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Technology Enhanced Learning in Programming Courses – International Perspective

Authors:
Mirjana Ivanović, Stelios Xinogalos, Tomáš Pitner, Miloš Savić

Corresponding author:
Miloš Savić
Department of Mathematics and Informatics
Faculty of Sciences, University of Novi Sad
Trg Dositeja Obradovića 4, 21000 Novi Sad, Serbia
email: svc@dmi.uns.ac.rs, **phone:** +381 21 458888, **fax:** +381 21 6350458

Affiliations, addresses and contact information:

Mirjana Ivanović
Department of Mathematics and Informatics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, 21000 Novi Sad, Serbia
email: mira@dmi.uns.ac.rs

Stelios Xinogalos
Department of Applied Informatics, School of Information Sciences, University of Macedonia, 156 Egnatia Street, GR-54636 Thessaloniki, Greece
email: stelios@uom.edu.gr

Tomáš Pitner
Department of Computer Systems and Communications, Faculty of Informatics, Masaryk University, Šumavská 416/15, Ponava, Brno, Czech Republic
email: tomp@fi.muni.cz

Miloš Savić
Department of Mathematics and Informatics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, 21000 Novi Sad, Serbia
email: svc@dmi.uns.ac.rs

Technology Enhanced Learning in Programming Courses – International Perspective

Abstract

Technology enhanced learning (TEL) is increasingly influencing university education, mainly in overcoming disadvantages of direct instruction teaching approaches, and encouraging creativity, problem solving and critical thinking in student-centered, interactive learning environments. In this paper, experiences from object-oriented programming (OOP) courses that are taught in three institutions from three different European countries are presented and compared. The courses are based on Java and are delivered in the second year of studies, after students have attended an introductory programming course. The emphasis is given on TEL approaches and accompanying tools and services, focusing mainly on Learning Management Systems (LMS). Our students completed an appropriate questionnaire to evaluate the importance and utilization of TEL services that are used or planned to be used at the programming courses. The results of statistical analysis of collected data show that students from all three institutional groups consider organizational services provided by TEL tools as much or very much important in their education, while communicational services are rarely used. Using non-parametric statistical tests we studied the similarities and differences in perceived importance of TEL services among students from different institutional groups.

Keywords: *Technology-enhanced learning, Java programming courses, students' perception, comparative study*

1. Introduction

Teaching and learning programming is not an easy task either for teachers or for students. One of the first challenges teachers face in introductory programming courses (CS1) is choosing the programming approach and the language that will be adopted. The most prevalent approaches are the objects-first and the structured-first, while the programming language utilized can be either a language designed for teaching purposes or a production language. In the objects-first approach students are exposed to the fundamental concepts and principles of object-oriented programming and design at the very beginning of introductory programming courses (Bennedsen and Schulte, 2007). The main idea of the structured-first approach is to introduce concepts and constructs of structured programming (primitive data types, expressions, statements and blocks, control-flow structures, procedures, recursion and abstract data types) before introducing object-oriented concepts in a subsequent OOP course. Several programming languages have been used the last decades in the context of CS1 courses. Some well known programming languages considered appropriate for teaching purposes are Pascal, Modula-2 and Ada, while common production languages used in CS1 are C and C++ (Brilliant and Wiseman 1996). Java is also a popular language

used in CS1 courses that are based either on the structured-first or the objects-first approach, while a language that is currently used in CS1 is Python (Dierbach 2014).

Our institutions have adopted the structured-first approach and within the CS1 course, the Masaryk University, Faculty of Informatics, Czech Republic (further referred to as MUNI-FI) and the University of Novi Sad, Faculty of Sciences, Serbia (further referred to as UNS-PMF) use languages designed for teaching purposes. Specifically, MUNI-FI uses Python or C (formerly Pascal) in structured style and UNS-PMF uses Pascal and Modula-2. The Department of Technology Management (currently Technology Management direction of studies within the Department of Applied Informatics) at the University of Macedonia in Greece (further referred to as UOM-TMD) uses C, a production language. In subsequent programming courses the three institutions switch to the OOP paradigm using Java as the programming language. So our intention in this paper is to concentrate not on experiences from CS1 courses but to put emphasis on the use of TEL and present experiences of TEL effects in subsequent OOP courses.

