, it is much more complicated to implement suitable interactive teaching methods and techniques efficiently.

Today, adult learning theories have series of characteristics that differentiate adult learners. These determine the teaching methods that will most successfully promote

learning in an older population of students¹ [37]. According to theories and practices on adult learning these characteristics are as follows:

1. Selective learning - adults determine what is meaningful to them.
2. Self-directed learning - adults take responsibility for their education.
3. Previous knowledge and experience of adult learners.
4. Problem-centered approach – adults are interested in content that has a direct application to their lives.
5. Anxiety and low self-esteem due to possible negative previous experiences with school [14, 16, 32].

The impact of these characteristics on adult learning is not limited to the face-to-face classroom as they also affect the way that adult learners will approach learning in the online environment as well [24]. Named characteristics have to be considered when training personnel within ADR regulations training. From the perspective of a diversity of methods in use and resulting approach to adult learner's peculiarity within ADR training courses, the United Kingdom can be highlighted as a best-practice. The existing models of ADR related training in the UK apparently differentiate learners by their category – drivers and DGSA. When registering for the training course the learner can select among different approaches how to study. Due to the preferences traditional classroom learning, full or partial e-learning, as well as webinar-based learning options, are possible. The training model of existing ADR training provider companies of Estonia is alike and methodologically outdated as it doesn't take into account learners' unique features nor their preferences.

Rapid development of ICT has facilitated an approach to traditional face-to-face and technology-mediated learning environments, which is called “blended/hybrid learning.” In the scope of this paper blended learning methodological approach, where digital media meets with traditional classroom methods is brought into focus as appropriate for Estonia’s case to start with the methodological development of an existing model of ADR regulations training courses. In following parts of this paper alternative, learner-centered training model is proposed for efficient ADR regulations training courses with the integrated use of interactive teaching methods.

3 Methodology

3.1 Problem description

The primary purpose of teaching at any level of education is to bring a fundamental change in the learner [42]. Due to the high risk of DG, there is a must to learn before doing in the content of ensuring safety. The ADR implementation and the knowledge transfer concerning DG are complex.

Existing learning model of DG training courses in Estonia today is standard for all learners without differentiating them into categories: drivers and DGSA. Moreover,

¹ According to the statistics during the period from 2012-2016 (*i.e.*, currently valid certificates) the total number of issued ADR driver licenses in Estonia was 30 539 and the number of issued DGSA training certificates during the same period 118 [8, 44].

ADR regulations training courses are formed based on teacher-centered course design mainly, i.e., learning activity is performed during classroom lectures supported by the slideshow presentation. ADR regulations training courses are mostly in-class and theoretical proceedings, even in cases, where a practical example would be considered necessary, as in the case of fire confronting and first aid issues. In most cases, in-class training is followed by the use of books, issued by the training companies, slide presentations and internal tests [18].

Today this methodological approach is outdated as the concept of a learner with its needs is changing rapidly. Moreover, existing learning form does not meet efficient risk management within the transportation chain that is evolving more complex due to the number of parties involved as well as due to additional risks concerned new DG and their danger characteristics. The methodological approach of professional training should be student-centered and focused on developing learner autonomy and independence by putting responsibility for the learning path in the hands of learners [12]. This approach ensures the fact that after completing the training course a trainee can handle problems in practice independently. This is essential in the scope of DGT. The present paper aims to perform the analysis and identification of teaching methods suitable to be integrated into existing ADR professional training courses in Estonia with the scope to increase the proportion of practice and thereby to minimise operational risks related to human factors in further studies.

3.2 Data collection and analysis

A research design is the set of methods and procedures used in collecting and analysing measures of the variables specified in the research problem research study [10]. The research problem defines the research design of this study according to which the methodological approach of ADR regulations training courses in Estonia is outdated as the concept of a learner is changing rapidly. In the scope of this paper primary data collecting on learners' attitude regarding the current format of courses is collected from all main parties who operate with DG on a daily basis, i.e. consignor/ consignee, freight forwarder and carrier company. Respondents were divided into clusters according to the type of ADR regulation training course type which is aimed at them. Clustering was performed as follows:

1. CLUSTER 1 (truck drivers; ADR driver training course),
2. CLUSTER 2 (consignors/ consignees, freight forwarders, carrier companies, other participants; ADR DGSA training course).

Truck drivers have been separated from carrier role to identify their preferences individually. The primary objective is to understand attitudes and preferences by clusters toward specific teaching methods respectively. The essence of specific methods that were focused on was explained to respondents. A structured questionnaire with close-ended ordinal-scale questions has been prepared as main data collecting form, where respondents were asked to decide where they fit along a scale continuum regarding the use of particular teaching method within ADR training classes.

Implementing methodology of qualitative comparison analysis (QCA) combinations of suitable teaching methods are identified that are effective both in the scope of operational risk management as well as from the perspective of learner's needs and expectations. QCA is a means of analysing the causal contribution of different conditions (*e.g.*, aspects of an intervention and the broader context) to an outcome of interest [28]. QCA starts with the documentation of the different configurations of conditions associated with each case of an observed outcome [29, 34]. These are then subject to a minimisation procedure that identifies the simplest set of conditions that can account all the observed outcomes, as well as their absence. Results are typically represented in statements expressed in ordinary language or as Boolean algebra. According to formula (1) expressed in Boolean notation combination of Condition A AND (*) condition B OR (+) a combination of condition C AND (*) condition D will lead to an OUTCOME (\rightarrow) E [*Ibid.*].

$$A * B + C * D \rightarrow E \quad (1)$$

The paper presents a qualitative development research strategy based on studies regarding ADR regulations training courses in Estonia as well as on the analysis of teaching methods applied in the professional training of adults with the implementation of ICT possibilities to contribute to effective human factor risk management. Upon the results of QCA analysis and in-depth interviews with DG training companies' representatives, preliminary models of training courses are developed for further validation during the focus group with selected experts from DG training activity. Focus group research involves an organised discussion with a selected group of individuals to gain information about their views and experiences on a topic [19]. Within this research stage, the initially developed training model for drivers and DGSA are in focus. The participants of a focus group influence each other through their answers to the ideas and contributions during the discussion by assessing advanced training model with regards to human risk management.

3.3 Research design

Within the process of developing research, the study can be broken down into 3-4 distinct stages. Firstly it is establishing a research type, secondly naming research strategy and finally determining a research design by defining specific methods and research procedures [10]. The research design refers to the overall strategy that is chosen to integrate different components of the study in a coherent and logical way, thereby, ensuring the effective address to the research problem [*Ibid.*].

The research problem defines the research design of this study according to which the existing course model in Estonia is teacher-centered and the role of using interactive teaching methods within ADR regulations training courses are underestimated by trainees. In the scope of this paper, the research object is the existing model of ADR regulations training courses in Estonia, methodologically the same both for drivers and for DGSA. The research design for this study is built upon the principle of qualitative development research as it is seen in Figure 3.

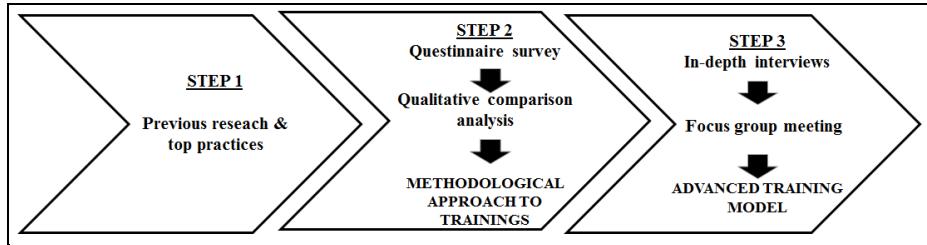


Fig. 3. Research design. Source: Authors.

The first step in a complete research design of this study involves identifying top previous research on a topic related and reviewing the published empirical articles to diversify possible methods. At this stage, the best practice is identified (the training models of the UK) and results of previous studies on the example of Estonia [18] are brought together.

The second step presents a combined questionnaire survey on learners' attitude and preferences concerning the methodological format of courses. QCA analyses collected data. Hence, the methodological approach to training is developed respectively for ADR course training for drivers and DGSA separately.

Individual in-depth interviews with ADR training provider companies within the third stage of the research is a data-collecting phase mainly. According to the information from Estonian Road Administration, there are altogether five trainer companies that have a license to train drivers and one that prepares DGSA [25]. Based on some trainees per trainers in 2016 four interviewee trainer companies that provide ADR training for drivers is chosen. Regarding training DGSA interview with the single representative business was carried out (share of 100%). The results of interviews are structured with the implementation of comparative analysis methodology and commented by contrasting them with the best practice on an example of the UK training course models. Focus group with DG training provider companies and the representative of Estonian Road Administration gives an objective assessment to the advanced ADR regulations training model that considers human factor risk managing elements of all parties.

4 Results

4.1 Learners' methodological approach

The data collecting on learners' attitude and preferences concerning the methodological format of courses was performed during the period from February 3 – May 3, 2017. The online survey was prepared using Google Forms both in Estonian and in Russian. The distribution of the questionnaire was provided via email invitations (60 companies that work with DG on a daily basis) and social media channels addressed directly to specialty-focused groups (e.g., Estonian truck drivers with an estimated number of 1800 ADR licensed drivers). Altogether 189 replies were gathered

(CLUSTER 1 – 151 respondents, CLUSTER 2 – 38 respondents). By theory, the sample must represent the population as well as possible. Current sub-samples are not statistically representative enough to draw accurate conclusions concerning population. To ensure the representativeness, the sub-samplings were formatted in a non-probability sampling technique where the samples are gathered in a process that does not give all the individuals in the population equal chances of being selected [4]. In the scope of this study, samplings are also qualified as purposive samplings where subjects are chosen to be part of the sample with a specific purpose in mind that sufficient to draw objective conclusions concerning the methodological approach of some subjects are fit for the research compared to other individuals [*Ibid.*]. This is ARD regulations training courses but is insufficient to give an accurate picture of attitudes and preferences of all DG transportation chain participants in details.

Within the structured questionnaire, interactive teaching methods were firstly explained thoroughly and then proposed to be evaluated in contrast to leading existing methodological approach today - classroom lecturing with the support of slideshow. These methods were selected into the study mainly based on the practice of other countries (i.e., France, the Netherlands). See Table 1 and Table 2 that present respondents' attitude and preferences by clusters concerning different methods that learners have experienced or are willing to undergo when taking ADR regulations training courses. Results are given in some respondents and percentage share of the total cluster.

Table 1. Teaching methods evaluation (CLUSTER 1)

Teaching/ learning method (Category)	Evaluation scale				
	1 (most inefficient)	2	3	4	5 (most efficient)
E-learning on a distance (A)	54 (36%)	57 (38%)	28 (18%)	6 (4%)	6 (4%)
Peer-learning (B)	29 (19%)	19 (13%)	73 (48%)	21 (14%)	9 (6%)
Practical tasks (C)	28 (19%)	17 (11%)	19 (13%)	40 (26%)	47 (31%)
Solving case studies in groups (D)	23 (15%)	27 (18%)	26 (17%)	35 (23%)	40 (27%)
Watching, analysing teaching videos (E)	28 (19%)	9 (6%)	20 (13%)	48 (32%)	46 (30%)
Reading individually materials (F)	29 (19%)	38 (25%)	34 (23%)	27 (18%)	23 (15%)
Listening to lectures with assistance of slide presentations (G)	19 (13%)	12 (8%)	34 (22%)	71 (47%)	15 (10%)

Source: Authors

Table 2. Teaching methods evaluation (CLUSTER 2)

Teaching/ learning method (Category)	Evaluation scale	1 (most inefficient)	2	3	4	5 (most efficient)
E-learning on a distance (A)		5 (13%)	10 (26%)	15 (40%)	3 (8%)	5 (13%)
Peer-learning (B)		4 (11%)	7 (18%)	10 (26%)	12 (32%)	5 (13%)
Practical tasks (C)		5 (13%)	3 (8%)	12 (32%)	10 (26%)	8 (21%)
Solving case studies in groups (D)		3 (8%)	6 (16%)	7 (18%)	10 (26%)	12 (32%)
Watching, analysing teaching videos (E)		4 (11%)	6 (16%)	10 (26%)	8 (21%)	10 (26%)
Reading individually materials (F)		20 (52%)	7 (18%)	4 (11%)	4 (11%)	3 (8%)
Listening to lectures with assistance of slide presentations (G)		16 (42%)	5 (13%)	6 (16%)	8 (21%)	3 (8%)

Source: Authors

By implementing QCA methodology best, suitable combinations of teaching methods were studied. As learners' operational risks within DG transportation chain differ, as well as expectations toward training courses, two separate truth tables were formed. According to methodological approach, categorical variables (conditions) were defined as following: e-learning on a distance (A), peer-learning (B), practical tasks (C), solving case studies in groups (D), *etc.* As a result combinations of conditions A-G were combined that would lead to the outcome. Effective methodological approach (outcome W) for ADR regulations training courses for drivers (W1 for CLUSTER 1) and DGSAs (W2 for CLUSTER 2) in Estonia are expressed in Boolean notation below in the form of formulas (2) and (3).

$$(C * D * F + B * E * G) - A \rightarrow W1 \quad (2)$$

$$E * (D * A + B * C * G) - F \rightarrow W2 \quad (3)$$

The results underline that methodological approach differs by learners' category. Empirical results indicate that traditional lecturing with the support of slide presentation is still adequate and suitable teaching method concerning drivers training. Learner-centered interactive methods are expected to be implemented within classroom lessons, and individual theoretical learning is clearly outdated with regards to DGSAs training. Hence, interactive methods differ greatly on a national level. Well-implemented blended learning methodological approach on the example of Italy (TIP) is not suitable for Estonia's case according to results of this study. This leads to the stand-point that trainees clearly underestimate the attitude towards the possible use of blended learning methodology at this point within ADR regulations training courses.

4.2 Advanced methodological approach

This chapter gives an overview of results of analysed data collected during in-depth interviews with four ADR training provider companies for drivers and one training company which is responsible for training DGSA in Estonia.

Table 3. Main findings of in-depth interviews.

Researched aspects	Trainer A	Trainer B	Trainer C	Trainer D	Trainer E
Design of existing training course	Teacher-centered/ student-centered	Teacher-centered	Teacher-centered	Teacher-centered/ student-centered	Teacher-centered/ student-centered
Active-learning methods in use	Discussions	Discussions	Discussions	Discussions	Discussions / Q&A
Current use of ICT	No	No	No	No	Not significant use
Comments on results of previous studies	A great contribution of a trainer are expected	More practical aspects should be included; active-learning methods can be implemented without ICT usage	Existing approach supports learners' expectations	DG related information has to be introduced within occupational training of drivers	Important information in scope of further developments
Changes in existing training	Partial e-learning	Improving handout materials	Improving handout materials	Involvement of more voluntary DG related training to companies	Involvement of more expert lecturers
Comments on further developments of training system	Focus on knowledge; license issued to trainers individually (not to a training providing company)	Ask for systematic feedback on training course	Changes in supervision of an ADR regulations training system	Greater emphasis on DGSA training	Audio lecturing possibilities should be studied; slow transition onto blended learning

Source: Authors

As in-depth interviews are useful when the focus is on getting detailed information about a person's thoughts and behaviors or the aim is to explore new issues in depth on the particular matter [6], this method was chosen suitable for collecting data within the third stage of the research. Table 3 gives a summary of essential findings of interviews that are relevant input for improving training models with the integrated use of interactive teaching methods and implementing blended learning. Results are presented summarised in the form of table where training provider companies' names are left hidden (named as Trainer A, B, C, D for driver training companies, Trainer E for DGSA training company), as the intention of comparability analysis is not to compare companies or their services, but to identify opinions and views regarding integration of ICT opportunities and interactive teaching methods into existing ADR regulations training course system in Estonia.

The result of individual interviews confirms the aspect that ADR regulations training courses in Estonia are primarily teacher-centered since the only mainly used learners-centered method is a discussion according to main findings presented in Table 3. However, some points indicate on the fact that training providers are interested in implementing new approaches to carry out training courses, including with support of ICT possibilities. At the moment none of the interviewed trainers in Estonia are taking advantage of ICT opportunities with-in ADR training course for drivers. On the other hand, implementing partial e-learning is considered as further development within the existing course model. Such topics as first aid, basic knowledge of the use of protective equipment, *etc.* can be presented in the form of e-learning already soon.

Considering results of QCA of this study and results of in-depth interviews, preliminary training model for ADR regulations training courses for drivers and DGSA with the implementation of interactive and e-teaching methods were developed. This was presented as an interim result of research during a focus group meeting with ADR training provider companies and a representative of Estonian Road Administration to collect opinions on the relevance of the methodological approach in the scope of applicability in training and the possible effect on managing human-related risks. Considering remarks made by focus group participants the advanced training model for the model for ADR regulations training courses for drivers and DGSA was developed as it is presented in Figure 4.

When developing models for ADR related training courses in Estonia following principles and additional remarks made by focus group participants were taken into account:

1. Teaching methods make a difference with regards to human-related risk management.
2. Transition to blended learning course model has to be slow and step-by-step to take into account both trainers' possibilities as well as learners' readiness for a renewed approach to learning.
3. The DGSA trainee is more independent learner than the trainee who is undergoing ADR training course for drivers. Therefore methods that support independent

- learning (e-learning opportunities) are included in training model for DGSA (seen in Figure 4).
4. Due to personal learning habits and preferences, learner needs for different learning options.
 5. Learners' ICT skills have to be considered.
 6. During self-assessment as well as final-assessment the use of materials (Internet) should be allowed. The assessment has to be more integrated in the learning process and, learners will also take responsibility in it [35].
 7. Implementation of the advanced methodological approach of ADR related training courses in Estonia should begin with DGSA training.
 8. Further development of training course model with the implementation of virtual reality solutions with the variety of specialised simulations for education and training purposes.²

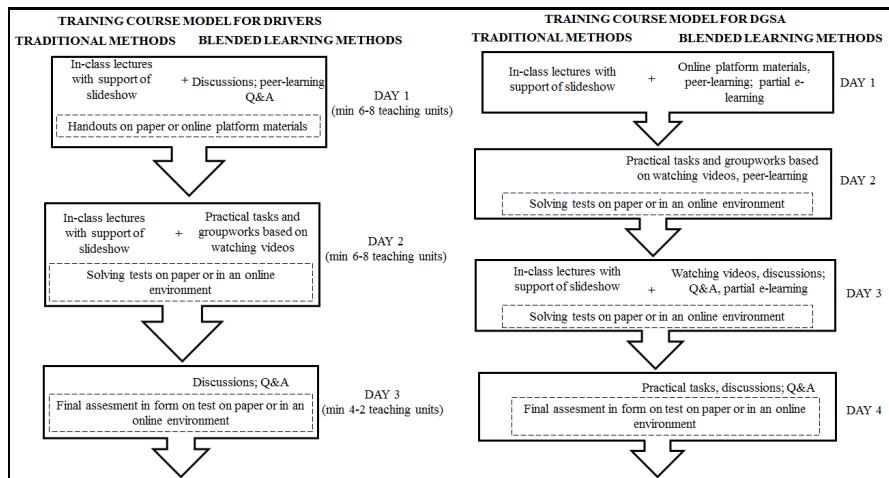


Fig. 4. Blended learning training course models. Source: Authors

Within this research finally developed training course model is final and considered ready to be implemented in practice for piloting. Herein opinions of all parties have been viewed with regards to applying blended learning techniques into ADR regulations training courses. Developed blended learning training course model is considered to be a good starting point for piloting and for establishing specific conditions and metrics on its' effect with regards to managing human-related risks when transporting DG by roads.

² Simulating complex incidents and accidents with DG on roads may have a positive effect on managing risks, as drivers/ DGSA may never face similar situations in practice unlike the awareness of a danger that is acquired through simulation. Similar simulations are in use for training of fire and medical emergency situations on example of German Chemical Industry. Firefighters can train their behavior on complex transport accidents with dangerous goods on motorways, rails, and country roads. Most of the firefighters have not been called very often to those accidents in their daily business. Within virtual training spaces, it is possible to train staff's behavior and to cope with complex operations [31].