Teaching and learning OOP is accompanied by several difficulties for both teachers and students. In order to support learning of programming, all three institutions have invested time and effort in utilizing and developing various TEL tools and services, including: LMS and Tutoring Systems, Programming Environments and Tools, Assessment Tools, Communication and Cooperation. The programming environments and tools used at the three institutions have been evaluated with positive results (Ivanović et al. 2008; Komlenov et al. 2010; Pribela et al. 2009; Xinogalos et al. 2006; Xinogalos 2015; Xinogalos 2016; Xinogalos et al. 2007). Moreover, the teaching approaches adopted in each one of the three institutions have been studied and compared in previous papers (Ivanović and Pitner 2011; Ivanović et al. 2011; Ivanović et al. 2015). The main goal of this study is to investigate students' perceptions regarding the importance of various tools and services offered by the LMS used, as well as to study the potential importance of other technologies, resources and tools that could be utilized. A questionnaire survey was carried out in order to achieve this goal and to investigate students' views of the importance of various TEL services that are either currently used or are being planned to be employed in the educational processes at our institutions.

The rest of the paper is organized as follows. In the next section a brief literature review on TEL in programming courses is presented. This is followed by a brief presentation of the OOP course design and important TEL aspects in the three institutions. The next section gives a motivation for this study and presents its research questions. Data collection and analysis methods are explained in the fifth section. The next section presents obtained results. Finally, in the last section conclusions are drawn.

2. Literature Review on TEL in Programming Courses

Teaching and learning programming is challenging for instructors and students respectively. An important aspect of a programming course is finding appropriate programming environments and tools that will give students the chance

to practice programming in the context of labs and assignments. Another important aspect of a programming course is finding the appropriate systems for sharing material, communicating and collaborating, assigning and submitting programs, as well as assessing them. TEL is applied for achieving all the aforementioned tasks in the context of programming courses for several years. A brief literature review on programming environments and tools, as well as on learning management and assessment systems is presented in the following subsections.

2.1 Programming environments and tools

Students learning programming face great difficulties with syntax and semantics of programming languages. These difficulties are exacerbated by the lack of support from programming environments when it comes to developing programs and understanding error messages and flow of control. In order to support students in dealing with these difficulties different educational *programming environments and tools* have been developed and used in CS1 but also intensively in subsequent programming courses. Typically, environments of this kind aim to make the process of programming easier for students, as well as to motivate them. For example (Xinogalos and Satratzemi 2004): structure editors are used for developing programs through templates and menus and avoiding syntax errors; compilers that report user-friendly errors are incorporated for supporting students in debugging their programs; step by step execution of programs is provided for understanding the semantics of programming constructs and flow of control; visualization of the results of a program during execution is used for comprehending abstract programming concepts and constructs. The main types of programming environments and tools utilized in programming courses are the following:

Programming microworlds (Brusilovsky et al. 1998) aim at using a simple language with a limited instruction set and a metaphor familiar and attractive to students that is depicted on the screen, such as the metaphor of a world of robots in Karel++ (Bergin et al. 1997). Programming microworlds commonly use step by step execution and visualization of program execution results (Xinogalos et al. 2006). A well-known OOP microworld based on Karel++ is Jeroo (Sanders and Dorn 2003). Another microworld based on Karel++ is objectKarel (Xinogalos et al. 2006) that has been used for several years at UOM-TMD for a brief two-lecture introduction to OOP concepts.

Educational programming environments use either an educational or a conventional programming language and aim at supporting students in dealing with difficulties through aids such as software visualization techniques, simplified user interfaces and enhanced error reporting. The most well-known educational programming environment for Java is BlueJ (Kölling et al. 2003), which has all the aforementioned features and the possibility of direct manipulation of classes and objects. The BlueJ environment has been used with positive results in all three institutions (Ivanović et al. 2015).

Algorithm and program visualization tools visualize the structure of a program or the results of its execution. Such tools can visualize either the static or the dynamic aspects of a program (Pears et al 2007). Jeliot (Ben-Ari et al. 2011), for example, is a code-visualization tool used for supporting students in comprehending the dynamic aspects

of OOP. It can be used as a plug-in for BlueJ as well. Students at UNS-PMF are encouraged to use Jeliot for code visualization.

More recently, *educational games for programming* (Malliarakis et al. 2016) and *distributed pair programming (DPP) systems* (Tsompanoudi et al. 2016) have been developed for supporting students in dealing with difficulties and improving their performance. Educational games succeed in this mainly by motivating students through their immersive qualities, while DPP systems succeed by supporting collaboration between students.

2.2 Learning management and assessment systems

Besides programming environments and tools, another important aspect of any programming course are programming exercises solved at labs and also assigned to students as homework. The assignment of exercises and submission of solutions, communication and collaboration during problem solving, access to educational material and assessment of assignments are usually accomplished with the help of LMS (Govender and Govender 2010) and automated assessment tools (Pears et al 2007).

Automated assessment tools automate the assessment of assignments and provide students and/or instructors with immediate feedback. Such tools can fully automate the grading of assignments, especially in cases of large numbers of students, or carry out an initial evaluation and indicate problems in students' programs (Pears et al 2007). Moreover, automated assessment tools can check the coding style and specific design aspects of a program, as well as the usage of specific language features (Pears et al. 2007). In some cases, assessment tools provide the capability of *online submission* as well, as is the case with BOSS and Web-CAT (Rößling et al. 2008). In UOM-TMD and MUNI-FI the in-house LMS are used for managing the submission of exercises. However, these exercises are not automatically assessed. On the other hand, UNS-PMF uses an in-house submission system (Pribela et al. 2009) with enhanced possibilities: a structure editor is integrated for easier program development; eLessons with theory and hands-on activities are offered; a significant part of standard Java documentation, extended instruction set and hints are incorporated; understandable and informative error messages are detected and reported.

No matter what the abilities of an automated assessment tool are, the utilization of an LMS in a programming course is considered important. LMS in general are heavily used for enhancing the learning experience of students by providing them access to educational material, improving communication and collaboration and aiding in testing of the acquired knowledge. In the case of programming courses, students expect to receive even more enhanced support from the LMS, such as support in problem solving (Govender and Govender 2010). As mentioned in the report of the ITiCSE 2008 "Working Group on Design Patterns for Online Learning Environments in Computer Science" the features of a typical LMS do not meet certain needs of Computer Science Education (Rößling et al. 2008). For this purpose, an LMS that is extended specifically for CSE is proposed and referred to as *Computing Augmented Learning Management System* (*CALMS*) (Rößling et al. 2008). Thota and Whitfield (2009), for example, report on the ongoing development of a CALMS based on Moodle for an introductory programming course, which

they envision to enrich with facilities for automatic assessment and plagiarism detection, automatic feedback for programming assignments and peer evaluation of programming assignments. UNS-PMF also utilizes Moodle with extended personalization features (Komlenov et al. 2010), as well as an integrated learning environment MILE (Ivanović et al. 2008) that supports teaching, learning and student assessment. At UOM-TMD and MUNI-FI an in-house LMS is used, which is however used for all courses at the corresponding institutions. The LMS used in the three institutions have all an integrated discussion forum and an email system that are heavily used for communication and collaboration.

3 Motivation and Research Questions

Past research found that students' satisfaction with TEL services tends to be positively correlated with different factors such as:

- course content and quality (Naveh et al. 2010; Selim 2007; Sun et al. 2008),
- instructors' attitudes towards technology enhanced learning and students' technical competency (Selim, 2007; Sun et al. 2008),
- diversity in assessments (Sun et al., 2008),
- the existence of bulletin boards and discussion forums (Basioudis et al. 2012),
- efficient transmission of course materials and announcements (Lonn et al. 2009),
- actual use and students' involvement (Klobas and McGill, 2010).

The study by Emelyanova and Voronina (2014) indicated that there is a remarkable divergence of students' and teachers' perceptions of LMS regarding their usefulness, appropriateness, and interest for the students. In a recent literature review of students' usage of LMS, Lust et al. (2012) showed that students generally perceive LMS as useful and easy to use.