5 Conclusions

There are many prescriptions, which need to be followed by different parties within the transportation chain of DG to ensure safe transport and handling operations as well as to minimise operational risks related to human factors. The change in existing teaching practice today regarding ADR training courses is necessary due to many aspects. Due to the continuously increasing number of the possible harm to the health of people and the environment in general, it is essential that all parties being involved are trained accordingly.

Educated and competent personnel is the critical factor that defines the competitiveness and efficiency of a system. What comes to competitive and efficient transportation chain of DG this all refers to a minimised level of risks; hence it is essential that personnel involved is capable of managing these risks properly when arranging or performing DGT. Due to possible risks with high consequence and the fact that trainees are adults, the training of employees of transportation chain of DG has to be detailed and practical giving a learner the opportunity to acquire the knowledge using different methods. Integration of ICT and implementing blended learning methodology within existing ADR regulations training courses were studied within this research.

According to collected and analysed data as well as to results in the form of developed training courses model conclusions have didactical and regulative nature. Didactical findings are directly related to principles on which improved training models are developed. Regulative conclusions refer to an overall ADR regulations training course system in Estonia. These are as following:

1. The trainer's qualification requirements are questionable – review and, if necessary, change conditions.
2. The trainer's knowledge of the methods used is insufficient
3. The control system of trainees has to be improved.

Conclusions presented above on regulative issues of ADR regulations training courses system rises next questions that need attention on a national level. Further researches related to this issue will focus on testing improved ADR regulations training course models in practice.

6 Acknowledgment

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Teaching Concurrent Programming Concepts Using Scratch in Primary School: Methodology and Evaluation

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Abstract—Computer programming can help children develop problem solving and analytical skills. Thus, many countries have included computer science in the curriculum of primary school. Given differences in culture, available infrastructures, as well as the age pupils are introduced to computer science, forming a computer science curriculum still remains a challenge. Towards this end, this study focuses on exploring the potential merits of introducing concurrent programming concepts early in the learning process. The basic premise is that although concurrent programming at its full details is a rather advanced topic even at university level, it is everyday practice to perform two or more tasks simultaneously that might need (or not) some sort of synchronization. Therefore, the tutor can capitalize on everyday experience to explain basic concepts on concurrency. Such correlation between life experience and concurrent programming challenges may expand the cognitive functions of the pupils and provide them with further background to improve analytical thinking. The proposed curriculum for fifth and sixth grade primary school was adopted in seven classes in Greece. Results indicate that uninitiated to programming pupils at the age of ten (fifth grade) were able to comprehend basic concurrency topics, while pupils at the age of eleven (sixth grade) with some programming familiarity were able to understand more advanced concepts.

Keywords—concurrent programming, computer programming, constructivism, Scratch, primary school

1 Introduction

Computer programming is considered a basic literacy in the digital age helping children to develop creative problem solving skills, logical thinking and mental flexibility. As indicated by European Schoolnet in [6], only ten European countries have fully integrated computer programming in their primary school curriculum, as of 2015. Given differences in culture, available infrastructures, as well as the age pupils are introduced to computer science, the challenge of forming a computer science curriculum that not only offers basic background but expands the cognitive horizon and cultivates the imagination of students, still remains a challenge.

Early computer science courses typically focus on structured programming concepts such as: control/selection constructs and iterations. The primary educational effort (particularly in the case of Greece) is tailored towards applying these building blocks into single thread execution scenarios, overlooking scenarios with concurrent multiple threads. However, concurrency rises more than often in educational programming platforms such as Scratch. For instance, when two independent entities, e.g., sprites, move and act in a labyrinth, it is not uncommon that racing conditions appear, whenever the entities require simultaneous access to a common resource, e.g., some treasure object. As a result, pupils might experience “unexpected” program behavior and occasional program crashes. The teacher has then two practical options: (i) either overlook the problem, diminishing its importance, and continue focusing on single thread correctness criteria, or, (ii) attempt to give a thorough explanation of the reasons of such “unexpected behavior”, thus, introducing concurrency issues to pupils, albeit in an ad-hoc, unstructured and unplanned manner which might prove discouraging.

Motivated by: (i) the apparent “knowledge gap” concerning concurrency that exists on many typical early computer programming syllabuses, (ii) the fact that pupils are accustomed to multitasking in their everyday life and (iii) the importance of multithreading and multitasking in modern software and hardware, this study investigates the enrichment of a typical syllabus with multithreading concurrency issues. The main aim is to introduce the pupils to the basic challenges of concurrent programming in a systematic manner, without sacrificing the level of detail contained on a typical syllabus as far as simple single thread structured programming is concerned. The developed syllabus was tailored and evaluated for the education system of Greece, whereby pupils are introduced to programming concepts at the age of ten using Scratch.

The rest of the paper is organized as follows. Section 2 presents the related work from the particular standpoint of the pedagogical approach followed (constructivism). Section 3 illustrates the methodology together with the proposed syllabuses. Section 4 gives an overview of the main computer programming pitfalls experienced by students and the pedagogical approach to tackle them. Section 5 includes the evaluation setup and discusses results. Finally, Section 6 provides the concluding remarks.

2 Related work

The core approach of the study adheres to the constructionist theory, according to which the learning process is not only transmitted from teacher to pupil, but rather constructed in the mind of the pupil in the form of active learning [16], [18]. Constructivism theorists such as Piaget and Papert view children as the builders of their own cognitive tools, as well as their external realities [1]. Moreover, Papert believes that programming has a tremendous potential to improve classroom teaching [13]. Thus, the dominant theory of learning, supports that knowledge is actively constructed by the pupil and not passively absorbed from text books and lectures [1].

Constructivism has been intensively studied by researchers of science and mathematics education [1]. However, there has been much less work on constructivism in

computer science education [2]. In 1980 computer programming projects became to appear with more frequency in schools, but observations of student learning did not always match the powerful claims. The ideal vision of students' becoming better due to hands on Logo learning collided with the documented reality of students' difficulties to learn even fundamentals of Logo [11]. Nowadays, research has entered into a new phase of multidisciplinary theory based protocols [5], [11]. The initial vision of teaching and learning computer programming has been altered. The focus of current researches is on understanding the conditions under which the skills that are learned in programming can transfer to cognitive development of learners [3]. For instance in [10] it was concluded that programming in pairs (a common situation due to laboratory restrictions in schools) has limitations, while in [7] it was pointed out that despite its original limitations, the newer versions of Logo with enhanced graphics and interface might find applications in pre-school ages.

Visual programming languages such as Scratch have been widely adopted recently as the means for early introduction to programming concepts. Scratch uses blocks, which the pupils drag and drop to form their scripts. An avid research interest exists on how to fine tune the learning process with Scratch in order to achieve the best pedagogical results in primary schools [8], [12], [17], but also in elementary ones [14]. Towards, this end the research presented in this paper aims at filling a tutoring gap that often appears when following a classic introductory syllabus to Scratch programming, namely the teaching of concurrency concepts.

3 Methodology

3.1 Educational context and targets

The application of the methodology was performed in the Greek primary school whereby computer programming is taught at the last two years of the school (ages ten and eleven). The official curriculum involves a total of 12 weeks of hourly laboratory lessons per year at each class (fifth and sixth grade). Applying the constructionist theory in the present study required the design of programming challenges that are incremental in nature and led after a certain point to concurrency problems that were self evident. It is straightforward that the proposed syllabuses should adhere to official curriculum constraints (for evaluation reasons). The rather limited timeframe for the computer programming courses offered a serious challenge in defining the educational goals and design a subsequent plan to achieve them.

The research conducted involved both classes that were already familiar with basic structured programming concepts and classes with no prior programming experience. As a result, it was decided that two different projects should be implemented. Instructional scaffolding was used for the learning process. Each project was split into equally hourly tasks. Pupils worked on the same file, extending or changing game functionality. The teaching approach followed, was to introduce the notion of multiple running threads early on and incrementally build knowledge on concurrency issues according to the assigned tasks. A Scratch player often executes “simultaneous”

scripts, so when different scripts are triggered by the same event, pupils must check if race conditions apply and if so, learn a way to tackle the problem. Building around this feature, tasks were escalated in order for pupils to achieve the following educational targets:

- T1. Implement concurrent moves of a single sprite;
- T2. Implement concurrent moves of two or more sprites;
- T3. Synchronize sprites using time primitives;
- T4. Synchronize sprites using messages;
- T5. Distinguish local, sprite-level variables from global variables;
- T6. Synchronize sprites using condition variables.

The first four educational targets concerned both the beginners and the more advanced classes, while the last two were only attempted for pupils with prior programming knowledge. It should be noted that the aforementioned six learning objectives were on top of the classic targets related to basic structural programming constructs.

3.2 Beginners' syllabus

The beginners' project concerned a maze game whereby a hero sprite tries to capture a trophy, while chased by enemy sprites. Maze games are very common Scratch projects and are suitable for beginners. As a testament a google search for "maze", performed on 16/5/2017 on the site <https://scratch.mit.edu> returned roughly 140.000 results. The syllabus presented in Table 1 is designed to incrementally build fundamental programming knowledge, while introducing concurrency concepts and solutions, in a gradual self evident manner. It also contains a midterm and a final project presentation. In the table the intermediate checkpoints for achieving the desired learning objectives are also shown. Aside from T2 for which two checkpoints exist, one for handling two sprites and one for more than two, all other learning objectives were associated with a particular week. On the respective week, the progress of student projects was evaluated according to the corresponding learning objective by the teacher and without the students being aware that an evaluation took place. This was done in order to provide better guidance to students both before and after the midterm project milestone.

Table 1. Beginners' syllabus outline

	Plan	Objectives	Concurrent issues addressed
1	Draw a maze stage. Make a new sprite (hero).	Draw a maze. Distinguish sprite from stage.	N/A
2	Use commands to move the sprite from the beginning of the maze to the end.	Execute a sequence of blocks.	N/A
3	Make the sprite move using arrow keys.	Use a trigger event to start a script.	(T1) Concurrent scripts on a single sprite. Pupils explain what happens if accidentally the same key is used for up and down movement.
4	Draw two or more sprites as enemies. Use command forever to make the enemies move around constantly when green flag is clicked.	Use iteration (forever)	(T2) Two sprites move at the same time. But no synchronization issues exist yet.
5	Create trophy sprite for the hero and use command if to make trophy disappear when touched by the hero.	Use iteration and condition. Use hide command.	A script loops until a condition applies but no synchronization issues apply yet.
6	Add a script to the hero, to make it disappear when touched by an enemy.	Use iteration and condition. Use hide command.	(T2) Concurrent scripts of two or more sprites. Place an enemy on food and make hero touch them
7	Midterm presentation		
8	Make nice guy, enemies and food appear in certain places when game starts.	Initialization. Use show command.	Concurrent scripts of two or more sprites. If show command proceeds move, then race conditions apply.
9	Make stage present an introductory message.	Use wait command.	(T3) Synchronize sprites using time primitives. Upon the game starts all sprites wait for a few seconds for the salutation to disappear
10	Make stage present a winning or losing message.	Use message passing.	(T4) Synchronize sprites using messages.
11	Add any functionality to the project.	Self assessment.	Self assessment.
12	Final project presentation		

An example screenshot from a final project handed down by an average performing fifth grade student is shown in Fig. 1.

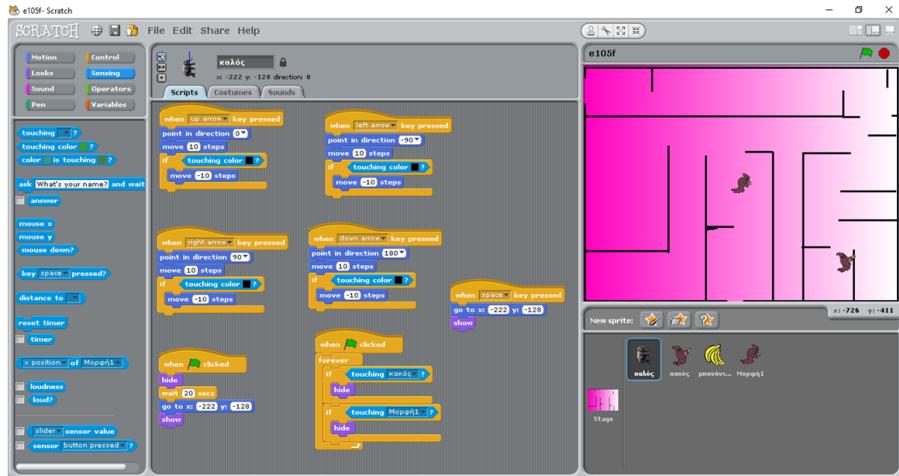


Fig. 1. Example of a final project by an average performing fifth grade student. Three sprites and a thesaurus exist (bananas). The hero sprite (elephant) is controlled by 7 scripts. It can be observed that two scripts execute when green flag is pressed. The initialization correctly uses time based synchronization (wait 20 secs) but is not completely correct (the two scripts should have been combined into one).

3.3 Advanced syllabus

The more advanced classes were already introduced (previous year) to basic programming concepts with Scratch. However, the syllabus used for the introduction differed from the one in Table 1, focusing only on structured programming constructs using a single thread view of the executed scripts. Therefore, it was deemed that knowledge on concurrency concepts should be built from scratch, albeit at a faster pace compared to the beginners. Table 2 illustrates the syllabus for the advanced classes. As it can be observed, apart from the heaviest workload on concurrency topics (T5 and T6 learning objectives are not included in Table 1), it contains two hours (instead of one) of free project additions and self-assessment. This served two purposes. Firstly, it encouraged a self-motivation attitude and secondly it served as a means of equalizing the effects of “missed hours” between classes that completed the 12 hour schedule and those that only completed 11 hours (due to national holidays).

Table 2. Advanced project outline

	Plan	Objectives	Concurrent issues addressed
1	Create two sprites representing players. Create a second costume for each one holding a die. Make them change costume on space pressed.	Distinguish sprites and costumes.	(T2) Concurrent scripts of two or more sprites.
2	Change in previous game. Make sprites change costume every 2 seconds.	Use timer.	(T3) Synchronize sprites using time primitives.
3	Delete costumes with the die. Create a die sprite. On click, the die goes to the other player. Use a variable to hold the dice owner.	Use variables.	N/A
4	When a player receives the die, says “I got it”	Use messages.	(T4) Synchronize sprites using messages.
5	Draw a die and cast it randomly when clicked.	Use random function.	N/A
6	Make the die turn for 2 seconds until it shows the result when space is pressed.	Use wait.	(T1) Concurrent scripts of a single sprite. When space is pressed twice within 2 seconds the interrupt is ignored
7	Midterm presentation		
8	Create a local variable pocket for each player and a global for the die. Initialize them. Each time the die is cast, it adds one to the players’ wallet.	Declare and use local and global variables.	(T5) Distinguish local, sprite-level variables from global variables.
9	Give or take money from the players depending on the value of the die and the player’s turn.		(T6) Synchronize sprites using condition variables.
10	Add any functionality to the project.	Self assessment.	Self assessment.
11	Add any functionality to the project.	Self assessment.	Self assessment.
12	Final project presentation.		

An example screenshot from a final project handed down by an average performing sixth grade student is shown in Fig. 2.

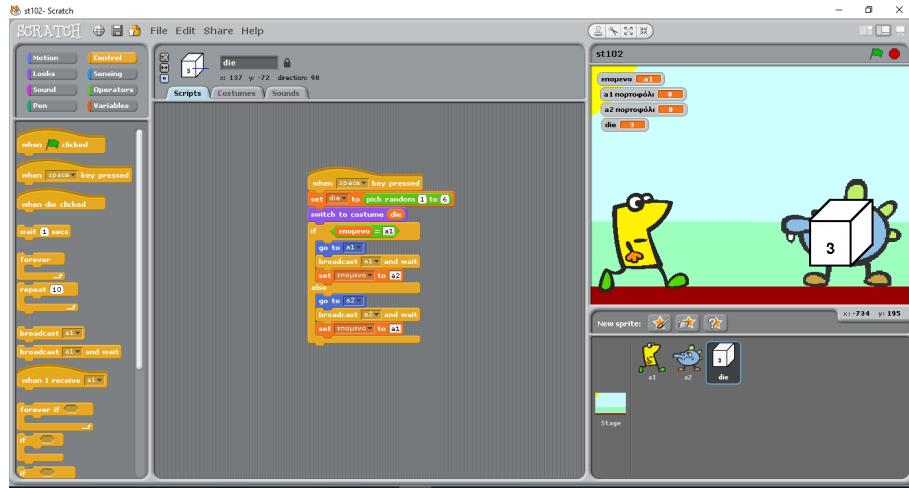


Fig. 2. Example of a final project by an average performing sixth grade student. The die script involves notifying the two players concerning whose turn it is. Notification was done by broadcasting and corrected to broadcast and wait by the teacher. This was necessary in order to block the dice script until players' scripts finish. Without blocking there is a risk that the dice script will continue executing and perform the assignment that follows the broadcast, which changes players' turn. Thus, a player could miss a turn.

4 Common programming pitfalls

The common programming errors made by students during the study can be categorized across two dimensions. The first concerns whether the error was related to concurrency (C) or not. The second is about the difficulty of detecting the error. Errors that proved difficult to be detected by students are denoted by (H) while the easier ones by (E). It should be noted that (E) errors usually led directly to abnormal behavior of sprites in the screen. Thus, students asked for teacher's help before moving to other aspects of their projects, leading to consolidating knowledge in a stepwise fashion.

Hard to be detected errors (H) rose from two causes. The first one was due to students not checking in a thorough manner the behavior of their programs. For instance an error that would have otherwise been apparent is hidden because the test runs never included the corresponding triggering event. The second type of hard to detect errors concerned the inherent at concurrent programming difficulty of reproducing errors. Namely, an error that occurs at some run (due to a particular script/thread execution combination) may prove difficult to repeat as script/thread execution sequence changes among different runs. This might cultivate a tendency at students of ignoring a particular faulty run because the remaining ones were correct, presumably attributing the fault to some system or environment glitch. In order to increase the likelihood of detecting immediately both kinds of (H) errors, the following steps were taken:

- A list of test cases was given to students, together with instructions of covering most or all event triggering cases;
- Students were instructed (especially in lessons where concurrency issues were involved) not to ignore faulty runs but alert the instructor immediately;
- Students were instructed to run their code repeatedly;
- Before a lab session, students' projects were checked for errors by the instructor.

The list of common errors follows.

- Wrong order of commands (E). For instance a sprite first moves and then turns instead of doing the opposite. Such errors occurred mostly at beginner level;
- Incorrect use of iteration (E). Infinite loops as well as lack of loops were a common mistake both at beginner and at advanced level;
- Wrong structure of events (E). The actions concerning an event, e.g., right arrow click, are erroneously characterized as belonging to another event, most commonly green flag click, i.e., program start event;
- Multiple scripts for the same event creating faulty behavior (C, E). This was quite common among beginners particularly at the initialization event (green flag click). The essence of the error is that students did not comprehend (at that point) that the actions invoked for the event should be done in a sequential manner. Instead, by splitting the actions into two or more scripts the actions' execution order could be arbitrary. For instance, consider an initialization script that first places a hero sprite at a safe position and then shows it. If these two actions are split into two scripts then it is possible to first show the hero script at an uninitialized position, whereby a monster sprite is placed ending the game abruptly.
- Incorrect identification of the sprites that need synchronization (C, H). For instance, many students synchronized the thesaurus with the hero sprite, but not with the enemies. This might create a conflict if the hero and an enemy advance to the thesaurus "simultaneously".
- Using conditional global variables for synchronization without proper initialization (C, E). Variable initialization errors occurred unexpectedly often hence, although simple in nature are reported here. As a side note it should be mentioned that synchronization using global/shared variables, requires in principle the variables to be atomic, i.e., no two threads should gain access concurrently. Although in Scratch atomic variables are not directly supported, the selected game play (die casting) made it difficult for racing conditions to appear. Thus, given the available time schedule, a necessary compromise was reached whereby students were not taught of atomicity issues but were taught of how to use atomic variables for synchronization.
- Using broadcast messages instead of broadcast and wait (C, H). The difference between the two message sending primitives is quite subtle. The second primitive pauses the script until all the receivers of the message terminate.