To the best of our knowledge only one previous study gives an international analysis of students' perception of LMS. Namely, Basioudis et al. (2012) investigated how undergraduate accounting students from UK, Australia and New Zealand perceive importance of LMS services. We are not aware of any international analysis of computer science students' perception of LMS and other TEL services used in teaching OOP courses. Additionally, important factors such as year of study and average grade are often neglected in previous relevant studies. Thus, the main goal of this research is to provide answers to the following three research questions:

Research Question 1 (RQ 1): Is the perceived importance/actual utilization of various TEL services used in OOP courses different in independent groups of students from different countries?

Research Question 2 (RQ 2): Is the perceived importance/actual utilization of various TEL services used in OOP courses different for students from different years of study?

Research Question 3 (RQ3): Is the perceived importance/actual utilization of various TEL services used in OOP courses different for students having different average grade?

The TEL services investigated cover both:

1. TEL services currently used at our OOP courses (the organization and distribution of teaching material, assignment services, communication and cooperation services), and
2. TEL services planned to be used at our OOP courses in a near future (online self-evaluation quizzes, supplementary educational material and exemplary solved problems in electronic forms, and adaptability of e-lessons according to learning styles).

For the services from both groups we investigated their importance as perceived by students. On the other hand, for the services from the first group that are not directly imposed to students by the organization of courses (communication and cooperation services) we examined their actual use by students.

4 OOP Course Design and TEL aspects in the Three Institutions

At our institutions the 2nd year Java Programming courses focus on presenting the fundamental OOP concepts and share some common goals (Ivanović et al. 2015): focus on fundamental OO software development tasks; comprehending and using standard library classes; analyzing/extending existing user-defined classes; becoming familiar with the language syntax and semantics and implementing programs; designing simple OO applications. The successful completion of the courses gives students the necessary background for dealing with subsequent courses that use the OO technology or/and Java. In Table 1 information on some main issues regarding the OOP courses is summarized.

[TABLE 1]

The three institutions have invested greatly in the advantages of TEL and their usage in delivering OOP courses. Several programming environments and systems have been developed in the three institutions for supporting the OOP courses, including the programming microworld objectKarel, the Svetovid system for supporting program development and assessment, a Moodle extension with personalization features and in-house LMS. Besides these TEL environments and tools, well-known environments such as BlueJ and Jeliot are heavily utilized. In Table 2, a summary of the TEL tools utilized in teaching OOP at our institutions is presented.

[TABLE 2]

The programming environments and tools used in the courses have been extensively evaluated with positive results (Ivanović et al. 2008; Komlenov et al. 2010; Pribela et al. 2009; Xinogalos et al. 2006; Xinogalos 2015; Xinogalos 2016; Xinogalos et al. 2007). In this sense the rest of the paper focuses on the investigation of the support provided by the LMS and tutoring systems utilized, as well as the investigation of other technologies that could be utilized.

Teaching and learning of programming at UOM-TMD is supported by an in-house Course Management System with some enhanced features called CoMPUs - Course Management Platform for Universities. The features of the system are: course description; calendar; documents; student assignments; discussion forum; and announcements with integrated email system. These features are used for: overall course organization and management; distribution of educational material; announcing weekly programming assignments and submission of solutions by students; communication and collaboration among the instructor and students through the discussion forum; making announcements and sending them by email to all enrolled students. MUNI-FI also utilizes an in-house LMS, the Information System of Masaryk University (IS MU) featuring both study administration and TEL functionality that has several similarities with the aforementioned system.

At UNS-PMF students can use Moodle with extended personalization features (Komlenov et al. 2010; Verpoorten et al. 2009**)** or the integrated learning environment of MILE (Ivanović et al. 2008) that supports teaching, learning and student assessment. The OOP course within Moodle consists of teaching materials and a mix of synchronous/asynchronous activities and resources. The eLessons are used as asynchronous activities, such as quizzes glossaries, wikis, and discussion forums. In addition, live discussions occur regularly; some of the resources used during lab exercises and assignments are formulated and graded online and then solved individually during regular classes. The environment of MILE (Ivanović et al. 2008) offers many simple examples and elements of scaffolding teaching that help students to understand better and adopt difficult OO concepts.

5 Methods

Our main research question was to investigate students' perceptions regarding the importance of various TEL tools and services. This section presents research instruments, discussion on data collection, and data analysis procedure.

5.1 Research Instruments

In order to investigate students' perception about the usage of TEL tools in programming language courses, a questionnaire that consists of 13 questions separated in two parts (see Table 3) was designed. The first part (questions E1 – E8) asks students to evaluate the importance (questions E1 – E4) and utilization (questions E5 – E8) of the various TEL services that are used in the educational processes at our institutions. Evaluation of the programming environments and tools utilized at the three institutions has taken place in previous studies, referenced in the corresponding sections. The idea behind the second part (questions H1 – H5) was to obtain students' opinions about possible usage of additional functionalities that TEL tools offer. To each question, except for E6 and E8,

respondents answered by choosing exactly one of the responses arranged in the following five-point Likert-type scale: not important at all (1) / slightly important (2) / of average importance (3) / very important (4) / absolutely essential (5).

In items E6 and E8 respondents address their reasons for not using forums and instant messaging tools to communicate with instructors and classmates, respectively. In order to deal with a potential technical language barrier that could arise between the researchers designing the questionnaire (teachers) and the respondents (students), additional explanations are given in questions H3 and H4, since students in general are not familiar with terms related to advanced concepts of e-learning.

[TABLE 3]

5.2 Participants and Reliability of Collected Data

In each of the three institutions students that had enrolled in programming courses were informed about the study through an announcement posted in the corresponding LMS and sent by email to their institutional accounts. The participation of students in the study was anonymous and voluntary. The students that participated in the study completed the questionnaire online. Each respondent was in the position to provide basic demographic data (year of study and average grade), but the demographic part of the questionnaire was not obligatory to fill in. Also, since the questionnaire was offered online, students could submit it without providing answers to all questions.

Table 4 summarizes the size of examined samples, as well as demographic data of respondents for each institutional group. A questionnaire is considered completely filled if the respondent provided answers to items E1-E5, E7 and H1-H5, i.e. to all questions excluding the explanatory questions E6 and E8. There were 286 respondents, out of which 17 did not complete their questionnaires fully: 15 of them did not answer exactly one question, one student skipped three questions and another skipped four questions. Those respondents were not excluded from the analysis since they provided their opinions about the majority of questionnaire items. From the data presented in Table 4 it can be seen that respondents belong to all possible categories regarding the year of study and average grade.

[TABLE 4]

Internal consistency of questionnaire data was assessed using Cronbach's alpha coefficient (Cronbach 1951). The items for which Cronbach's α is calculated should cover different aspects of the same construct. Adequate α values higher than 0.7 are considered acceptable and values higher than 0.8 are considered excellent. However, α higher than 0.9 may indicate redundancy (too many similar questions in a group). In our questionnaire, items E1 – E4 and H1 – H5 measure different aspects of same constructs: E1 – E4 measure the importance of various services of TEL tools that are currently used in the educational processes, while items H1 – H5 measure the importance of TEL services that could be employed in the future. Therefore, we calculated two Cronbach's α coefficients for the whole

sample: α_E measuring internal consistency of items E1 – E4, and α_H measuring internal consistency of items H1 – H5. The obtained values, $\alpha_E = 0.72$ and $\alpha_H = 0.76$, indicate that the collected data possess the acceptable level of reliability for further statistical analysis.

5.3 Data Analysis Procedure

Responses to the items in the questionnaire were treated as ordinal data, because we could not assume that respondents perceived the difference between each two adjacent levels on the scale as equal. Therefore, the median and the mode (the most frequent value) were used as measures of central tendency, and the inter-quartile range (the difference between the third and first quartile) as the measure of variability in respondents' perception of an item. Non-parametrical statistical procedures were employed to analyze questionnaire data, firstly because they were suitable for ordinal data, and secondly because they do not assume any particular distribution of analyzed data (distribution-free methods). Namely, the Kruskal-Wallis ANOVA, the Mann-Whitney U and two sample Kolmogorov-Smirnov test were used to address the stated research questions. In particular, Kruskal-Wallis ANOVA was used to address all three research questions with respect to the comparison of perceived importance and actual utilization of various TEL services across more than two independent groups of students determined by the criteria derived from research questions (institutional belonging for RQ1, year of study for RQ2, and average grade for RQ3). This test is an omnibus test for statistically significant differences among more than two independent groups and cannot indicate which specific groups are significantly different from each other. Thus, Mann-Whitney U test and two sample Kolmogorov-Smirnov test were employed as post-hoc tests for the detailed comparison of perceived importance and actual utilization of TEL services considering exactly two independent groups of students.