Piaget and Vygotsky as constructivists suggest that students bring their prior knowledge and experiences into any learning process which in turn influence the way they respond to new information. It is further suggested that students frequently resist

changing their minds until data to the contrary is overwhelming. [4]. If students' already constructed problem solving models cannot be implemented in solving newly faced problems they (with the appropriate guidance of the tutor) form models that become plausible and fruitful [9]. Part of what qualifies as good teaching methodology discovers what students already believe and creates the required cognitive disagreement leading to the hard work of adjusting their conceptual understanding [15]. Such conflicts occurred often in the classroom and learners (with teacher's guidance) had to reconstruct their ideas when the desired outcome was not shown in the screen of their computer.

5 Evaluation

5.1 Participants

The syllabuses described in Sec. 3.2 and 3.3 were evaluated in 7 primary school classes in Greece. The total number of participating students was 123 of which 66 males (age range 10-11 years old $M=10.59$, $SD=0.495$) and 57 females (age range 10-11 years old $M=10.51$, $SD=0.504$). According to age and prior knowledge at computer programming the evaluation group exhibited the following characteristics: (i) 55 students were of fifth grade primary school and completely novice to computer programming, (ii) 68 students attended the sixth grade and (iii) among the sixth grade student only 42 had attended a computer programming lab at fifth grade, while 26 were novices. It should be mentioned that such differences on the knowledge level among students of the same grade are not uncommon in Greek primary schools since there is no fixed Computer Science curriculum (just generic guidelines) and there are no fixed standards concerning lab hardware (many schools experience hardware shortage).

The basic syllabus presented in Sec. 3.2 was followed by the fifth grade students and the 26 novice students of sixth grade for a total of 81 students. The advanced syllabus (Sec. 3.3) was followed by the 42 sixth grade students that had some prior experience with programming in Scratch. Of the 123 participants, 83 had a personal computer station, while 40 students had to share a computer at groups of two and sometimes three. The implementation of the curriculum took place during school time in the class of Informatics. Additionally, all children that participated in the present study did not have a history of major medical illness, psychiatric disorder, developmental disorder or significant visual or auditory impairments according to their medical reports available at their schools.

Table 3. Performance in the first four objectives of Sec. 3.1 (123 total students)

Learning Objectives	Students Achieving Objective	Ratio (%)
T1	105	85.4%
T2	108	87.8%
T3	67	54.5%
T4	26	21.1%

5.2 Comprehension of learning objectives

First, results are presented concerning the evaluation of the learning objectives and how many students managed to accomplish them. The evaluation was done over the final project. Table 3 summarizes the performance of the students on the first four learning objectives which were common in both the beginner and advanced syllabus.

From the results, it is clear that the first two objectives that concerned the concurrent movement of single and multiple sprites were achievable by the vast majority of the students. It is also moderately encouraging that more than half of the students managed to successfully implement sprite synchronization using time primitives (T3). This is presumably due to the fact that time based synchronization is closer to real life experiences rather than message based (T4) which was only successfully incorporated in the projects of roughly 1 out of 5 students. Delving more on the results, Table 4 characterizes students' performance based on age. It also includes results from one way ANOVA between the performance of the two age groups.

Table 4. Performance according to age (fifth grade: age 10, sixth grade: age 11, **p<0.01)

Learning Objectives	Fifth grade students (55 total)		Sixth grade students (68 total)		ANOVA F
	Students Achieving Objective	Ratio (%)	Students Achieving Objective	Ratio (%)	
T1	41	74.5%	64	94.1%	9.491**
T2	46	83.6%	62	91.2%	1.121
T3	32	58.2%	35	51.5%	0.443
T4	4	7.3%	22	32.4%	12.742**

As it is apparent, the majority of students successfully comprehending synchronization using messages belong to age group of eleven years old (sixth grade). This is an indication that T4 topic was not taught at fifth grade to a sufficient extend (only at week 10 according to syllabus) and at least one more lecture was needed. Given the tight constraints on primary school schedule in Greece it might be worth considering removing the topic of T4 from fifth grade and use the extra slot to further improve comprehension of T3. Similarly, the especially high ratios for T1 and T2 in sixth grade reveal a possible option of adapting the advanced syllabus so that T1 and T2 context occupies one instead of two weeks, leaving the extra slot to be used for deepening the comprehension of T4.

Table 5. Performance in the last two objectives of Sec. 3.1 (42 students)

Learning Objectives	Students Achieving Objective	Ratio (%)
T5	17	40.5%
T6	20	47.6%

Evaluation according to learning objectives T5 and T6 is presented in Table 5. Recall, that the advanced syllabus containing T5 and T6 related topics was only followed by sixth grade students that had some prior experience with Scratch. The results show that a portion (in the mid-range) of students, managed to acquire the extra background offered by T5 and T6 successfully.

5.3 Statistical analysis

Analysis according to gender revealed that aside from T2 there were no other statistically significant performance differences between male and female participants. In T2 male students achieved a better understanding ($M=1.06$, $SD=0.24$) compared to female students ($M=1.19$, $SD=0.40$), while ANOVA gave $F=5.113$ with $p=0.025$. This result is somehow surprising since T2, i.e., concurrent move of multiple sprites is an easier topic when compared for instance against T3 which involves time based synchronization.

Subsequently, a one way ANOVA was performed in order to identify differences between the group of children that did not have to share their computer station and those who did. Results are presented in Table 6. As it can be observed, sharing a computer has a detrimental effect on performance that is statistically significant for all but the first and easiest to comprehend task.

Table 6. Differences between children that had their own computer and children that were required to share a computer (* $p<0.05$, ** $p<0.01$)

Learning Objectives	One child per computer station (83 students)		Shared computer stations (40 students)		ANOVA
	Mean	SD	Mean	SD	
T1	1.13	0.34	1.18	0.39	0.38
T2	1.07	0.26	1.23	0.42	6.073**
T3	1.37	0.49	1.63	0.49	7.174**
T4	1.73	0.44	1.90	0.31	4.501*

Next, correlation analysis was done in order to identify possible connections among the learning objectives and provide with further hindsight as to the strengths and weaknesses of the syllabuses. Table 7 presents the analysis for the basic syllabus while Table 8 for the advanced one.

Table 7. Correlation analysis for the basic syllabus (* $p<0.05$, ** $p<0.01$)

	T1	T2	T3	T4
T1	1	0.646**	0.515**	0.159
T2	0.646**	1	0.445**	0.024
T3	0.515**	0.445**	1	0.275*
T4	0.159	0.024	0.275*	1

Table 8. Correlation analysis for the advanced syllabus (* p<0.05, ** p<0.01)

	T1	T2	T3	T4	T5	T6
T1	1	0.513**	0.08	0.05	0.12	0.27
T2	0.513**	1	0.20	0.06	0.09	0.03
T3	0.08	0.20	1	0.11	0.07	0.25
T4	0.05	0.06	0.11	1	0.42**	0.47**
T5	0.12	0.09	0.07	0.42**	1	0.38*
T6	0.27	0.03	0.25	0.47**	0.38*	1

In the basic syllabus T1, T2 and T3 are correlated with each other and these correlations are statistically significant. On the other hand T4 exhibits a weak correlation only with T3. These results further indicate that the first three learning objectives are well organized and sufficiently covered within the basic syllabus. They also suggest that T4 as a learning objective is rather well placed in the syllabus (after T3). Judging from the fact that T4 is not correlated with T2 a possible change in the syllabus to ameliorate results on T4 could involve shrinking the time devoted to T2 from 3 lectures (week 4 to 6) to 2 and increasing by 1 the lectures related to T4.

As far as the advanced syllabus is concerned (Table 8) results show that T1 and T2 exhibit the strongest correlation (similarly to the basic syllabus), but also T4, T5 and T6 are correlated or moderately correlated with each other. This can be viewed as a further testament that the advanced syllabus is well structured regarding the more complex topics it tackles. It also suggests (together with the high scores on T1 and T2 at Table 4) that T1 and T2 could be shrunk in length (1 week each in the advanced syllabus) and/or their teaching being merged with T3.

5.4 Summary of results

The main findings of the evaluation are summarized as follows:

- The first two learning objectives i.e., concurrent scripts on a single sprite (T1) and concurrent movement of multiple sprites (T2), were achievable by the *vast majority* of students both at the basic and at the advanced levels;
- Tackling simple racing conditions that occur during concurrent sprite movement using time based synchronization (T3) was achievable by roughly *half of the students* (both at basic and at advanced level);
- Message based synchronization (T4) proved to be a tough concept for beginners, while at the advanced level roughly *one third* of the students mastered it;
- Distinguishing between local (per sprite) variables and global ones (T5) and consequently using conditional variables for synchronization (T6) were mastered by roughly *4 out of 10* students that followed the advanced syllabus;
- As a general rule gender did not affect performance;
- Lab infrastructure played a significant role (it is favorable to have one working station per student);

- The following main correlations between learning objectives exist: (i) T1 and T2 have significant positive correlation in both syllabuses, (ii) T4, T5, and T6 have significant positive correlation in the advanced syllabus and (iii) T3 is correlated with all the remaining objectives in the basic syllabus, but is independent in the advanced.

It should be mentioned that the 6 learning objectives related to concurrency were incorporated to the syllabuses in addition to the classic topics taught such as: sequential programming structures and user interface concepts. Thus, the success ratios on the objectives should be viewed as extra gains. From this standpoint, both performance and correlation results indicate that both syllabuses are well structured overall, given the 12-hour timeframe that should be followed. Nevertheless, room for improvement exists and can be summarized as:

- Message based synchronization (T4) proved too complex to successfully convey it to beginners within one hourly lecture. Thus, unless the curriculum length is officially expanded, within the current 12 hours time limitation two options are available: (i) increase T4 lectures by one (possibly shrinking the T2 related lectures) or (ii) remove T4 objective from fifth grade and use the time slot for deepening the understanding of the first three objectives (particularly T3). Based on results from Table 4, it seems that T4 is better suited for more mature audience (sixth grade) making option (ii) more attractive;
- Based on the high success ratio on T1 and T2 at the advanced syllabus, a valid option would be to shrink their cover by one lecture devoting the extra time slot to T3 or T4.

6 Conclusions

The main purpose of this study was to investigate the introduction of concurrent programming concepts into a typical early computer programming syllabus using Scratch as a learning tool. Synchronization issues (race conditions) typically rise when building games with multiple interacting sprites, something that is a common approach to learning computer programming with Scratch. Instead of resorting to ad-hoc explanations when such errors inevitably occur that are difficult to understand by students only properly introduced to sequential program execution, this work advocates the systematic incorporation of concurrency issues in the followed syllabus. For this reason, learning tasks were built in a structured approach so that pupils incrementally build knowledge on concurrency issues, while also acquiring knowledge on classic structured programming topics and not missing the fun of game design. With the exception of only one objective at fifth grade, by the end of the 12-week course a large portion of the pupils achieved the 6 extra educational targets with ratios varying from 32.4% to 94.1% depending on the objective and students' ages. More importantly, pupils demonstrated for the largest part an ability to "think concurrently". This was also manifested by the fact that no "unexplained" program behavior was reported as such at the end demonstration, but was rather attributed correctly to racing conditions.

Summarizing, we can state that the results of the study illustrate the usefulness of introducing concurrent programming concepts in a structured way in primary school education. On the other hand, not all educational targets were successfully accomplished by all pupils, with timetable restrictions and infrastructure shortages playing role. Thus, suitable fine tuning of the presented syllabuses can bear further merits to the proposed approach.

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Collaborative Learning with Sustainability-driven Projects: A Summary of the EPS@ISEP Programme

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Abstract—This paper describes the collaborative learning environment, aligned with the United Nations Millennium Development Goals, provided by the European Project Semester (EPS). EPS is a one semester capstone project programme offered by eighteen European engineering schools as part of their student exchange programme portfolio. In this international programme, students are organized in teams, grouping individuals from diverse academic backgrounds and nationalities. The teams, after choosing a project proposal, become fully responsible for the conduction of their projects. By default, project proposals refer to open multidisciplinary real problems. The purpose of the project is to expose students to problems of a greater dimension and complexity than those faced throughout the degree programme as well as to put them in contact with the so-called real world, in opposition to the academic world. EPS provides an integrated framework for undertaking capstone projects, which is focused on multicultural and multidisciplinary teamwork, communication, problem-solving, creativity, leadership, entrepreneurship, ethical reasoning and global contextual analysis. Specifically, the design and development of sustainable systems for growing food allow students not only to reach the described objectives, but to foster sustainable development practices. As a result, we recommend the adoption of this category of projects within EPS for the benefit of engineering students and of the society as a whole.

Keywords—collaborative learning, project-based learning, engineering education, sustainability, aquaponics, escargots, insects

1 Introduction

Collaborative learning is an exercise in the field of knowledge construction (the most used terms in English are teaching and learning) that is based on the acquisition of knowledge by two or more autonomous and independent individuals, through sharing of ideas, and who are willing to learn and work together [1].

Humanitarian and environmental sensitivity are preponderant factors in terms of engineering decision making. The engineering profession, which is governed by a professional code of ethics, is driven by the improvement of the well-being of the humanity. As such, all engineering activities must be sustainable. This type of consciousness / knowledge is widely disseminated in the practice of collaborative learn-

ing since knowledge emerges within working groups, fruit of the individual sensibilities of students.

The European Project Semester (EPS) is a one semester student-centred and student-led training for engineering design [2]. The students, integrated in small groups of people willing to learn, have the objective of solving a problem, being the solution of the task always multidisciplinary. The collaborative process aims at the fluidity of ideas within the group of different protagonists, learners from different areas of knowledge and coming from very different cultural contexts, capitalizing on individual resources and skills for a final solution. All stakeholders are responsible for project management (identification, planning, and allocation of tasks), finding the solution (duly supported and scientifically justified), selection and specification of the materials and components, as well as later assembly and testing of the prototype to be delivered at the end of the semester. The whole process is monitored and coached during a weekly supervision meeting attended by a group of teachers (the team of supervisors) from different scientific areas who oversees the teamwork.

All projects developed within EPS are based on the application of scientific, economic, social and practical knowledge with the intention of designing and developing goods to improve the quality of life of the human species [3]. It is not rational to have tremendous development and accumulation of wealth in few regions and people, while, simultaneously, a significant part of the human population lives on the threshold of poverty.

Sustainability is based on a simple principle: “Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment.” This simple principle defined by the United States Environmental Protection Agency (EPA) is based on four interrelated axes: environmental responsibility; environmental sustainability; economic viability; and social acceptance [4]. More important than the considerations of governments and policy makers, what each one of the more than 7 billion people in the world does in his/her daily lives will be reflected permanently in the state of the planet today and in the future.

The United Nations, with its 189 member states, defined in September 2000 eight Millennium Development Goals to be achieved by 2015 [5]. The first major objective (Goal One) is: Eradicate extreme poverty and hunger, and, another important one (from the viewpoint of EPS) is Goal Seven: Ensure environmental sustainability. Although far from having been achieved, some positive progress has been made [5].

Moreover, one of the major issues for humanity is the lack of sustainable good quality food sources. The Food and Agriculture Organization (FAO) estimates that the world needs to increase its food production by 70 % by 2050 in order to serve a global population of 9 billion. Furthermore, the standard food production model is unsustainable in terms of resources required (energy, soil, water) and by-products produced (emissions). Research is forcing people to re-think food production and recommending, for instance, the adoption of specific insect species as a higher source of nutrition. Insects form part of the traditional diets of at least 2 billion people, mainly in Asia and Africa. In the remaining world regions, the main use of insects is for animal feeding. More than 1900 species have reportedly been used as human food [6].

This paper reports three projects developed within EPS: (i) the aquaponics system, a hybrid system to produce plants and fish in aqueous medium; (ii) the insectarium, a domestic system for growing edible insects; and (iii) the escargot nursery, a domestic system for growing edible snails.

The remainder of this paper is organized according to the following structure. Section 2 briefly introduces the European Project Semester (EPS) and its implementation at the School of Engineering of the Porto Polytechnic (EPS@ISEP), followed by Section 3 that describes three examples of projects developed in the scope of EPS@ISEP, which are aligned with the UNESCO Millennium Development Goals. Section 4 presents a discussion of the programme implementation and the main results achieved, and the paper finishes with the main conclusions in Section 5.

2 EPS – European Project Semester

2.1 The EPS Programme

The EPS framework is a one semester student-centred international capstone project/internship programme offered to engineering, product design and business undergraduates, designed by Arvid Andersen [7]. EPS started in 1995 in Denmark and is currently offered by a group of 18 European engineering schools, from 12 countries, called the EPS Providers, as part of their student exchange programme portfolio. The goal of the programme is to prepare future engineers to think and act globally, by adopting project-based learning and teamwork methodologies, fostering the development of scientific, technical and soft skills. In particular, multidisciplinary and multicultural collaborative learning and sustainable and ethical development are pervasive concerns within EPS projects. The programme provides an integrated framework to undertake engineering capstone projects supported by a project-based learning methodology. Moreover, it focusses on teamwork and exposes students to cultural, scientific and technical diversity. The EPS package is organised around one central module – the EPS project – and a set of complementary supportive modules. The project proposals should refer to open multidisciplinary real-world problems, empowering the teams for the conduction of their projects [8].

The EPS providers have discussed, agreed upon and posted on the EPS Providers site the specification of the EPS framework – the so-called “10 Golden Rules of EPS” that an EPS provider must comply with: (i) English is the working language of EPS; (ii) EPS is multinational with a group size of minimum three and maximum six students, being four or five the ideal number; a minimum of three nationalities must be represented in each EPS group; (iii) ideally, but not necessarily, an EPS project is multidisciplinary; (iv) an EPS semester is a 30 European Credit Transfer Units (ECTU) package, the duration of which is not less than 15 weeks; (v) an EPS project has a minimum of 20 ECTU and the complementary subjects account for a minimum of 5 ECTU and a maximum of 10 ECTU; (vi) the main focus on EPS is on teamwork; (vii) the subjects included in the EPS must be project supportive; English and a basic crash course in the local language must be offered; (viii) the subjects must include

Teambuilding in the very beginning and Project Management in the beginning of an EPS semester; (ix) project supervision/coaching must focus on the process as well as the product; and (x) EPS must have continuous assessment including an Interim Report and a Final Report. The different EPS programmes are not only compliant with this generic framework, but also with “diverse flavours”. There are programmes focused on engineering (most providers), business, product design or media and with different operational approaches. By default, EPS, as an engineering capstone programme framework, is intended for the final year of the engineering programme. There are programmes offered to 3rd year students (all providers), to 3rd and 4th year students (Polytechnic Institute of Porto) and 3rd, 4th and 5th year students.

2.2 EPS@ISEP

The School of Engineering of the Porto Polytechnic (ISEP/PPorto) became an EPS provider in 2011 and has since welcomed 3rd and 4th year mobility students during the spring semester. EPS@ISEP – the EPS programme provided by ISEP/PPorto – targets engineering, business and product design students and aims to prepare them for their professional life by fostering the autonomous development of scientific, technical, personal and social skills

The EPS@ISEP programme is structured in six modules: 20 ECTU assigned for the project module and 10 ECTU for complementary modules: Project Management and Team Work (2 ECTU), Marketing and Communication (2 ECTU), Foreign Language (2 ECTU), Energy and Sustainable Development (2 ECTU) and Ethics and Deontology (2 ECTU). The latter are project supportive seminars, oriented towards the specificities of each project, focussed on the development of the soft skills essential in the training of twenty-first century engineers: communication (including technical-scientific English) contributes to the development of the project deliverables; project management focuses on task identification, human resource allocation, task planning and scheduling, resource management, plan enforcing and eventual rescheduling; sustainability addresses the ecological footprint; ethics and deontology analyses the ethical and deontological concerns; and marketing tackles the market analysis, segmentation and positioning of the prototype [9]. There is also an Arduino crash course to provide students with basic knowledge about this simple control platform. Figure 1 presents the EPS@ISEP schedule and illustrates the concretization of golden rules *viii* and *x*.