Let X and Y be two random variables, where X and Y represent perceived importance of item I in two independent groups of students G_1 and G_2, respectively. For example, item I can be one of the questions E1 - E4, E5, E7 and H1 - H5 in our questionnaire, while groups can be determined by the institution, average grade or year of study. Let f and g denote cumulative distribution functions of X and Y. The variable X is said to be stochastically smaller than Y if $f(r) > g(r)$ for every r, where r is the ordinal variable representing response to item I. The Mann-Whitney U test (MWU test) is used to test the hypothesis that the probability $P(X > Y)$ is equal to 1/2, i.e. that X is not stochastically smaller or greater than Y (Mann and Whitney 1947). Consequently, the alternative hypothesis is that the ratings in one sample tend to be greater than the ratings in another sample. Thus, the MWU test with the correction for ties was used to test the following series of hypotheses directly related to *Research Question 1* that have been parameterized with questionnaire item I and two independent groups of students G_1 and G_2:

> **Hypothesis** $H_1(I, G_1, G_2)$: There is no statistically significant difference in perceived importance/actual utilization of the TEL service corresponding to questionnaire item I in two independent groups of students G_1 and G_2.
>
> **Alternative** A_1**:** Students from one group have a more positive view/ use more often a TEL service corresponding to the questionnaire item I compared to students from another group.

The effect size of the MWU test can be estimated by probability of superiority (*PS*) (Erceg-Hurn and Mirosevich 2008). *PS* is the probability that a randomly selected score from one group is higher than a randomly selected score from another group. *PS* can be calculated from U statistic using the following formula $PS = U/mn$, where m and n are the number of respondents in the first and second group, respectively. If $PS = 0.5$ then none of the groups is stochastically superior to another. Thus, the difference between two groups can be quantified as $|PS - 0.5|$. The following rule was used:

- $|PS - 0.5| < 0.05$ indicates insignificant difference,
- $0.05 \leq |PS - 0.5| < 0.1$ indicates small difference,
- $0.1 \leq |PS - 0.5| < 0.2$ indicates medium difference, and
- $|PS - 0.5| \geq 0.2$ indicates large difference between two independent groups.

Hypotheses $H_1(I, G_1, G_2)$ directly related to *Research Question 1* can be also tested with the two sample Kolmogorov-Smirnov test (KS test). This test is based on calculation of *D* statistic which is the maximum distance between cumulative distribution functions of the groups. This means that the KS test checks the null hypothesis $f = g$, i.e. that there are no statistically significant differences in the shapes and spreads of the cumulative distribution functions (Feller 1948). If $H_1(I, G_1, G_2)$ is accepted by both MWU and KS tests then it can be concluded that there are no statistically significant differences in central tendencies (medians) of perceived importance/actual utilization of TEL service I between two independent groups of students.

The Kruskal-Wallis ANOVA test (KW test) is a generalization of the Mann-Whitney U test for three or more independent groups. This test is based on the calculation of the Kruskal-Wallis *H* statistic. Under the null hypothesis that there are no statistically significant differences among groups, *H* has an asymptotic chi-square distribution with n - 1 degrees of freedom, where n is the number of independent groups (Kruskal and Wallis 1952). This statistical procedure was used to test the following hypotheses directly related to *Research Question 1* that have been parameterized with questionnaire item *I*:

> **Hypothesis** $H_2(I)$: There is no statistically significant difference in perceived importance/actual utilization of TEL service *I* among students from different institutional groups.
>
> **Alternative** A_2: Students from one or more groups have a more positive view/use more often TEL service *I* compared to the rest of the groups.

The same test was used to investigate differences in perceived importance/utilization of TEL services among the students from the same institutional group according to their average grade and year of study (Research Questions 2 and 3):

> **Hypothesis** $H_3(I, G)$: There is no statistically significant difference in perceived importance/actual utilization of TEL service *I* among students from institutional group *G* that are in different years of study.
>
> **Alternative** A_3: Students from certain years of study have a more positive view/use more often TEL service *I* compared to others.

Hypothesis $H_4(I, G)$: There is no statistically significant difference in perceived importance/actual utilization of TEL service *I* among students from institutional group *G* that have different average grades.
Alternative A_4: Students with certain average grades have a more positive view/use more often TEL service *I* compared to others.

6. Results

This section is devoted to threefold discussion including perception and utilization of TEL services across international institutional groups, across year of study and across different students' average grades.

6.1. RQ 1 - Perception and utilization of TEL services across independent, international institutional groups

Descriptive statistics of analyzed samples are summarized in Table 5. For each institutional group, the number of respondents, median, mode and inter-quartile range are presented. It can be seen that E1 (usage of CMS/Moodle for organization and distribution of didactical material), E2 (usage of CMS/Moodle for assignment related activities), and E3 (announcements and automatic notifications) are perceived as very important or absolutely essential in all institutional groups. The UOM-TMD students consider items E1, E2 and E3 as absolutely essential, while the MUNI-FI students view those items as very important. In the UNS-PMF group E3 is perceived as absolutely essential, while E1 and E2 are valued as very important.

[TABLE 5]

Although students from all institutional groups value the ability to post questions and interact with classmates and instructors using forums as very important (item E4 in Table 5), they use them very rarely at UOM-TMD, rarely at UNS-PMF and occasionally at MUNI-FI (item E5 in Table 5). As the main reason for not using forums, 51% of the UOM-TMD and 57% of the UNS-PMF students stated that they only wanted to read posts, while 26% of the MUNI-FI students did not need it. As the second most frequent answer, 16% of the MUNI-FI and 18% of the UOM-TMD students explained that they did not want other enrolled students see their questions, while 9% of the UNS-PMF students did not know that they could use forums to communicate with teachers and classmates.

A similar situation has been observed regarding the usage of instant messaging (IM) tools to communicate with instructors. This way of communication is very rarely used in all institutional groups (item E7 in Table 5): 92% of UOM-TMD, 61% of UNS-PMF and 95% of MUNI-FI students never contacted their teachers using IM tools. Usually students used e-mail (57% of the UOM-TMD, 22% of the UNS-PMF and 35% of MUNI-FI students) or approached instructors personally (34% in UOM-TMD, 19% in UNS-PMF and 28% in MUNI-FI group). There has been also a large fraction of students in all institutional groups which did not think that they needed IM tools to communicate with teachers: 17% in UOM-TMD, 33% in UNS-PMF and 27% in MUNI-FI group.

The second part of the questionnaire asked respondents to evaluate the importance of features that could be offered by TEL tools. From the descriptive statistics presented in Table 5 it can be seen that H2 (supplementary educational material) and H5 (exemplary problem solutions) are perceived as highly important by all three institutional groups. Students from UOM-TMD regard all H items as very important, while in the two other groups H1 (online self-evaluation quizzes), H3 (adaptability of e-lessons) and H4 (tracking learning style) are viewed as having average importance.

Table 6 summarizes the results of Kruskal-Wallis ANOVA (KWA) tests that were used to check hypotheses $H_2(I)$, where I is a questionnaire item. There are statistically significant differences in students' attitudes towards the importance of various services of TEL tools across different institutional groups, except for the importance of forums (item E2) and supplementary educational material (item H2). In all three institutional groups both TEL aspects are considered as very important and the central tendency is at the same time the most frequent opinion (see Table 2). Since most of the $H_2(I)$ hypotheses (9 out of 11) are rejected, it can be concluded that students from different institutional groups differently perceive the importance of technology enhanced learning of computer programming. However, the KWA test cannot tell us which independent groups are significantly different from each other and to what extent. Therefore, the Mann-Whitney U and two sample Kolmogorov-Smirnov tests were used to investigate differences among each two institutional groups, i.e. to test hypotheses $H_1(I, G_1, G_2)$.