Before the beginning of the semester, a set of project proposals regarding real world problems are collected, each one with a specific client, with a strong focus on sustainability, to raise the student’s awareness to the problem, and in multidisciplinary topics, so each team member can contribute to the project with his/her previous knowledge and background experience. The origin of proposals ranges from industry, services, R&D institutions or the school itself. The proposals tend to be multidisciplinary problems, i.e., require the integration of multiple technical and scientific competences. A proposal defines the problem/challenge to tackle, the minimal set of requirements, mostly mandatory directives and standards, and the maximum budget. This type of proposal directs the team towards the design thinking stages and, then,

towards the development and operation stages of the capstone project/internship. As all proposed projects are open ended, team discussions about the possible solutions provide an opportunity for the students to expose their different beliefs and values, in a multicultural setting. Depending on the complexity of the projects, the average budget of an EPS@ISEP project is typically around 150 €~ 250 €.

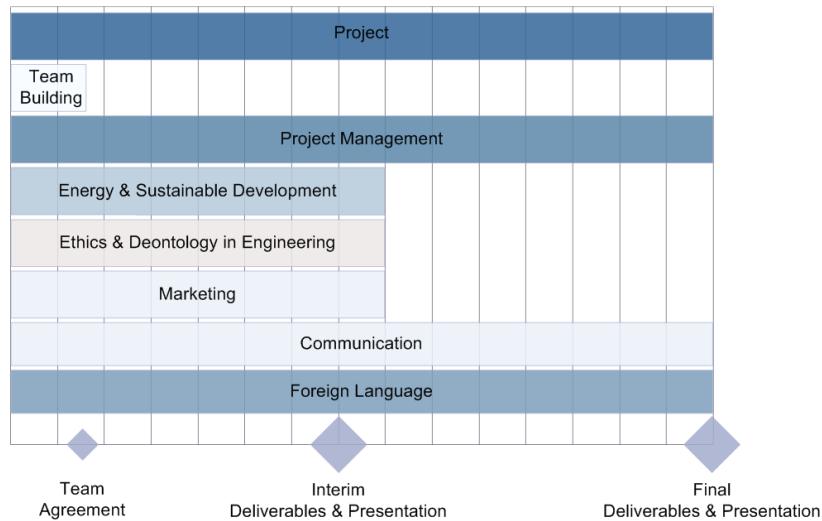


Fig. 1. EPS@ISEP schedule

Before the semester start, each student fills a Belbin questionnaire, used to identify its individual teamwork profile and design of teams according to rule *ii*. According to the EPS rules, not only teams must incorporate students from different fields of expertise and nationalities, but team building activities must be offered to allow team members to discover and perceive the existing cultural, scientific and personality differences. One of the first tasks team members face during team building activities (rule *viii*), is to define their own set of conflict resolution rules – Team Work Agreement – using the mechanism described by Hansen [10]. The resulting document, signed by all team members, is archived in the team folder. Next, teams select their project from the list of project proposals available and start their learning journey by conducting studies on marketing, ethics, deontology and sustainability together with scientific research (a state of the art analysis of the problem domain) to decide on the structure design and materials, as well as on the system design and control system. Students also must address other aspects concerning their projects, namely the detailed project planning and scheduling for the entire duration of the work.

EPS@ISEP adopts a unique supervision model where a panel of multidisciplinary experts, consisting of teachers from various study fields, acts as a consulting committee (Figure 2). Every week, this panel meets with each team for about 40 min during the weekly supervision meeting.

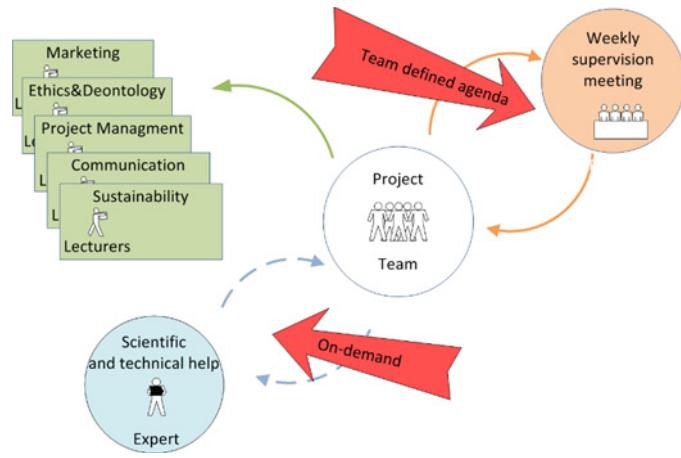


Fig. 2. EPS@ISEP model of student supervision

In the meeting with the panel, the teams conduct the meeting, and only the topics previously specified by the team in the wiki agenda are discussed. In this meeting, the teams are challenged to explain and justify any decisions taken during the previous week (shared in advance on the project wiki) and motivated to explore further. To be effective, the coaching panel is aware that it is interacting with students from diverse scientific and cultural backgrounds as well as that it must provide prompt feedback. In addition, the teams hold weekly meetings with their direct project supervisor(s) to promote further brainstorming, debugging, assembling and testing of the project. The teams can take the initiative to propose additional coaching meetings.

Assessment drives learning and hence a good assessment design is the key to effective student development [11]. EPS@ISEP uses the assessment scheme proposed by Hansen [10]. Assessment occurs twice during the semester and contemplates self and peer (S&P) and supervisor assessment (SA). The S&P assessment considers the quality and quantity of the technical contribution, openness to others ideas, teamwork performance, leadership, attitude and initiative shown [12]. The SA assessment reflects both team performance as well as the individual performance of each student. The interim assessment is intended to give individuals and teams feedback about their performance so far, from the point of view of their peers and of the supervisors. The supervisors use the assessment to monitor team working and to give constructive feedback and advice where needed [12].

The teams must produce several deliverables, including the project wiki, report, video, paper, manual, brochure and a proof of concept prototype. The report structure (provided beforehand) includes as mandatory sections the introduction, state of the art, marketing, sustainability, ethical concerns, project development and conclusions. Some chapters are produced and refined within the corresponding complementary modules. The structure and presentation of the deliverables are addressed in the communication seminar. The wiki is a key tool to the EPS process since it acts as a collaborative work platform and as the project show case.

3 Examples of EPS@ISEP Projects Aligned with the UNESCO Millennium Development Goals

In this section are introduced and described three examples of projects developed in the scope of EPS@ISEP, which are aligned with the UNESCO Millennium Development Goals 1 and 7.

3.1 Aquaponics System

In 2014 one of the EPS@ISEP project proposals was the development of an Aquaponics System, incorporating eco-friendly sustainable techniques. Aquaponics systems have received increased attention recently due to its possibilities in helping reduce strain on resources within 1st and 3rd world countries. Aquaponics is the combination of Hydroponics and Aquaculture and mimics a natural environment to successfully apply and enhance the understanding of natural cycles within an indoor process. By using this knowledge of natural cycles, it is possible to create a system with capabilities like that of a natural environment with the benefits of electronic adaptions to enhance the overall efficiency of the system.

The goal was to design and build an aquaponics system, as sustainable as possible, to support both fish and plant culture, based on water recirculation, limited to an overall budget for the prototype of 250 € [13]. The system should be able to monitor and control the most important system parameters, to ensure good conditions for both fish and plants, implying using sensors to check temperature and other parameters.

The multinational team involved in its development was composed of five students, with different nationalities and backgrounds: a Spanish Mechanical Engineer student, an English student of Electrical, Electronic and Energy Engineering, a French student of Environmental Sciences, a Polish studying Logistics and a student of Product Design from the UK. Their motivation for choosing this project was that: *“As a group we came to an early decision that we would like to choose a proposal that incorporated sustainable techniques and been eco-friendly, as this is the future of all Design/Engineering. As a group we were all interested in creating our own Aquaponics system as this is a system/technique that is becoming ever more popular throughout the world, more so in poorer regions and where water is a limited resource.”* [14].

The team started by making a study of the state of the art in this scientific field, focusing in Aquaculture and Hydroponics, and their integration, i.e., Aquaponics, which is based on a natural productive system. It can be described as the combination of Aquaculture and Hydroponics and this is where the name comes from: Aqua-ponics. Hydroponic systems rely on the use of nutrients made by humans (chemicals, mineral salts and trace elements) for optimum growth of plants. Water in hydroponic systems must be discharged periodically, so that the salts and chemicals do not accumulate in the water, which could become very toxic to plants. Aquaponics combines the two systems in a symbiotic environment, cancelling the negative aspects of each. Instead of adding toxic chemical solutions to cultivate plants, Aquaponics uses highly nutrient effluent from fish that contain virtually all the nutrients needed for optimum growth

of plants. Aquaponics uses plants to cleanse and purify the water, after which the water is put back in the aquarium. This water can be re-used but must be topped up at certain stages due to losses from evaporation and plant usage. A simple flood and drain system is what will be operated so the plants are able to receive oxygen and small breaks from the water to reduce the chance of root-rot [15].

In order to build a prototype with a high-quality standard, research into Aquaponics was performed, covering the existing methods and technologies. There are three commonly used types of aquaponics systems [16]: Media Filled Beds, Nutrient Film Technique and Deep-Water Culture. Since the media-based system was found to be the most reliable and simplest method of Aquaponics, and requires the least maintenance in comparison to the other types studied, the prototype was built this way [16].

The state-of-the-art survey analysed existing commercial aquaponics systems and several prototypes under development. Several aquaponics systems were found on the market [14] but the market shrinks vastly for Indoor Aquaponics systems. This market can be further reduced by adding the term ‘Designer’ to the aquaponics system, as many consumers do not want to decorate their home with unpleasant objects. From the research conducted, no commercial producers of aquaponics systems were found in Europe. Overall, there has been identified only one real competitor in the household aquaponics market [17]. All other systems reviewed lack the necessary appealing design to be placed indoors as an adornment [18-20].

There are some basic components that every aquaponics system needs, regardless of its type, namely: (i) a fish tank whose size depends on the number of fish to accommodate and on the size of the grow bed; (ii) a grow bed and growing medium, simply a suitable container that is filled with a growing media such as gravel, hydroton (expanded clay) or lava rock; (iii) a pump; (iv) tubing; (v) plants, since the Aquaponics System is described as a small kitchen garden, was suggested growing common herbs such as basil, thyme or rosemary; and (vi) fish – in this case, the tank was stocked with Convict cichlids (*Amatitlania nigrofasciata*) since they do not require much space and are easy to take care.

The design and development of an Aquaponics System emphasizes the eco-efficiency measures for sustainability considered during the system development. During the project, the team addressed the three spheres of sustainability, namely the environmental, economic and social impacts associated with the product they purposed to develop, as well as its lifecycle analysis [14]. Aquaponics reduces the strain on resources by allowing the user to both breed and eat the fish within the system and grow/harvest the produced plants. This system is not fully sustainable but has a significant reduction on resources such as water, requiring only 10 % compared to agricultural farming.

In parallel with this study, in the Marketing and Communication module, the students defined the market plan for the product. They researched the market and identified the customer’s requirements, to define a product fitting into these needs. This allowed the team to create a customer orientated marketing strategy and develop an integrated marketing program. With this purpose, the team performed an environmental analysis, consisting of a Political, Economic, Social and Technological analysis (PEST-Analysis) of the macro-environment and micro environment, and a Strengths,

Weaknesses, Opportunities and Threats (SWOT) analysis, defined the strategic objectives for the project, performed the market segmentation, defined the positioning of the product and, finally, defined the marketing mix. Based on the market analysis [14], the team decided to target the household market, as a small system would be easier to control and keep sustainable compared to a large (small farm) sized system. Such a system would also allow creating an aesthetic product for the home, easier control over the environment and require a smaller electronic system. Furthermore, as previously stated, even though there are several aquaponics systems in use at a large scale, there are not many for indoors usage, making this area an interesting target market, and with the recent increase in both sustainable products and the purchase of organic foods, there is a large market share available for quality aquaponics systems.

Finally, in the Ethics and Deontology module, the students analysed the ethical issues surrounding the product as well as more general ethics on a wider range of topics. Regarding the concerns faced while developing the aquaponics system, students addressed aspects related with engineering ethics, sales and marketing ethics, academic ethics, environmental ethics, liability aspects, and intellectual property rights.

Since the project proposal did not impose any restraints on the physical appearance of the product, the team could be creative during the design process, while also considering its manufacturing. The grow bed design followed the shape of the cuboid tank, apart from an area taken out the back-middle section allowing the pump to sit in the middle of the tank and feeding of the fish with ease. This area will often be covered from view by the plants growing within the grow bed and does not take anything away from the physical appearance of the tank itself (Figure 3, left).



Fig. 3. Design of the Aquaponics System (left) and picture of the final assembled system (right)

Given these ideas, the team developed the mechanical architecture for the Aquaponics System considering the required tank and grow bed, and the need to circulate the water among these two sub-systems considering a fail-safe design. There was the need to plan the placement of the electronics, which required a large amount of time, due to the safety risk of electronics contacting water [14]. It was decided to create a space within the grow bed for the electronics. This small area comes with a lid for

easy removal of the electronics while also keeping it safe from water splashes. The housing also includes a small cut out from the back where the wires can pass through so that the lid can stay secure [14].

Since aquaponics systems need to frequently check the water temperature and pH level, the Aquaponics System should ideally monitor temperature, pH and the ability of oxidation / reduction potential (ORP) of the tank, and display the results on a Liquid Crystal Display (LCD) screen, and control the water flow. A microcontroller board is responsible for performing these tasks automatically.

The next step was to choose the components and assemble the electronic control system. An Arduino Duemilanove ARDU-004 motherboard, programmable with the free Arduino software, was chosen. The selected LCD module, was connected to the power supply (5 V) and to the Arduino motherboard. The temperature sensor chosen was the DS18B20, since it is waterproof, has a temperature range sufficient for the application and is powered by the data line to the Phidget Interface Kit 8/8/8 Model: PHD-1018_2. The ASP2000 pH sensor was selected to measure the pH level from 0 to 14. Since all selected components need 5 V, the choice was the INM-0761 power supply, which outputs sufficient current for the whole control system (2.5 A) [14].

The Aquaponics System operates as following:

1. The water from the fish tank is pumped in the grow bed by the water pump. The pump is controlled by the Arduino, manipulated by the relay and programmed to switch on/off at certain intervals.
2. When the water level reaches the upper limit of the siphon bell, the grow bed is emptied and refilled. This process operates intermittently throughout the time duration that the pump is turned on. At this moment plants are provided with necessary nutrients and then water flows back to the fish tank through a small pipe.
3. Sensors within the tank send information to the Arduino, which is displayed on the LCD screen.

If, for an unknown reason, the siphon bell does not work, or is not sufficient to discharge the water at the same rate that the pump fills the grow bed, two side outputs ensure that the water level inside the grow bed does not increase and overflow out of the aquaponics system.

Tests were performed to ensure that all components were safe within the electronic system. Additionally, were completed tests to check three different areas of the electronics: (i) relay; (ii) current driver; and (iii) sensors. All these tests were accomplished successfully.

Figure 1 (right) depicts a photo of the assembled Aquaponics System. The system has been running successfully for about three years. It has sustained several Cichlid (*Amatitlania nigrofasciata*) fishes together with two ornamental plants: maidenhair fern (*Adiantum capillus veneri*) and creeping fig or climbing fig (*Ficus pimila*). During this period, the plants had to be pruned several times due to extensive growth.

As a concluding remark, the main objective was to create a working system that supported both fish and plant cultures and, through research and development, it is believed that a system has been created that can complete the required objective and be aesthetically pleasing. Due to the electronics put in place within the system, it is

possible to monitor the system and ensure optimum conditions permanently. To be sustainable, the system runs at 15 min to 30 min intervals. This saves power compared to a continuous system and provides plants extra oxygen in order for quicker growth. The students state that “*we have completed the requirements and also expanded so that the system will be successful within the intended target market due to an aesthetic design and simple functionality.*”

Regarding the process, the team reports that: “*After moving swiftly through the design stages and using all aspects (ethics, marketing, etc.) to create a quality design, we found that it was possible to create a simple product that fitted our needs. However, the technology/electronics that would be incorporated in the system also affected the final design due to restraints regarding size and placement. Taking this into account we developed an attractive system that combines art and technology together. Through development we were pushed to change many features of the design and many of these simplified the final product and led to an overall cheaper and easy to manufacture prototype. Overall, we found that from the initial brainstorming to the final renders, our ideas of a successful and quality aquaponics system had changed vastly. This knowledge was gained mostly through research and we believe that this led to the creation of a desirable and functioning system that fits well into the intended markets.*”

In the end of this project, the team members gained new knowledge and skills difficult to achieve in a traditional capstone project. The project itself is a fact of sustainable fish breeding and plant cultivation biology. Having the smart aquaponics system is an asset to the users, and this effort to add electronics and computing was a successful exercise of union of the chores of various aspects in which each specialty can only be enriched by the harmonization of all the different knowledge needed.

A more detailed description of this project can be found in this team final report [14] or on an accompanying paper [21].

3.2 Insectarium

One of the EPS@ISEP project proposals offered in 2015 was the development of an insectarium, encompassing two goals: (i) to raise student awareness to the problem of sustainable food production; and (ii) to design and develop a functional, cost-effective, eco-friendly and attractive insectarium prototype. As all EPS projects (each one with a specific client, responsible for defining the project requirements and checking its compliance), the objectives of the insectarium proposal were broad, and addressed: “... *the problem of how to produce food to feed the world's population. Since recent figures indicate that there are more than 200 million insects for each human on the planet, the challenge is to build an enclosure with the appropriate conditions to grow insects (e.g. mealworm or Tenebrio). This insectarium should be inexpensive, productive and have an elegant and functional design.*” [22].

The team that choose this project was composed of six students from different nationalities (Belgian, Polish, German, Spanish, Estonian and Scottish), and backgrounds (Digital media and graphic design, Computer science, Marketing, sales and purchases, Building engineering, Environmental engineering and Electronic engineer-

ing). The technical objective of the project was to create a functional, cost-effective, eco-friendly and attractive insectarium prototype.

The concept of insect farming is relatively new. Insects are reared in a confined area (*i.e.*, a farm) where the living conditions, diet and food quality are controlled. Farmed insects are kept in captivity, isolated from their natural populations [23]. One of its advantages is the relatively small ecological footprint compared to conventional livestock farming in terms of: (*i*) land use, (*ii*) the efficiency in converting feed into high value animal protein; and (*iii*) greenhouse gas and ammonia emission.

Studies conducted in the Netherlands, where mealworms are often cultivated as food for reptile and amphibian pets, concluded that insects, like mealworms, can help to solve this problem. Researchers, which analysed every input used in the process of breeding the worms, show that worms are a protein source considerably more eco-friendly than conventional protein sources. Insect farming requires less energy and produces less carbon dioxide into the atmosphere when compared with the production of milk, pork, chicken or beef. Pound for pound, mealworm protein (green) produces much lower amounts of greenhouse gas emissions than both the high (red) and low (blue) estimates for conventional protein sources [24].

After exploiting the topic, the team considered growing insects not only for animal feed, but also for human food. Their motivation resulted from the fact that insects are more sustainable, *i.e.*, require quite less resources per kg of protein, compared with traditional sources of protein. This approach, in the current Earth's population growth scenario, contributes to minimise the resources required for meeting food needs.

Driven by this multidisciplinary problem, the team performed: (*i*) a survey of competing products; (*ii*) a selection of the insect species to grow based on the study and comparison of the life cycle and habitat requirements of different species of insects; (*iii*) a marketing plan; (*iv*) a sustainability and an ethic and deontological analysis of the proposed solution; and (*v*) the design, assembling and testing of the prototype.

Although the insectarium may be used to house different insects because of the controllable temperature and humidity, the focus is on production of mealworms since they can be eaten by animals and humans. Moreover, compared to other insects, they contain a high level of protein and are one of the easiest insect species to grow.

Mealworms are the larval form of the mealworm beetle, *Tenebrio molitor*, a species of darkling beetle. Like all holometabolic insects, they go through four life stages: egg, larva, pupa and adult. Mealworms live in areas surrounded by what they eat under rocks, logs, in animal burrows and stored grains. They clean up after plants and animals and, therefore, can be found anywhere where there are such leftovers. Raising mealworms is fairly easy since they are prolific breeders and are hardy insects. Their growth is affected by the temperature and humidity. The ideal temperature and humidity for growing a colony is around 25 °C -27 °C and 70 % humidity, respectively.

Domestic *Tenebrio molitor* colonies usually hatch and live in standard plastic containers. The container should be kept away from windows and direct sunlight to prevent the temperature from rising. The daily light cycle is adequate, *i.e.* the process does not require artificial lighting. A colony of mealworms will reproduce faster with a higher humidity, but, in most cases, the natural humidity in the air will be sufficient. In a dry climate, it may be necessary to raise the humidity. The substrate of the con-

tainer will be the food – wheat bran, oatmeal, cornmeal, wheat flour, ground up dry dog food or a mixture of these dry foods. Slices of potatoes, apples, carrots, lettuce, cabbage or other fruits and vegetables are used to supply water to the worms. Potatoes are often preferred since they last a while and do not grow mould.

In Europe insect farming is at an early stage. The European Commission is currently co-financing a research project to explore the feasibility of using insect as a protein source, following a recommendation of the European Food Safety Authority [25]. The European Union prohibits the use of insects to feed livestock. Nevertheless, there are large companies investing in the sector like Proti-Farm, a producer of insect ingredients for the food and pharmaceutical industry [26]. In 2014, it acquired Kreca, a company with in-house knowledge of breeding and rearing 13 different species of insects [27]. Kreca's production, which includes 12 different insect species, is intended for human food (5 %) and pet food (95 %) [27]. The farm consists of eight barns where the temperature varies between 25 °C and 30 °C, depending on the insect species. The insects are fed on corn or groat meal obtained from local providers. Inside the barns, racks of boxes hold hundreds of kilograms of insects, eating several tonnes of meal and producing a few tonnes of insects per week. Proti-Farm sells whole insects, protein powders (isolated, concentrated, hydrolysed) and (refined) lipids.

During the elaboration of the marketing plan, the team conducted the SWOT analysis, performed market segmentation and defined the marketing programme for the product, concluding that the market offers many different types of bug-specific farming structures. However, it is lacking a general solution for household users, *i.e.* a solution for farming different species of insects. As a result, the team decided to create a home insectarium to house different species. For example, Space for Life suggests and provides instructions for raising ants, house crickets, mealworms, praying mantids and monarch butterflies at home [28]. Since the light, temperature and humidity requirements differ from species to species [28], such a product must be configurable. Ideally, the insectarium should include a control system to operate the heating, cooling and lighting subsystems in accordance with the readings from the installed temperature, humidity and light sensors. In addition, since it is intended for the domestic market, it should be attractive and easy to maintain. Figure 4 shows the initial structure drawings and the brand logo INSECTO, which were defined together with the marketing plan [22].

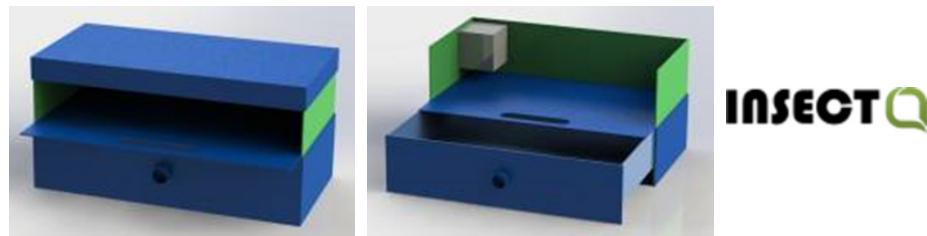


Fig. 4. First sketches of the Insectarium (left and centre) and INSECTO brand logo (right)

In terms of the structure, the team chose to keep the manufacturing, assembling and maintenance simple and easy. The result was INSECTO – a boxy, modular insectarium composed of a reduced number of parts – which allows stacking for larger production schemes. The team selected acrylic glass – polymethyl methacrylate (PMMA) – to build the structure of the insectarium since it is a durable material with a long-life cycle and a good temperature and sound isolation. The PMMA temperature insulation maintains the insects at a comfortable temperature with low power consumption. The electronic components were chosen according to their energy consumption (sustainability) and the selected software was open source (cost).

The air conditioning of the insectarium (temperature and humidity) is the main technical aspect of the project. Air conditioning can be divided into heating, cooling, humidification and dehumidification processes with specific energy demands. Since the simultaneous control of temperature and humidity is complex and exceeded the pre-defined budget (100 €), the team decided to incorporate in the insectarium two additional elements: an air heating resistor, to raise the internal temperature, and an air renewing fan, to reduce both the internal temperature and humidity.

The main function of the insectarium is to provide different species of insects with an appropriate environment to grow and reproduce. This was achieved by creating a configurable automatic humidity and temperature control system. The user can specify the desired temperature (°C) and humidity (%), the maximum temperature (°C) and humidity (%) variation, the percentage of heat power and the fan speed.

To control automatically the temperature and humidity inside the insectarium, was used a microcontroller board, a humidity sensor, a temperature sensor, a resistor, a fan and a LCD with a keyboard for the user interface. The microcontroller is connected to the humidity and temperature sensors (inputs), the keyboard (inputs), the LCD (output), the resistor (output) and to the fan (output). The microcontroller controls the fan speed and the resistor power through pulse width modulation (PWM).

The team performed the selection of materials and solutions, analysing the quality, economy and sustainability aspects. The structure was built reusing existing PMMA leftovers. For the control system, according to the study undertaken, the team chose: (i) an Arduino Uno microcontroller; (ii) a DHT22 humidity and temperature sensor with an accuracy of $\pm 2\%$ for the humidity and $\pm 0.5\text{ }^{\circ}\text{C}$ for the temperature; (iii) a $28\text{ }\Omega$ resistor (reused from a toaster); (iv) a 12 V 0.13 A fan (reused from a Personal Computer); (v) a ULN2003A high-current Darlington transistor array to boost the current for the fan and resistor; (vi) an Itead 1602 LCD shield with keyboard; and (vii) a power supply AC/DC 230 V AC/12 V 2 A [22]. The cost of these components was 60 €.

The proposed system differs from the Do It Yourself (DIY) home solutions because it is modular, reconfigurable (via the user interface) and automatically controls (via the control system) the most relevant environmental parameters (temperature and humidity) for breeding different species of insects at home. This approach meets the client requirements and extends further the spectrum of possible clients.

The power consumption estimation (in the most demanding scenario) of any electric appliance is a sustainability indicator. In a continuous operation scenario, the Arduino, LCD shield and the sensors are always on. In this situation, the estimated

annual power consumption is 7.6 kWh. In addition, in the worst-case scenario, the heater or the fan will be on, but not simultaneously. When the heater is also on, the estimated annual power consumption reaches 49.6 kWh. This results in an estimated annual average power consumption of 26.5 kWh (equivalent to a 3 W lamp).

Initially, the team undertook basic tests regarding: (i) the heating and cooling functions (to determine the maximum attained temperature and the fan ability to renew the air) without control; and (ii) the debugging and validation of the control code. With the resistor connected to 12 V, it took in average 227 min to raise the internal temperature from 24 °C to 31 °C and, once it reached this maximum value, it stabilized. With the fan connected to 12 V, the temperature inside diminishes until it reaches the external room temperature. For example, lowering the internal temperature from 31 °C to 27 °C (room temperature) took 50 min.

Finally, with the insectarium prototype assembled (depicted in Figure 5), the team conducted the functional tests and measured the actual power consumption. These tests contemplated the normal operation of the insectarium, i.e. the maintenance of the temperature and humidity parameters within the user specified values. The user interface menu was fully functional, allowing the user to specify the desired input parameters. The control system was able to maintain the internal temperature and humidity within the user specified values and the power consumption measured in the three operation modes (idle, air heating and air renewal), resulted in an average annual power consumption of 24.1 kWh (lower than the estimated 26.5 kWh).

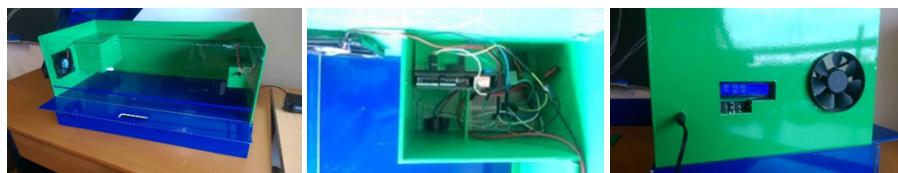


Fig. 5. Photographs of the assembled insectarium

The team perceived the project development process as “[...] a fun and exhilarating challenge from which we benefited greatly as an experience for our careers by living in a different country and working with people from all over Europe.”, and the INSECTO prototype as “[...] a product that provides sustainable food for now, but, more important, for the future”, while aiming “[...] to be as sustainable as possible [...] and innovative compared to other insectarium products.” [22]. These views illustrate the relevance the team attributed to this project in terms of multicultural teamwork and sustainable development practices.

A more detailed description of this project can be found in this team final report [22] or on an accompanying paper [29].

3.3 Escargot Nursery

In 2017 an EPS@ISEP team composed of a Biology and Medical Laboratory student from the Netherlands, a Product Development student from Belgium, a Mechani-

cal Electronic Systems Engineering student from Scotland, a General Engineering student from France, and an Engineering and Architecture student from Spain, chose to develop an Escargot Nursery [30]. The challenge was to design, develop and test a snail farm compliant with the applicable EU directives.

Nowadays, while many tend to live disentangled from the natural habitat, others are in pursuit of natural processes and experiences. On one hand, the digital revolution, which improved communication channels through social media, mobile phones and video conferencing, also isolated people from a real social life. On the other hand, more people are aware of the use of genetically modified organisms and, consequently, want to know the origins and growth processes of their food. Genetic modification is being used to improve the colour, smell and taste of food, trying to make it more attractive and durable in terms of the shelf life. However, there is not enough scientific knowledge regarding its long-term side effects on people [31].

The team saw this project as an opportunity to contribute to the mitigation of both problems by deciding to build a unique and innovative product to help people produce their own snails at home for educational and consumption purposes. The focus was on the design of an educational product mainly targeted for families with children. This would help children relate and establish bonds with nature, while developing autonomy, responsibility and an interest in science. To create a new and fun way of producing food, the team identified the need to include technology and create a comfortable habitat for the snails, allowing the end user to grow snails for food or as pets.

The team performed a series of background studies to specify the requirements, design and control system of “EscarGO”. There are several snail farms available on the market. Since most of the home-use competitors of the “EscarGO” were not designed for snails, a comparison between large scale snail farming solutions was made. The team considered this comparison relevant to the development of the product, due to the lack of technologies used in the products for domestic use. These technologies were dedicated to the production of a much larger number of snails, whereas this project is designed for a much smaller number and for domestic use.

After this comparison, the team decided to choose the species that seemed the most relevant, with the goal to adapt the product to this particular species. It was decided to use the *Cornu aspersum*, one of the most common snail breeds and the most consumed in France, the main market target. The *Cornu aspersum* species belongs to the Gastropoda class and they prefer an undisturbed habitat with adequate high moisture level and good food supply, and it takes six months to grow to their optimal size [32].

This species needs a specific habitat. First, these snails require a temperature between 15 °C and 25 °C, with an optimal temperature of 21 °C [30]. The humidity level is essential for the activity of the snails. They are more comfortable with humidity levels from 75 % to 90 %. For an optimal reproduction and breeding process, the snails require 16 h/d of light [30]. Finally, the snail population density must be considered since too many snails have a negative impact in their successful growth and breeding. The recommended density for *Cornu aspersum* is 1.0 to 1.5 kg/m². Since an adult snail weights approximately 10 g, it was possible to have up to 100 snails/m² [30].

Based on this study, the team derived the following requirements: (i) breed up to 50 snails, producing two meals a year for a family of four; (ii) design a terrarium with dimension of $400 \times 300 \times 375$ mm; and (iii) include a light, humidity and temperature control system to make the product user-friendly. It should be kept on mind that when the user touches the snails, for hygiene purposes, it is necessary to wash their hands.

During the marketing study, the team worked on logos and commercial names and decided to launch “EscarGO” in France, since the cultural barriers related to snails consumption seem more diluted. The product is to be sold on the Internet, targeting the gourmet costumer, wanting to grow snails at home for self-consumption, and the parent costumer, wanting an educational and recreational product. Despite no competitors were identified during the study, the team determined the need to keep the production costs low enough to generate profit while selling the product at a competitive price of 50 € to 70 €. In terms of marketing plan, the team concluded that “EscarGO” should be a domestic product and, therefore, its dimensions should not be bigger than any other home-size product, *e.g.*, a microwave, while being able to host 50 snails.

Concerning the product sustainability, its design must be simple to reduce the environmental impact. The team tried to create a low impact system by choosing low impact materials and recycling as much as possible. The structure of the final product is in polypropylene (PP) since it is resistant to the growth of bacteria and has a lower impact on the environment compared with other plastics. Due to budget constraints, the team chose to use Polyvinyl Chloride (PVC) for the prototype structure. Finally, it was decided to use the curtain method to increase the liveable surface area for the snails, while keeping the dimensions smaller. This method consists of two curtains, made of Nylon mesh, allowing hosting more snails in a smaller space.

The team adopted the French ethics charter for engineers drafted by CNISF, since the target is the French market, and made every effort to create a safe and sustainable Escargot Nursery, *i.e.*, with a minimal impact on the environment regarding to the environmental ethics [33].

The team started by specifying the project requirements. The requirements imposed in the project proposal were using sustainable materials, using low cost hardware solutions and sticking to the budget 100 €. Additionally, the Escargot Nursery had to meet other requirements, namely an aesthetically pleasing design, as the product would be on display, so the team wanted the product to be an attractive appliance. Regarding its electronics, the team wanted the escargot nursery to be as fully automated as possible, with little need for human interaction. It had to be able to set and display the temperature, humidity and light, while using as little power as possible.

Ease of use was one of the most important design motivators of “EscarGO”. The Escargot Nursery is expected to achieve certain functions. It has to keep the climate inside at a comfortable level for the snails. For this, the humidity needs to be controlled, so a liquid spray system needs to be used to keep the soil moist, the temperature also needs to be kept within the safe range, *i.e.* between 15 °C and 25 °C. Lighting in the form of LED needs to be controlled to ensure the snails have enough light to thrive. The system measures the temperature and humidity inside the nursery and measures the light level outside the nursery. The program stored in the Arduino board gathers information and controls each output, to ensure automatic climate control.

The final design of the “EscarGO” is minimalistic yet functional (see Figure 6). The housing is made of black and white PP, and the front and rear cover have a transparent area made of PMMA. The black PP in the front covers a display with relevant information about temperature, humidity and light. On the top there are two removable plates: one gives access to the living environment of the snails and one to the water supply. The water supply and the curtains are easily removable for feeding and maintenance. The right side has openings to check the water level and vents for the fan and both sides are provided with sunken handles to easily move the product.

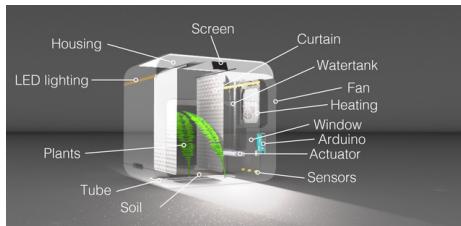


Fig. 6. 3D model of the “EscarGO” with all the components

Inside the nursery there are two compartments. A large one, equipped with planting, curtains, soil and small rocks to act as natural heat regulators, hosts the snail habitat. The curtains are made from Nylon mesh, so they are easy to clean. The tube under the soil helps to keep the humidity at a certain level. The LED lighting gives additional light when needed. All electronics are kept to the right side of the product in a smaller compartment, next to the water tank. These components are a microcontroller board, a fan, a heating device, an actuator and sensors. The microcontroller controls all processes so the snails can live in good conditions. The fan blows air into the nursery which can also be heated by the heating device. The actuator releases water from the tank to the tubing when the microcontroller sends a signal. The sensors give all the information needed to the microcontroller board. The 3D model of the product is depicted in Figure 6 with all its components.

Concerning the main functions of the “EscarGO” control system, an Arduino Uno is used as the microcontroller board. It was mainly chosen since the team did not have experience designing electronic systems, and had little coding experience, so the variety and number of Arduino Uno online tutorials made it the most attractive prospect.

The control system requirements are as follows. The enclosure needs to be able to maintain a comfortable temperature for the snails, without requiring much energy. It is recommended that the enclosure stays inside the home. Proposed is a heater element that will turn on if the temperature drops below 15 °C and a cooling fan that will turn on if the temperature rises above 25 °C. The final product uses power resistors as heating elements, and a fan to cool the air and provide air movement.

Humidity is another aspect that needs to be controlled. A moisture sensor was inserted into the enclosure, and there is a sprinkler hose pipe inside to release water if the environment is not humid enough. These have to be short bursts since over watering, or flooding, might drown the snails. There is also a possibility of a small water tank on the system for the humidity control so that the tank does not need to be fed

with a constant water supply. The team decided to use the DHT22 combined temperature and humidity sensor, to reduce the number of components and keep the electronics as compact, and with as little intrusion into the space as possible.

A final system requirement was to display the temperature and humidity on a small LCD screen.

One of the concerns with the project was that because there needed to be a humid environment for the snails, and they also required oxygen, there was the issue of dampness and humidity getting into the room where the terrarium is stored. This needs to be carefully controlled and monitored because dampness can cause damage to the room around the enclosure.

To evaluate the work and to make the product as safe as possible, the team performed functional tests, related with the verification of the correct operation of the control system, and soil tests [30]. The functional tests gave an insight into whether the Escargot Nursery complied with the requirements, and was ready to be produced and released onto the market. The soil tests focussed on the determination of the most appropriate soil conditions for growing snails.

Moisture along with available calcium content are two extremely important environmental factors that dictate the health of molluscan fauna such as snails. In order to keep the soil moist, two different strategies were used in the present work, namely the addition to the soil of calcium alginate microspheres or sodium polyacrylate particles. Alginate is a natural biodegradable polymer extracted from brown algae that forms hydrogels under mild conditions, in the presence of divalent cations, such as calcium. Sodium polyacrylate is a superabsorbent polymer that has the ability to absorb as much as 200 to 300 times its mass in water. It is frequently used in agriculture since it can absorb water when it rains and release it when needed [34].

The calcium alginate microsphere solution is the material of choice to keep the soil moist, not only because the humidity level was the highest attained during the whole test, but also because as they degrade, they release calcium into the soil, and calcium is very important for the snails' health. Snail shell is made of calcium carbonate and keeps growing as long as the snail grows. In this particular application, microspheres can act simultaneously as a water and calcium reservoir. Additionally, alginate microspheres can also be used as a controlled-release product of other substances that are identified as necessary for snail's development, such as, for instance, vitamins.

The team tested all electronic components separately, to be sure that all components worked, and then combined them to test the whole system.

Figure 7 displays the final prototype, which includes all the electronics for the optimal living conditions of the snails.

There were some problems with the development of the control system during the project due to some bad connections and since no team element had previously worked with Arduino. Nevertheless, the team solved everything and could do almost all tests. There were also some time constraints and, for this reason, it was not possible to test the water tank and the heating element could not be added on time for the prototype.



Fig. 7. Photographs of the assembled insectarium

However, and despite these minor problems, the different team members mention the following personal and learning outcomes of this process: “[...] I learned a lot of knowledge from my team members and it was really good for my development in the English language. [...] Going abroad on my own was far out my comfort zone. [...] I learned so much hard and soft skills while having the time of my life [...] ; [...] EPS was a brilliant opportunity for me to work with people from all over Europe on a project similar to what I would be expected to work on in a professional environment [...] ; [...] I have learned many things I did not know before about many different fields of knowledge and I have worked in a professional atmosphere similar to what I may have to deal with in the future [...]” [30].

A more detailed description of this project can be found in this team final report [30] or on an accompanying paper [35]

4 Discussion

In Project Based Learning courses, one of the main issues is getting an open project, as the basis of the student’s work. Often the teachers use the name Project incorrectly, when referring to a long practical work. In a real Project the solution to be implemented must be designed by the students, while on a practical work the technologies/solutions to be used are fixed by the teachers. As engineers, the teachers are more focused on the technological part of the solutions, so usually many Projects slowly morph into practical works.

One of obstacles to a more sustainability oriented curriculum is the pressure to teach “more engineering”. The usual faculty opposition is grounded on the argument that to teach sustainability, one must teach “less engineering”. From these projects one can see that while the focus was on sustainability, all the students were busy with engineering tasks.

The sustainable purpose of the project was incorporated in the requirements analysis, and to do the requirements analysis, cultural and social implications were considered. But, a correct design of an engineering system should always consider cultural and social implications. So as can be seen from these projects, the adoption of sustainable objectives in the EPS projects, has not resulted in “less engineering” education, but, on the contrary, has resulted in a better engineering education.

The sustainability focus of the projects helps to maintain the openness, and avoids purely technological project discussions, as can be seen in the students reports. So, the

focus on sustainability of EPS projects, exists not only for ethical reasons but also for strong pedagogical reasons.

In a sustainability oriented project, it may seem a mistake to include control electronics, microcontrollers and other sophisticated parts. This results of an effort to provide people with products/tools that allow them to be more involved in sustainable activities.

One of the main reasons why people are not more involved in sustainability related activities is lack of time, not absence of concern about sustainability or ecological issues. The sustainable care of plants or/and animals requires both the execution of tasks on a fixed schedule (feeding, watering, etc...) and the on-demand execution of other tasks on an unpredictable schedule (reacting to weather changes, abnormal conditions, etc...). The junction of these two types of schedules with a typical working life schedule may be impossible. The automation and/or the monitoring of some of the tasks related to sustainable activities may work as a catalyst to provide people already concerned by sustainability, the necessary conditions for a more practical involvement, and for them to pass from thoughts to action.

The sustainable focus of the EPS projects extends on the open source nature of all the produced documents, placed on the EPS Wiki, for general public availability and ease of maintenance, repair, customization and improvements.

So, the sustainability focus of the EPS projects not only has helped the students (and teachers) to think more about sustainability, but has provided them with a correct engineering mindset.

5 Conclusions

The EPS student-centred collaborative learning process is based on promoting the autonomy and responsibility in the teams, adopting technical and scientific coaching and offering project supportive and soft skills complementary modules. This process drives the teams to design and develop a concrete prototype and produce multiple deliverables, while learning to manage the project, to study the state of the art in the different fields of the project, to create a marketing plan, to work together and to justify all design, materials and development decisions based on the analysis of the sustainability, ethics, scientific and technological aspects.

In the EPS@ISEP Programme project proposals refer to open multidisciplinary real problems. Its purpose is to expose students to problems of a greater dimension and complexity than those faced throughout the degree programme as well as to put them in contact with the so-called real world, in opposition to the academic world.

A line that has been followed is to offer project proposals aligned with the United Nations Millennium Development Goals. Specifically, the design and development of sustainable systems for growing food (of which three examples have been described in this paper) allow students not only to reach the described objectives, but to foster sustainable development practices. As a result, we recommend the adoption of this category of projects within EPS for the benefit of engineering students and of the society.

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Promoting PBL Through an Active Learning Model and the Use of Rapid Prototyping Resources

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Abstract—This paper aims to present an active learning model for the implementation of innovative teaching-learning practices in Higher Education, based on Active Learning Methodologies by highlighting especially, PBL – Problem Based Learning using Rapid Prototyping devices. In order to apply PBL's methodology to the courses, an implementation model with four levels of implementation was developed. Each level has four class attributes, which are the problem's scope, student autonomy, teaching role and classroom space-time. The obtained results show that the students demonstrate higher levels of interest, participation, and involvement with classmates, motivation and content's perennial assimilation. With the application of these methodologies, skills required by job market, such as teamwork, relationship, collaboration, proactivity and entrepreneurship are also developed.

Keywords—PBL, Implementation Model, Active Learning, Rapid Prototyping

1 Introduction

Introducing active learning in Higher Education is challenging because it brings disruptive changes in the way that teaching and learning process traditionally occurs. Around the world, many institutions identified the need for a cultural shift in order to rescue the societal relevance, nature and protagonism of undergraduate engineering courses, which were based on traditional curriculum [1]. The shift involves the transition from an educational system based on teaching to a system based on learning, making the student the center of the educational process [2].

Until the advent of the Internet and its massification in the 1990's, the traditional method had been considered the only way to teach. However, from 2000 onwards, we witnessed the closure of information Era and the start of the knowledge Era and as a consequence, the traditional and established methods of teaching has been questioned and the need to promote learning in new spaces emerged. Especially because currently, we are experiencing the Fourth Industrial Revolution; that is, the merging of digital, physical and biological technologies in a cybernetic world. The 4.0 industry with the Internet of Things (IoT), cloud computing and manufacturing information are already part of our daily lives and the teaching model, which persists up to this day, is similar to one first established in the year of 1088, the year that Bologna's University

was founded. Therefore, it is important to promote innovative teaching-learning practices to provide an education in engineering that is consistent with the needs of the 21st century. Thus, overcoming outdated teaching models.

Problem-Based Learning (PBL) is an educational approach that is learner-centered. The focus changes from a teacher-driven approach that leads the students to one that aims to empower students, promoting self-directed and perennial learning, developing also their cognitive and metacognitive skills [3]. When implementing PBL, at its highest level of implementation, the student is “mentored and encouraged to conduct research, integrate what is learned, and apply it to develop a viable solution to an ill-defined problem” as stated in ref. [4]. This methodology engages students in active learning, and in addition, it promotes and increases students’ cognitive and practical abilities, as well as developing other important skills to professional life, such as collaboration, teamwork, creativity and proactivity to solve problems and face challenges. At this point, the materialization of solutions, made via Rapid Prototyping (RP) resources becomes the class’ synthesis, promoting a perennial and meaningful learning.

Searching for innovation and reform of higher education in engineering courses via Active Learning implementation starts with the need to develop important abilities and skills, widely discussed in national and international scope [5],[6]. Furthermore, once problems have become more complex, achieving the highest level requires professionals of several fields to solve them, thus it is indispensable that engineers are able to work in multidisciplinary teams. Therefore, it is important that teachers experience and develop among their students’ creativity, teamwork, decision-making, communication and problem solving.

Thus, the present work shows the development and application of a PBL model in engineering courses at SATC, a Brazilian College, which aims to integrate theory and practice by promoting learning through the integration of university and the demands of enterprises and bringing real life problems for students to solve. However, the methodological changes needed to attend the demands of the job market depend on a design that considers the need for a cultural transformation. Therefore, taking into the consideration how complex Higher Educational settings are and how difficult it is to implement new learning models; we propose to implement the PBL-based learning model gradually.

2 Problem-based learning model

Based on research of Problem-Based Learning (PBL) applications in engineering courses, in previous inquiries [4], [7], [8], [9], as well as having institutional visits to American universities (MIT and Olin College in November, 2016) and also through experiences we have had in our own institution, it was developed a PBL implementation model for engineering courses’ curriculum (Fig. 1). For the development of this model, we have considered teachers and students’ view of learning, infrastructure and the integration between academic work and the industrial needs. As a result, a model presenting four levels (PBL Levels, left side in Fig. 1) of implementation was devel-

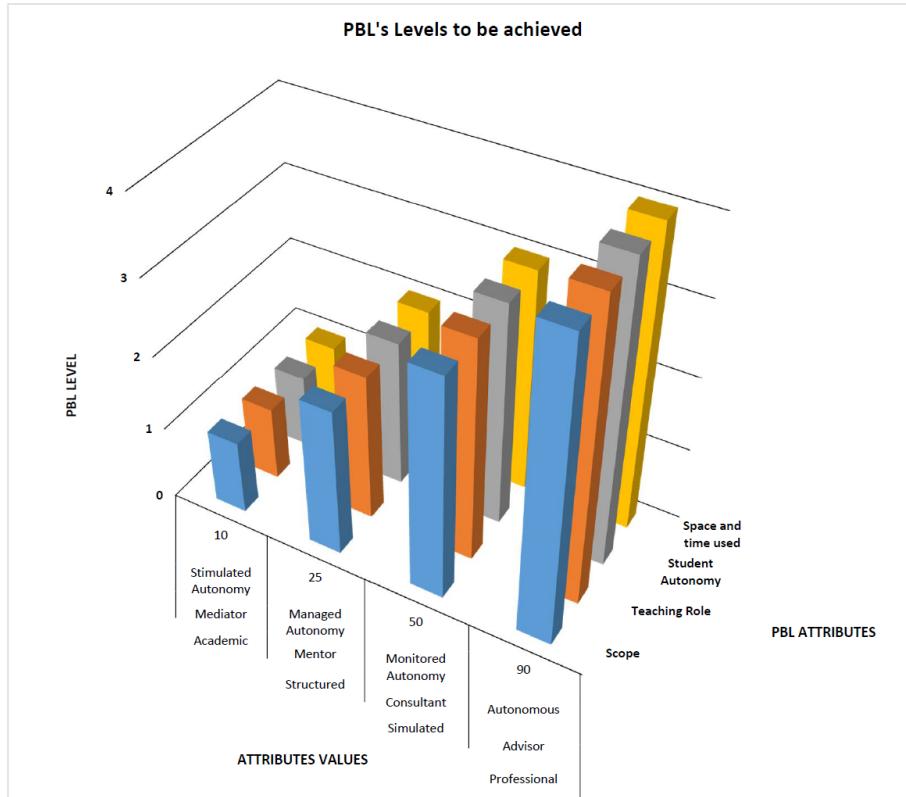


Fig. 1. PBL'S level of development

oped and each one cover four attributes (PBL Attributes, right side in Fig. 1). Following, each attribute has a four-degree scale (from Level 1 up to Level 4). Level 1 as the most basic, and the first to be applied; Levels 2 and 3 are intermediate ones and Level 4 is the most advanced, thus the last one to be applied.

The first attribute relates to the *space and time* needed. It is related to where PBL lessons occur and how long it takes to solve the problem. In Level 1, space and time are confined, respectively, to regular class time and physical classroom space, whereas Level 4 extrapolates both.

The second one is related to the development of *students' autonomy*. This attribute considers the required autonomy to lead students towards auto-learning. As pointed out before, students expected learning to resume in listening to lectures and resolving lists of exercises. The fact that students were unprepared to work with ill-structured problems led to the need of planning PBL considering students' autonomy and the teacher role in the process as interdependent. Therefore, the role of the teacher in creating the conditions for autonomy to be gradually developed is essential. While in the Academic level (Level 1), problems are well-defined and autonomy is stimulated,

in Professional Level (Level 4), which is the final goal, students become autonomous and professors' role become more of an advisor.

The third aspect is the importance of teachers in the learning process and their *role* in the different levels. The implementation project of this model also takes into account the need to provide teacher development for the faculty in order to achieve the highest level of PBL. The first step is to review with professors the learning theory on which their practice is based on, and then promote their understanding of the need for changing as well as discussing principles of learning based on research. The attribute that considers Teaching Role is the one that describes the role of professors as mediator, mentor, consultant or advisor, which changes how the space and time of classes are used. That means that depending on the level of PBL that has been planned, the space-time also varies.

The fourth and final aspect covered in our learning implementation project is the *scope*, which is the problem itself. It can be from an academic perspective to a real problem. The scope can be named as *Academic, Structured, Simulated or Professional*, according to domain of the problem, as problems can vary from well-defined to ill-defined. Well-defined problems are the types of problems presented in a very structured way with usually only one possible solution and a well-known procedure whereas ill-structured problems are complex and not clear-cut. Thus, the problem-solving process in ill-defined problems depends upon the understanding of the problem situation, its nature and the conditions to solve it, leading to multiple possible solutions [10].

The need to implement PBL gradually rises from the need to consider different aspects of an educational setting and the ins and outs that affect the implementation of a new pedagogical model. In order to minimize the impact of ill-structured problems, it is important to consider the receptivity of students and professors and create the right conditions for change to become possible, therefore, the model presented below gives an overview of how the model aims to achieve its goal, that is, by considering each attribute. Further details of PBL's levels are presented in the following section. Then, a case showing how rapid prototyping resources can be used in a PBL class is discussed.

2.1 Level 1: solving an academic problem inside the classroom

Considering that the main practice at SATC College was lecturing students and giving lists of exercises, Level 1 was the first natural step towards the implementation of active learning. Most professors and students were used to the traditional model, which considers teaching as passing on knowledge from teacher to students while students' role would be to attentively listening to the lectures and doing lists of exercises. Therefore, the need for gradually preparing students and professors to work with problem-based learning by expecting it to be implemented through small projects where professors would stimulate a more autonomous student work was paramount.

In this level, the space-time attribute presented above with a value of 10 means, for example, that in a discipline with a semester of 60-hour workload (20 week-meetings with 3h for each class), 10% of time for the development of PBL's activity, which is equivalent to two meetings, about 6 hours. Due to the short period available for this level, which expected to be about two meetings at any time during the semester, the workspace is likely to be the classroom; however, other academic learning spaces such as the library, computer lab or hands-on labs could also be used.

Regarding developing student Autonomy, the Stimulated takes into consideration that students, on their first contact with PBL, have not experienced this kind of learning but the traditional one. Therefore, autonomy is encouraged and problem solving is constantly stimulated. Teacher Role attribute is that of a Mediator who needs to mediate the process of learning constantly. The mediator does not give the answer, but provokes the students with meaningful questions and constantly challenges them, recommends research sources and leads students in the process of finding solutions. This role requires that professor-mediator to give short lectures and intervene during the PBL activity. Thus, continually nurturing the learning process by monitoring and leading the teams of students.

The problem falls into the academic scope likely to focus on a specific discipline's topic. The students work in groups and the solutions are likely to be similar. It is less likely, therefore, to produce a work that is unique due to a few variables and the low complexity of the problem itself.

2.2 Level 2: solving a structured problem

The space-time attribute shows a value of 25, that is, we may need 25% of the discipline's total workload for the PBL activities. Considering again a discipline that has 60 hours in a semester (20 meetings of 3 hours each one), that would be 15 hours – equivalent to 5 meetings for class work. With more time, there are more possibilities to extrapolate the classroom's space and using other academic spaces (library, computing labs and practice or hands-on labs). There is also more flexibility. The professor can plan one activity, based on level 2 criteria, expecting to take up to five meetings to complete the PBL or two PBL activities of two and three meetings, respectively. The first one, perhaps, at level 1 and the second one, more elaborated, according to the criteria of level 2. The intention is to provide students and teachers the opportunity to become more familiar with the methodology, allowing a judicious evaluation of the progress as well as of the failures that occur during the implementation.

Regarding student autonomy (Managed Autonomy), considering that stimulation has occurred in the previous experiences, students should at this level show a discreet skill to self-learning and proactivity. Thus, rather than constant, the stimulation become frequent. As for the Teaching role, the professor in this level becomes a Mentor. The mentor, according to the dictionary, is an individual considered wise and inspiring, that drives, leads and encourages someone. The propositions presented in this level might be less structured and in an intermediate complexity. In the mentoring role, the professor will answer questions that students might have by pointing out possibilities ("and if...") and showing previous cases, nudging students to search and

make new discoveries. However, teaching through short lectures to small groups will still occur on demand, and lecturing the whole group only when needed, but likely to be less frequent than in level 1. Even though this level aims to foster self-directed learning, constant group monitoring will occur, like in the first level.

The scope of the problem becomes “Structured”. In this one, the resolution attends the medium complexity of the problem and may require content integration of two or more disciplines that are concomitants or pre-requirements. The PBL’s activities in some cases can go beyond the academic and classroom spaces. In loco visits, where the problem is happening, is a real possibility, but not expected at this level. The final product, presented commonly in class, could be presented to the external community (liberal professionals, representatives and enterprise’s CEOs). In this level, the solution to the problem must be validated by using structured scientific approach by including the references, justification, methods, results, discussion and conclusion.

2.3 Level 3: simulating a problem’s solution

Here, 50% of total workload may be available to PBL’s activities. Thereby, of the 60 reference-hours, 30 will be for implementing active learning, where students become protagonists of the learning process; they acquire more responsibilities and the outcomes more elaborated, as learning situations are more complex as well. These situations are obtained from professional observation of several places: shops, offices, agencies, factories, farms, inside a coalmine, means of public transportation, in-side a car, hospitals, at the bank, other schools, in their own house, etc...).

Based on the assumption that the designed problems in this level are embedded in situations that are part of professional or personal students’ lives, the engagement is expected to be spontaneous, without the need to tap into students’ intrinsic motivation or emphasize how meaningful the activity is. The professor, therefore, is not obliged to motivate constantly the student, since they are expected to have already developed some skills by level 3. Thus, student’s autonomy is monitored as occasional stimulation to avoid deviations from the task might be needed. In this sense, the professor acts like a consultant, acting on demand.

The simulated scope means that the obtained solution to a real problem exposed at the start of PBL activity is validated and presented, but it is not in fact applied. An engineer designing a crane bridge can simulate and validate it using real data (constructive materials, dimensions, friction, lubrication, safety factor, energy consumption, ultimate tensions, etc...) without, in fact, the need to build one. Likewise, a discussion about drivers’ aggressive behavior in sociology can be synthesized in an advertising campaign or a toll planning about defensive driving without having to produce them.

As such, the resolution via problem’s simulation will require concepts’ integration and, consequently, will develop skills and abilities that are important for the job market.

2.4 Level 4: solving a professional problem

In the last level, while practically all the classroom time (about 90%) is dedicated to PBL activities, the classroom space itself is minimally occupied and restricted to meetings with professor-advisor. The learning itself develops on the space-time where the phenomena to be investigated occur. At this level, students are the main actors and become responsible for driving and accomplishing the pre-established goals and achieving their full autonomy. In this context, the crane bridge and the toll examples given above would be developed and the results evaluated according to professional criteria (costs, technical viability, ethics and safety) to attest or not the students' ability to solve a problem. There is no lecturing and the conversations that occur between advisor-student happens on an individual basis. This could be exemplified by the Course Work expected to be accomplished at the end of the engineering course (called TCC in Portuguese), which is similar to senior capstone projects where a student engages in a project as part of their senior year and is completed in close consultation of a faculty mentor. However, it is tacit and explicit that a great number of graduating students, educated in a traditional context, when enrolled in the last semester, do not show skills, abilities and attitudes needed to deal with the highest level of PBL. Consequently, the professor, who should act like an advisor, returns to level 1, mediating the process, stimulating the autonomy and assuming responsibilities about deadlines, fulfillment of goals and outcome's analysis. This is the reason by which TCC causes stressful situations and is uncomfortable for the students. We educate them during all the academic cycle in the passive, traditional, unilateral, and non-autonomous form and focuses mainly on theory. Suddenly, at the end of program, we insert them in an active process, which is contemporaneous, multilateral, fully autonomous and free to obtain knowledge based on real experiences. Consequently, the work presented to a faculty board council at the end of the course (TCC) is disorganized, lacks originality, texts bypassing the theme and oral presentations are discouraging, not to say disastrous. It is the right formula to create embarrassment to everyone involved, especially for the student.

3 The use of Rapid Prototyping (RP) Resources in the PBL levels

According to Orey [11], who based his levels of thinking in the ‘Learning Pyramid’ (Fig. 2) of Bloom’s Taxonomy, in order to ensure cognitive development, it is important to work with all levels of thinking, from lower to higher order. Therefore, lecturing followed by memorization exercises are examples of a low-level learning; the listen-read-write-look activities can generate some medium-level learning but still not effective as an excellent student learns – and does not forget – around 40% to 50% of what is taught. Furthermore, desirable skills are not contemplated (teamwork, collaboration, creativity and proactivity). On the other hand, high levels of thinking are achieved when a professor provides discussion-evaluation moments and activities that foster creativity and hands-on work. Because of that, it is not enough for students to

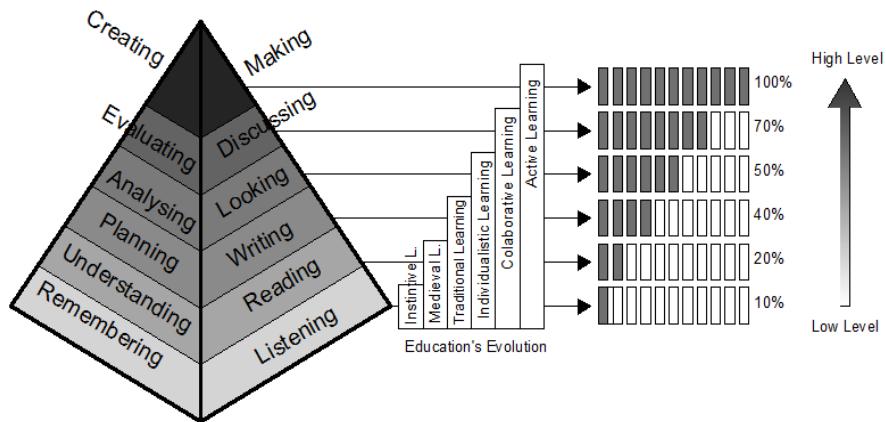


Fig. 2. Relation between the Bloom's Taxonomy, academic actions, education's historic evolution, perennial learning percent and thinking levels. Adapted and modified from [11].

listen to a lecture or understand a text. By creating, drawing and manufacturing a new product, students are working with a range of cognitive levels of thinking, especially higher-order thinking. Hence, using RP in the classroom provides the opportunities for students analyze, evaluate and apply knowledge.

PRONTO 3D – Laboratory of Prototyping and Digital Manufacture Oriented to 3D is part of the Brazilian labs network linked to the FAB Foundation, associated to MIT – Massachusetts Institute of Technology. The Fab Lab Network is an open, creative community of fabricators, artists, scientists, engineers, educators, students, amateurs, professionals, who has the mission to share and promote access to the tools for technical invention. This community is simultaneously a manufacturing network, a distributed technical education campus, and a distributed research laboratory working to digitize fabrication, inventing the next generation of manufacturing and personal fabrication. In each unit of PRONTO 3D there are 3D printers, router milling, laser cutting machines, computers and software (Fig. 3). There, it is developed CAD modeling, print 3D physical models, manufacture of prototypes, final products, complex structures, assemblies and installations. Several areas are attended, such as architecture, civil, mechanical, mechatronics and electrical engineering, industrial and graphic design, among others. The PRONTO 3D unit from SATC is composed by a coordinator (Professor-researcher) and students who receive scholarship, and provides services to internal customers (SATC undergraduate, high school and technical education courses) and external customers (companies and others PRONTO 3D units from Santa Catarina State).



Fig. 3. RP equipment to develop PBL classes (3D Printer, Laser cutting machine and Milling Router).

3.1 PBL's classes development in Level 1

An important aspect to implement the PBL is related to classroom layout, which allows to foster collaboration and interactive learning. Because of that, we designed our own active learning room (Fig. 4) We have whiteboards for students to share and express their ideas. We also have a mobile camera that allows students to showcase their work by streaming in the big screens.



Fig. 4. SATC Active Learning room.

The following is an example of a class where PBL was applied – Level 1, during the 2nd semester 2016 (Fig. 5). The project's aim was to promote cognitive activities that achieve higher order thinking, allowing students to become creative and problem solvers. Therefore, class was divided into groups of four students to solve a problem related to the subject of Technical Drawing. The PBL's task was to develop a Mini Baja's prototype by applying the discipline basic contents (dot, line, planes and graphics process to obtain distances and areas). Normally when implementing PBL, the classroom's layout is different from the traditional (rows of desks), so tables for

four or more students to work together in this experience were used. In this case, several tools (scissors, pliers, stilettos, screws and other mechanical tools) were made available and raw materials (wood and acrylic sheets) were provided to manufacture the prototypes.

The professor (red shirt, seated next to students, left side of figure 5) does not stay seated in his chair - he remains very close to the teams, helping them to solve the proposed problem. There were short lectures, but most of the time was spent helping the groups. Not all groups delivered the complete task (incomplete assembly) but all groups performed drawings and used them to build the prototype. As can be seen, to plan and execute PBL class, it requires important changes (classroom layout, equipment, planning, and infrastructure adaptation). However, the main and most difficult change to be sought is in the professor's mindset, who needs to leave their comfort zone and adapt to provide the education of the XXI century.



Fig. 5. Left side: Active Learning classes (Level 1); 2nd semester 2016, SATC College, Mechanical Engineering Course. Subject: Technical Drawing. Right side: manufacture of prototypes using the basic concepts of the subject (design) and rapid prototyping resources (laser cut machine and 3D printer).

4 Conclusions

It is important to consider that the applicability of this PBL-based learning model to different disciplines needs to take into consideration the nature of each discipline, due to limitations imposed by course's current structure. Thus, it is plausible to expect professors to achieve level 2 when implementing in one discipline and level 3 in another, without moving up to next level. On the other hand, the incapacity to apply levels 1 and 2 indicated that there were structural problems, in which prevented defining the objective, importance, nature, protagonism and utility of the discipline itself. Furthermore, each attribute cannot occur in the same intensity even if it is in the same level of implementation. A problem of simulated scope (Level 3) can be solved through a mediator professor (Level 1). Actually, it is a possible situation but unlikely, in according to case studies observed. The integral application of PBL, contemplating every learning unit and every level, requires a revision of the curriculum for all the courses. However, the current proposition does not see this as a possibility.

PBL's curricular implementation requires change of teachers' consciousness towards teaching-learning process, the steeped application of each level, the radical change from content-based curriculum to skills-based curriculum, the immersion of universities on professional world and vice-versa. This immersion can be achieved via partnership between enterprise and the university, providing and fomenting research projects; scholarship and extra-curricular internship; university learning units inserted into the enterprises and enterprise laboratory units inserted into university.

Following, are displayed a resume of PBL-based learning model aspects (positives and negatives). On the positive side, we have seen the improvement in the engagement of teachers and students during PBL classes as well as a decrease in student dropout because students become more motivated. This active learning project, also promotes more recognition and differentiation from the job market. That also increase scientific production and external quality indicators. The negative aspects we have found is that engineering professors, specially, are more resistant to implement PBL, despite the fact that we have all the structure and provide all the conditions and support to plan and implement active learning. We also know that deep changes in the curriculum of each graduation course is needed. There is a need to make a financial investment because there are expenses with equipment maintenance, inputs and raw materials.

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Heuristics as Mental Shortcuts in Evaluating Interactive Systems

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Abstract—Heuristics refer to the specific “rules-of-thumb” discovered from knowledge or experience which can simplify the complexity of making judgments. Heuristics are mental shortcuts to draw conclusions when evaluating interactive systems. In this study, a set of heuristics had been discovered by end-users while developing a series of prototypes of a test blueprint system. This study suggests that the design process of an interactive system should cater to the following two (2) components, namely: technical heuristics and specialized domain heuristics. Heuristics from these components should be the emphasis during the evaluation of the interactive system that has been designed using a user-centered paradigm of development called the Interaction Design Model (IDM).

Keywords—heuristics, test blueprint, user-centered development, prototypes

1 Introduction

In this study, the end users had been consulted and collaborated with the author to effectively capture the actual requirements for the development of an interactive system. The interactive system under study is a test blueprint designed to judge students’ learning performance [1]. The author believes that the users are key resources to capture system’s requirements. As shown in Fig. 1, collaboration by a cohesive team of user representatives is evident that ultimately promotes the attainment of a shared goal and continuous improvement of the interactive system. Each user has a specific role to play, thus, actively engaged into the design of the interactive system.

As shown in Fig. 1, the test construction is performed in a two-way line of collaborative process of communication process by the users, namely: Course Lecturers, Course Coordinators, Program Coordinator, and Head of Section – all of whom are directly involved in the several stages of the interactive system design and implementation. The author asserts that in an organization where peer collaboration is valued and supported, the best way to capture the requirements among themselves in the design of an interactive system is to utilize prototypes where they could interact among each other.

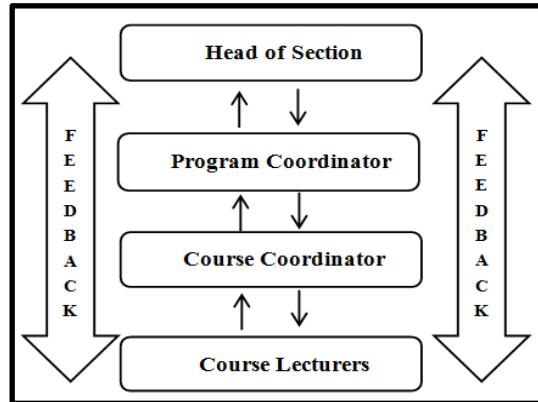


Fig. 1. Organizational Structure and Protocol (Course Level)

2 Conceptual Framework

A robust user-centered paradigm called Interaction Design Model (IDM) has been broadly used in designing interactive system. As shown in Fig. 2, the following four (4) interwoven key stages optimize the involvement of users throughout the design process: a) Establishing Requirements Stage which solidifies a constant evidence-based mode of searching information from a vast-range of sources to form requirements; b) Designing Alternatives Stage which includes the creation of a number of creative ideas that materialize the users' requirements; c) Prototyping Stage which enables user to interact with the system by immersing them through a look-and-feel-walkthrough with the system. According to the author, interaction with the prototype is the most sensible and collaborative way for users to evaluate the interactive system design; and d) Evaluation Stage which is an ongoing appraisal about the acceptability level of the system. Once the system is up-to-acceptable-level, it is going to get released ready for use by the intended users. However, if some requirements require refinements then these are fed back to the preceding stage(s) for appropriate action.

The specific stage which has been emphasized in this study is PROTOTYPING which greatly relies on the insights and feedback of the intended users regarding the prototypes of the interactive system. It allows designers to better understand users' real needs and preferences as it allows them to generate more ideas and articulate constructive feedback. Experts [2] claimed that "[...] prototypes are widely recognized to be a core means of exploring and expressing designs for interactive computer artifacts. It is a common practice to build prototypes in order to represent different states of an evolving design and to explore options. Simulating a design through prototyping can reduce design risks without committing to the time and cost of full production." Prototyping is highly intensive in the design process of interactive systems as it may suggest iterations, if needed.

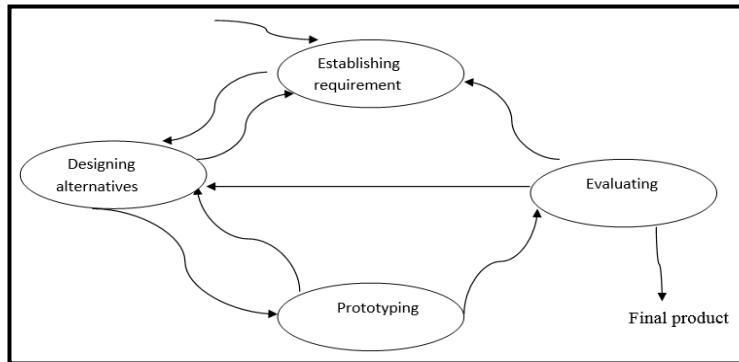


Fig. 2. Interaction Design Model [3]

The author observed that throughout the design of the interactive system, the intended users had been showing a sense of ownership as revealed by their active participation. Also, an apparent collaboration had enriched the interaction and improved communication by ‘thinking aloud’ their insights, feedback, and concerns towards the improvement of the system.

It is suggested to have a number of prototypes in order to allow users to select the best solution from the set of alternatives. Some designers are using prototypes to evaluate existing ideas. Users’ rationale about their needs and requirements greatly influences the design of a more usable interactive system. There are many tools and techniques available for prototyping which ranges from ‘paper-and-pencil’ to ‘more advanced technologies’. Prototypes do not necessarily produce fully-functional alternatives but rather are concrete representations that may envision and reflect the final product. It can be a low fidelity prototype or high fidelity prototype. In this study, two (2) samples of prototypes of the test blueprint have been iteratively developed: (1) test blueprint using paper-and-pencil as the earlier version and (2) test blueprint using spreadsheets as the derivative version. The final product is a web-based test blueprint system.

3 Statement of the Problem

This study is motivated to show how to design an interactive system (e.g. web-based test blueprint system) using a user-centered model of development. Specifically, it aims to discover the appropriate heuristics from the series of test blueprint prototypes that are essential in the development of a usable interactive system. Such heuristics are subsequently used as mental shortcuts to evaluate the said interactive system with emphasis on two (2) components, namely: technical heuristics and specialized domain heuristics.

4 Research Design: Methods and Procedures

This study made use of a descriptive research design with the following methods and procedures.

4.1 Literature Review

The author finds it very helpful to do a thorough review of related literature to establish content validity resulting to acceptable content validity index of the heuristics.

4.2 Focus Group Discussion (FGD)

The FGD session comprises of user representatives who could provide information, insights, feedback, and suggestions that are related to their respective role/tasks. It is a useful qualitative method of capturing specialized domain requirements that may assist the designer. The author of this study served as the moderator of the FGD.

4.3 Prototyping

A series of early versions called prototypes had been used in the development of a usable interactive system. Several iterations had been done in order to accommodate the intended users' needs and requirements.

5 Participants of the Study

There were double experts ($n=5$) who participated in determining the content validity of the heuristics identified by the designer in consultation with the users. Double experts are those individuals who have multiple areas of expertise, including an area related to the specialized domain-under-study.

The number of participants ($n=10$) during the Focus Group Discussion (FGD) session was within the recommended range which is six to twelve key informants [4]. The FGD comprises of the Course Coordinators, Course Lecturers, Program Coordinators, and Heads of Section.

Moreover, there were ninety-three (93) intended users who actually interacted with the sample prototypes of the interactive system.

6 Data Analysis

The following tools were used to determine the content validity and reliability of the identified heuristics:

6.1 Content Validity Index (CVI)

The researcher made use of an empirical method called Content Validity Index (CVI) to analyze the feedback of the panel of double experts. The CVI determines the relevance of the heuristics. It is used to check whether or not the items adequately represent the specialized domain of content [5]. The double experts rated the items of heuristics based on their level of relevance, using the rating scale shown in Table 1.

The different key formulae used in Content Validity Indexing are listed in Table 2.

Table 1. Relevance Scale for Content Validity Indexing

Rating	Description
1	Not Relevant
2	Somewhat Relevant
3	Quite Relevant
4	Highly Relevant

Table 2. Key Formulae for Content Validity Testing

Entity	Formula
I-CVI (Item Content Validity Index)	$I-CVI = \text{No. of Agreement} / \text{No. of Raters}$
S-CVI/Ave (Subscale Content Validity Index / Average)	$S-CVI/Ave = \text{Average of I-CVI}$
S-CVI/UA (Subscale Content Validity Index / Universal Average)	$S-CVI/UA = \text{Total Agreement} / \text{No. of Items}$
No. of Agreement	The count of raters whose response is greater than or equal to 3, 3 being the marginal response
Total Agreement	The count of No. of Agreed Items by the raters $\text{Total Agreement} = \text{Total number of items agreed by raters}$

6.2 Cronbach's Alpha

The Cronbach's alpha, which is sometimes called the coefficient of reliability, is used to measure the internal consistency of a test or scale [6], which had been used to determine the reliability of the items of heuristics identified in this study.

The rules of thumb corresponding to a Cronbach's alpha coefficient is shown in Table 3. Generally, it ranges from 0 to 1. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale.

Table 3. Cronbach's Alpha Coefficient [7]

Cronbach's Alpha Coefficient	Description
0.91 – 1.00	Excellent
0.81 – 0.90	Good
0.71 – 0.80	Acceptable
0.61 – 0.70	Questionable
0.50 – 0.60	Poor
Less than 0.50	Unacceptable

7 Results and Findings

7.1 Prototypes

The author found out that prototypes used by the intended users can be “proofs-of-concept” geared to discover the appropriate heuristics derived from the sample prototypes through the use of Literature Review. It was revealed that the longer these prototypes have been exposed to users, the greater ideas are generated by them that could contribute to the enhancement of the design of the interactive system. From the feedback received from users, the procedure for test construction preparation and examination approval of the institution had also been improved. To put it simply, the logical and physical designs of the interactive system, as well as the business process of the institution, had been enhanced.

Below were the two samples of prototypes of the test blueprint that had been iteratively developed: (1) test blueprint using paper-and-pencil as the earlier version, shown in Fig. 3, and (2) test blueprint using spreadsheets as the derivative version, shown in Fig. 4.

TABLE OF SPECIFICATIONS E-Commerce for IT (ITBS2203) First Semester, AY 2011-2012							
Course Code: <u>ITBS2203</u>			Course Title: <u>E-Commerce for IT</u>				
TOPICS TAUGHT/ CHAPTER TITLE	LEARNING OUTCOME NO.	INSTRUCTIONAL OBJECTIVES	BLOOM'S TAXONOMY COGNITIVE LEVEL	NO. OF HOURS SPENT	% OF TOTAL HOURS SPENT	NUMBER OF MARKS PER TOPIC	Allocated Marks Per Question/Cognitive Level
IA. Introduction to Electronic Commerce	3, 4, 7, 10	Explain the differences between E-Commerce and E-Business.	Comprehension				1
Course Code: <u>ITBS2203</u>							
CHAPTER NO.	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Total
Chapter 1T		9		3			12
Chapter 2T		2		4			6
Chapter 3T	1	4					5
Chapter 1P			27				27
TOTAL	1 (2%)	15 (30%)	27 (54%)	7(14%)	0 (0%)	0 (0%)	50(100%)
Note: Synthesis and evaluation levels are tested in their course project/assignment.							

Fig. 3. Paper-and-Pencil Prototype of the Test Blueprint

2	HCT_IT_EXAM_001		Department of Information Technology		
3				TABLE OF SPECIFICATIONS (TOS)	
4	Semester:	2	AY:	2016-2017	
5	Type of Exam:	FINAL	Date of Exam (dd/mm/yyyy):	4/4/2017	
6	Course Code & Title:	ITBS4000-Human-Computer Interaction			
7	Nature of Course:	ITBS2203-E-Commerce for IT			
8	Level:	ITBS3112-Decision Support System			
9		ITBS3200-Computer Hardware and Network Essentials			
10		ITBS4300-Modern Operating Systems			
11		ITDB1102-Introduction to Database			
12		ITDB1204-Applied Database			
13		ITDB2101-Systems Analysis and Design			
14	Chapter No.	Chapter Title			
15	1				
16	2				
17	3				
18	TOTAL	0	0.0	0.0	0.0
19	Required Total Marks Between LOT & HOT			8	32
20	Ratio Between LOT & HOT Based on Course Nature & Level			20	80
21	Prepared by:	Designation (Course Coordinator)	Name	Signature	
22	Agreed by:	(Course Lecturers)			
23					

Fig. 4. Spreadsheet Prototype of the Test Blueprint

7.2 Identified Specialized Domain Heuristics through Literature Review

A substantial and rigorous literature review had supported in framing heuristics that pertain to the specialized domain i.e. Classroom Assessment vis-a-vis web-based test blueprint system. The following specialized domain heuristics had been identified as summarized in Table 4, namely: (1) Content Validity, (2) Fairness and Comprehensiveness, (3) Accountability, and (4) Flexibility. Under each heuristic, there are sub-heuristics ($n=5$) written in clear statements. The specialized domain heuristics contain twenty (20) specific heuristics in total. These heuristics may serve as mental shortcuts when evaluating the usability of the interactive system.

Table 4. Specialized Domain Heuristics

Test Blueprint Heuristics	
1. Content Validity	
1.1	The Test Blueprint improves content validity of my students' exam [8].
1.2	The Test Blueprint ensures that my students have achieved a specified standard of achievement or learning expectation at the end of their exam [9], [10].
1.3	The Test Blueprint makes it easier for me to identify what types of test questions are required based on the cognitive levels of LOT and HOT [11].
1.4	The Test Blueprint helps me to construct a test which focuses on the key areas or topics which are weighted according to importance or significance [12], [13], [14].
1.5	The Test Blueprint provides a link between what is taught and what is tested both in content and in skills required [8].
2. Fairness and Comprehensiveness	
2.1	The Test Blueprint ensures that all the required course outcomes to be tested have been adequately covered [11], [14].
2.2	The Test Blueprint ensures that there is a representative sample of questions from each chapter required to be covered [8].
2.3	The Test Blueprint measures appropriate varied cognitive levels of my students which test different learning skills and types of exams [11], [14].
2.4	The Test Blueprint creates a balance of testing between lower-ordered thinking skills and higher-ordered thinking skills that are appropriate to the level of my students [11], [14].
2.5	The Test Blueprint produces an exam paper that does not discriminate the different types of learners [8].

3. Accountability
3.1 The Test Blueprint helps me to create a degree of my own accountability [8].
3.2 The Test Blueprint makes me confident to answer students' complaints of dissatisfaction or any kind of exam appeals at the end of the exam [12], [13], [14].
3.3 The Test Blueprint can create quality exam resulting in a high GPA's credibility of my students [11], [14].
3.4 The Test Blueprint is my effective exam paper preparation tool [12], [13], [14].
3.5 The Test Blueprint is more effective when collaboratively prepared by a team [9], [10].
4. Flexibility
4.1 The Test Blueprint makes the teachers creative in writing an exam paper [8].
4.2 The Test Blueprint preparation is a simple task after having been used to it [11].
4.3 The Test Blueprint can prepare a common exam paper among multiple sections [9], [10].
4.4 The Test Blueprint format can be modified according to the needs of the institution. [12], [13], [14].
4.5 The Test Blueprint is following the existing exam procedures of the institution [8].

7.3 Content Validity Index and Reliability of Heuristics

The heuristics listed in Table 4 were tested by 3-5 expert evaluators using Content Validity Index (CVI). With this number of expert evaluators, the most acceptable value for I-CVI is 1 and the ideal value for S-CVI/Ave is 0.90 or higher [15].

As reported in Table 5, all the expert evaluators agreed that each item is relevant as shown by the S-CVI/Ave which is equivalent to 1, which exceeded the ideal value for S-CVI/Ave which is 0.90. All the items under each subscale are correlated well with each other as shown by the S-CVI/UA which is equivalent to 1.

Table 5. Summary of Content Validity Testing Results using Content Validity Index (CVI)

Domain Heuristics (Test Blueprint Heuristics)			
Subscale	S-CVI/Ave	Total Agreement	S-CVI/UA
1. Content Validity	1	5	1
2. Fairness and Comprehensiveness	1	5	1
3. Accountability	1	5	1
4. Flexibility	1	5	1

On the other hand, the heuristics are deemed reliable as reported by the reliability coefficient of each item which is greater than 0.7. As shown in Table 6, the Cronbach's alpha coefficient is 0.76 which is considered acceptable.

Table 6. Reliability Statistics

Cronbach's Alpha	Interpretation	No. of Items
0.76	Acceptable	20

7.4 Final Product (Web-based Test Blueprint System)

Using the Interaction Design Model, the designer in consultation with the intended users, was able to craft the final product (web-based test blueprint) as shown in Fig. 5.

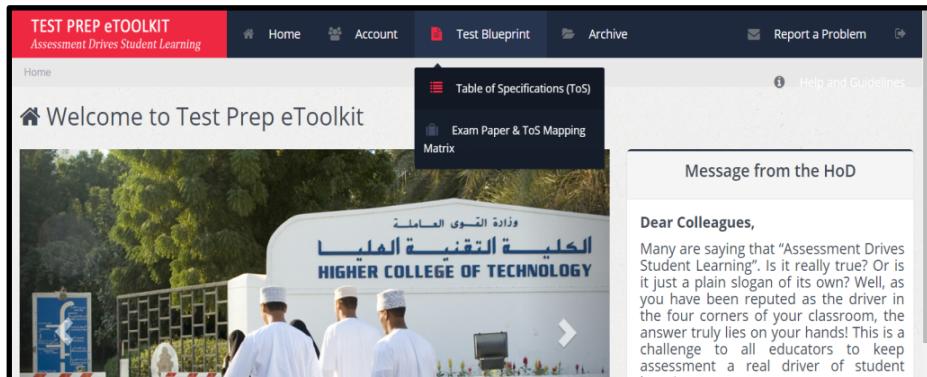


Fig. 5. Web-based Test Blueprint System Home Page

Fig. 5 shows the interface of the web-based test blueprint system which contains several menus that make it even more usable. There are two (2) submenus, namely: Table of Specifications (TOS) and Exam Paper & TOS Mapping Matrix. The test blueprint comprises of the chapter number and chapter title, the percentage of chapter weight, the weighted mark, the actual allotted mark, and the level of difficulty (LOT/HOT ratio). On the other hand, the ‘Exam Paper and TOS Mapping Matrix’ shows how items should be mapped against the cognitive levels of the Bloom’s Taxonomy of Learning. The exam paper should perfectly match with the approved TOS.

8 Conclusion and Recommendations

Based on the summary of findings of the study, (1) Heuristics can be discovered while interacting with prototypes. Such heuristics may serve as helpful mental shortcuts or benchmarks when evaluating the usability of an interactive system; (2) Prototypes are cost-effective and easy to use in generating more ideas from the intended users. Prototyping activities should always be included in the design process of an interactive system. It can be utilized as “proofs-of-concept”; (3) The following two (2) essential domains should be considered in the development of interactive system, namely: technical domain (e.g. user interface design) and specialized domain (e.g. classroom assessment); (4) The users acquire a sense of ownership, support, and goodwill over the final product because of their level of involvement throughout the design. The use of the user-centered approach to development called Interaction Design Model is recommended in designing interactive systems; and (5) The interactive system and the other prototypes presented in this study can be used as patterns for developing test blueprints by other educational institutions. The format of the test blueprint may vary depending on the needs and requirements of the educational institution.

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Game-Based Learning while Research Activities of Engineering Students

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Abstract—This work describes the experience of Tomsk Polytechnic University in involving students in scientific research. The involvement is to be achieved by including scientific research elements into laboratory class programs, game-based learning, conducting laboratory classes in real-life scientific research facilities, including "Scientific research work for students" into Bachelor's curriculum (starting the second grade) and other actions. The experience described should be considered a success, as over the last decade the number of Bachelor's graduates at TPU willing to pursue the Master's degree (and then do postgraduate studies) has multiplied. The competition for enrolling into postgraduate studies has increased as well.

Keywords—game-based learning, laboratory practicum, active learning, scientific research activities, team training, engineering education

1 Introduction

Tomsk Polytechnic University (TPU) is ranking fourth domestically and is the oldest institute of technology in the Asian part of Russia. In the last decade, the university has set a goal to get high rankings in the top part of major international ratings. The development of a research university is implausible without involving students into scientific research, starting from their junior years.

The research work this annotation is a part of describes the university's experience in involving junior grade students in scientific research. The above goal is to be achieved by including scientific research elements into laboratory class programs, game-based learning, conducting laboratory classes in real-life scientific research

facilities, including "Scientific research work for students" into Bachelor's curriculum (starting the second grade) and other actions.

The experience described should be considered a success, as in the last decade the number of Bachelor's graduates at TPU willing to pursue the Master's degree (and then do postgraduate studies) has multiplied.

2 Background

Tomsk Polytechnic University was founded in 1896 as an institute for training practicing engineers. From the very onset, TPU has become the heart of engineering and technical creativity in the Russia's Asian part. From the very beginning of its history, the institute has conducted scientific research within the frame of professional training, and, of course, the students were involved as well. In engineering sciences, the demarcation line between scientific research and engineering development is very thin, if sometimes noticeable at all.

That is why serious scientific research projects have been developed in engineering student project groups (created under the auspices of the respective institute departments as early as in the beginning of the 20th century). Thus, in 1913 the aeronautics department student group directed by professor B.P. Veinberg has built the world's first experimental maglev. In 1927 students from the same team, but this time directed by professor G.V. Trapeznikov, built Siberia's first airplane whose engine was created by students from another department's group (thermal engineering) directed by professor A.V. Kvasnikov.

In 1953 in the radio engineering department's group directed by associate professor V.S. Melikhov, an amateur TV broadcast station was created that has laid foundation for Tomsk TV broadcast station, the fifth of a kind in the USSR. In all of the above cases, engineering design development was preceded by deep scientific research [1, 2, 3].

Still, despite all these (and other) success stories, the cultivation of student-driven scientific research through science groups is obviously not enough to position the university as a major research center.

3 “Training through collaboration”, a pedagogical technology for game-based learning

The theoretical foundation for this technology was laid by American teacher John Dewey, 1916. In Russian pedagogy science, "training through collaboration" has acquired widespread acceptance, thanks to the works by Ye.S. Polat [4, 5].

According to Ye.S. Polat, "training through collaboration", as different from the traditional forms of group work, is peculiar for the following aspects:

1. Mutual dependence of all group members
2. Personal responsibility of each group member both for their own success and for the success of other fellow members

3. Joint educational, cognitive, creative and other activities of students in a group
4. Student activity socialization in groups
5. Overall group activities are evaluated by adding up the results of assessing students' form of group communication as well as their academic achievements.

The implementation of education through collaboration is underpinned by a common system. The teacher selects students to form a group. Each group should be formed to include students with a varying level of command of the foreign language, different experience of collaborative educational efforts, the group should be a mix of genders, etc. Such principles of selection give each team member a real opportunity to develop the necessary skills in the course of collaborative project delivery. Also, it is obvious that there a different skill set will be developed by each member. For students lacking in linguistic proficiency, that would be language communication skills. For students with high linguistic proficiency, the skills acquired previously will develop, as well as leadership skills, the ability to organize team education, etc.

1. Each group is given a problem that requires each member to participate in the solution. Roles are allocated between group members, and each is provided with a separate work cluster.
2. Each group is given a set of required materials (one text copy, one set of exercises, one web page to keep track of the project, etc.).
3. One mark is given to the whole group for the project delivery [6, 7, 8].

The peculiarity of the “education through collaboration” pedagogical technology is that each participant is responsible both for their part of the job and for the entire project. Eventually, it is not the work of every single team member that gets evaluated. It is the result of the collaborative effort. The final product will tell how the students managed to collaborate. This teaching technology encourages communication and teamwork to achieve the best result.

The general experience of project work shows that education through collaboration as a pedagogical technology for game-based learning may become efficient for groups of 4-5 persons with varying level of competence. It can be presented as a part of blended learning [9, 10]. While working together on the project, the participants are inherently placed into a situation when the project can be delivered, and positive results can be achieved through collaboration only. In the meantime, in the course of project delivery, the team decides which member is capable of leadership and who is apt for research activities and who is more comfortable as a doer.

4 Possible solutions to the problem

The first step to solve this problem was the introduction of scientific research elements into the laboratory practicum, utilizing the "training through collaboration" technology as game-based learning. Laboratory practicum is an integral part of engineering and natural science courses and is a required activity for all students without exception. Traditionally, a student group is broken into teams, three to five persons

each. Each team's program is compiled in such a way, so that it's impossible to complete it without role allocation and personal responsibility of each student for their respective part of the common effort. Such workflow is applied for all laboratory practicum as training through collaboration, irrespective of the university department. Role allocation is done by team members, and the teacher is not getting involved in any way. However, the teacher takes notes which roles which students take. Later on, this information is useful for outlining the student's education path and deciding whether to offer the student to participate in real scientific research, send the student to work at an industrial plant or in a scientific laboratory or recommend them to pursue Master's or Specialist's degree, or to graduate with Bachelor's. Of course, role allocation alone is not enough to draw conclusions about aptitudes and capabilities. Still, when putting together a student's profile, this information may come handy.

Starting with the second grade already, students are taught to correctly set up experiments and are required to substantiate their choice of the physical model of the researched process/ phenomenon as well as the experimental toolset. It is also important to teach students how to process experimental results. At the department of experimental physics and general physics, this is taught as early as the 1st semester of the Bachelor's course [11, 12, 13]. Since teaching physical and technical subjects is the current work authors' specialty, the examples are taken from the departments of the respective profiles. The result of this training is the convincement of a student that any natural science experiment is an event with certain probability, so the result thereof must be treated accordingly. Further on, when experiments are set up and conducted in the course of other laboratory courses and educational and scientific research efforts are carried out, the students do not feel repulsion or have difficulties doing multiple repeat measurements (i.e. collecting statistical material) and further statistical treatment of the experimental results [14, 15, 16].

Starting from the first grade of Bachelor program, scientific research elements are included into the laboratory works curricula. For example, for the work "Determining the free fall acceleration", the department of experimental physics suggests that students not only determine the acceleration but also calculate the dependency between the free fall acceleration and the latitude, taking into account the Coriolis force and the altitude above sea level. The department of electric networks and electric engineering suggests that when performing the laboratory work "Emission of a two terminal circuit", the dependency of the output parameters of the circuit on the load intensity and type as well as internal impedance of the circuit should be researched. Also, the conditions for matching an active two terminal circuit with the load are to be determined.

Correctly documenting the research results is another important aspect. That is why specific attention is paid to adequately composing laboratory work results. Students might think those are just teachers' critiques but we need students to achieve understanding that a research result only matters when it is has been made publicly available to scientists. Therefore, the publication must be easily readable and comply with the academic standards.

Senior grade Bachelor students get access to experimental facilities and installations that were used (or are used) for real scientific research. This way, the depart-

ment of high voltage electricity physics and high current electronics uses the installation described in [7] (see Figure 1). A research of the characteristics of contaminated insulation of overhead power transmission lines (a real-life scientific research) was performed on that installation.



Fig. 1. Insulator testing unit

At the Physical and technical institute, a series of laboratory courses have been developed for the operational scientific nuclear reactor IRT-T (see Figure 2, 3), that is actively used for scientific research and isotope production. Now it is also used in the students' laboratory courses.



Fig. 2. A group of students at the IRT-T reactor

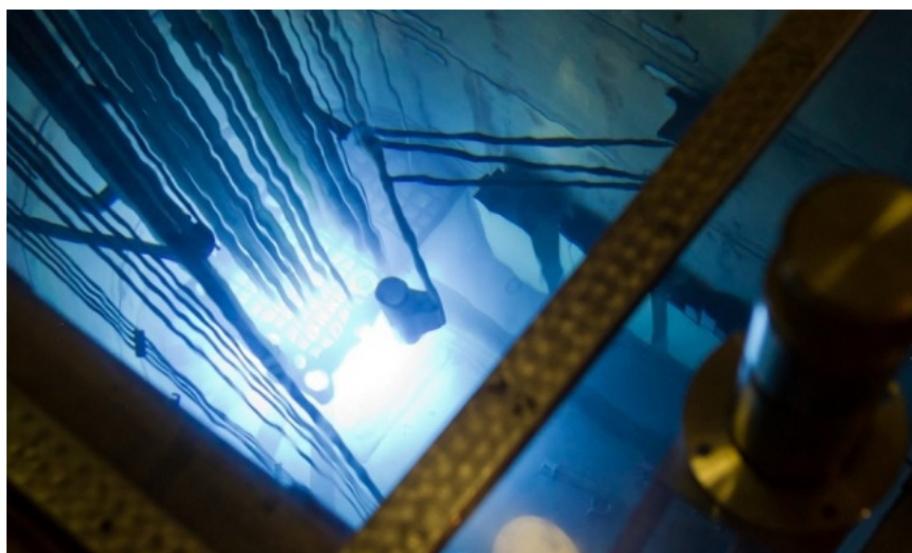


Fig. 3. Reactor's active zone

The next step is introducing discipline named "Educational and research work for students" into the curriculum of virtually all engineering specializations. This discipline is taught starting the second grade of Bachelor's degree course. Within the scope of this discipline, sets of lectures are delivered to students: bibliographic search, theo-

ry of inventive problem solving, rules and techniques for preparing research publications, etc. This is very useful for a future researcher: student will already be able to properly handle experimental equipment, thanks to laboratory practical trainings on chemistry, physics, theoretical and applied mechanics and electrical engineering. Then, with the assistance from their mentors, the students will gain the expertise and skills that they lack in when they start real research work. However, it is equally important to correctly set the research goal, define the approaches to its solution, choose the adequate physical model for setting up the experiment and choose the mathematical model for processing the experimental results. Besides, as we have already mentioned, any research result is only worthy if it becomes publicly available.

Starting from the second grade, students work with literary sources pertinent to their specialization and write papers on topics set by their academic advisors. For solving real research objectives, third grade students are assigned to labs. There they participate in experimental research in conditions that are as close to real life as possible, the whole process based on game-based learning used together with "training through collaboration" [18]. By that time, the students will have had enough time to study the research topics and to master experimental research methods. It allows them to become co-authors of articles written by their academic advisors and deliver reports at international science conferences.

Thus, by the moment when a student earns their Bachelor's degree, they will have become a full-featured member of a scientific research team. The student will have a set of science research skills, from setting the goal to adequately interpreting experimental results. Such students' graduation papers are normally based on the results of real scientific research conducted in the laboratory where they have been studying. In most cases, such papers are the starting point of more serious works performed to pursue Master's degree.

For Master's Degree students, scientific research involvement is the cornerstone of their curriculum. Master's Degree students can only pass graduation certification if they have published an article or delivered a report at a science conference. The paper itself is called a dissertation (i.e. "a document submitted in support of candidature for an academic degree or professional qualification presenting the author's research and findings" [19, 20]) for a reason.

5 Conclusion

The above efforts have allowed for substantially increasing students' interest and motivation towards scientific research activities. There is a steady annual inflow of graduates (between 900 and 1100 Bachelor degree holders) who choose to continue their education and seek Master's degree. Also, about 200 Master degree holders go for post-graduate. It is also worth noting that in the recent four years, the number of graduates who have chosen science research as their profession is increasing, year to year. As of current, over 80% of Master degree students have received their Bachelor's degree at TPU. You can decide for yourself whether this is good or bad, depending on how you look at it. On one side, when students from outside TPU come to TPU

to pursue Master's degree, it is a win because it means TPU's popularity in the education community increases, domestically and internationally. On the other hand, candidates compete to enroll into Master's course (in 2016 the competition was 2.5 contestants per vacancy). So, if more students of Tomsk Polytechnic University succeed, that means they are better prepared. Being experience in scientific research activities, gained in the frames of education through collaboration as a pedagogical technology for game-based learning let Master's degree students take an active part in international scientific and educational areas in the frames of international collaborative projects and funds. It is possible to implement not only while studying but in the future professional work.

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