[TABLE 6]

Detailed comparison of each two institutional groups is given in Tables 7, 8 and 9 where the results of Mann-Whitney U (MWU) and two sample Kolmogorov-Smirnov (KS) test are presented. The results of MWU and KS tests show that:

- There is a high similarity between the MUNI-FI and UNS-PMF groups: 7 out of 11 $H_1(I$, MUNI-FI, UNS-PMF) hypotheses are accepted. Moreover, in the other four items, there are no large differences (see Table 8).
- Students from UOM-TMD mostly give higher importance, in comparison to other institutional groups, to those items where significant differences are observed: in 5 out of 6 items comparing to the MUNI-FI group (see Table 7), and in 6 out of 8 items comparing to the UNS-PMF group (see Table 9).

The use of CMS/Moodle for organization and distribution of didactical material (item E1) is perceived as more important in the UOM-TMD group than in the two other groups. The same phenomenon is observed for items E2 (the use of CMS/Moodle for activities related to assignments), H3 (adaptability of e-lessons) and H4 (tracking learning style). There are no statistically significant differences between the PMF-UNS and MUNI-FI groups for any of these items. Announcements and automatic notifications (item E3) are viewed as less important in the MUNI-FI group. The MWU and KS tests also show that the MUNI-FI students used forum more often than others. Although rarely, students from PMF-UNS tended to use instant messaging tools (item E7) more often than students

from the two other groups. There is a medium sized difference in perception of importance of self-evaluation quizzes (item H1) between the UOM-TMD and UNS-PMF groups. Students from the UNS-PMF group rate the importance of exemplary problem solutions lower than the students from the two other groups.

[TABLE 7] [TABLE 8] [TABLE 9]

6.2. RQ 2 - Perception and utilization of TEL services across year of study

Table 10 presents the results of the KW tests that were used to check if there were statistically significant differences in the perception/utilization of TEL services for students from the same institutional group that are in different years of study (hypotheses $H_3(I, G)$). It can be seen that students' perception/usage of TEL services are generally not influenced by the year of study: two H_3 hypotheses are rejected for UOM-TMD group (items E7 and H5), one for UNS-PMF (item E2) and one for MUNI-FI group (item E4). The following significant differences were observed:

- UOM-TMD, item E7: although the central tendencies in usage of instant messaging tools across different years of study are the same (very rarely used), the variance in the usage of IM tools for the second year students (IQR = 1) is higher than the variances for other years (IQR = 0). This means that the second year students used IM tools more often than students of other years of studies, where statistically significant differences were not found (KW ANOVA H(df = 3, N = 65) = 4.93, p = 0.18)).
- UOM-TMD, item H5: the first year students view supplementary educational material less important (very important central tendency) than students of other years (absolutely essential central tendency). There are no statistically significant differences among students in higher years of study (KW ANOVA H(df = 3, N = 49) = 7.33, p = 0.06)).
- UNS-PMF, item E2: final year students consider the usage of CMS/Moodle for assignment activities more important (absolutely essential central tendency) compared to lower years students (very important and of average importance central tendencies).
- MUNI-FI, item E4: students of the fourth and fifth year consider CMS/Moodle forums less important (average importance central tendency) in comparison with students of other years (very important central tendency).

[TABLE 10]

6.3. RQ 3 - Perception and utilization of TEL services across average grade

The results of the KW tests used to examine differences in the perception and utilization of TEL services among students with different average grades are summarized in Table 11. It can be seen that the perception and utilization of TEL services is not affected by the average grade for the UNS-PMF and MUNI-FI group. In both groups only the H4(I, G) hypothesis is rejected. Highest grade students from UNS-PMF think that forums (item E4) are of little importance, while students with lower grades regard them as absolutely essential. Announcements and automatic

notifications (item E3) are considered as absolutely essential by the MUNI-FI highest grade students, while this service is either of average importance or very important for others.

[TABLE 11]

In contrast with the UNS-PMF and MUNI-FI groups, students from UOM-TMD having different average grades have different opinions regarding the importance of the five TEL services. However, the pattern of differences is the same: students with the lowest average grade consider that E2, H1, H2 and H4 as less important than students with higher grades. The largest difference is related to the importance of supplementary educational material (H2) which is perceived as slightly important by the lowest grade students, while students with higher average grades value it as either very important or absolutely essential. Online self-evaluation quizzes (H1) and tracking learning style (H4) are rated as having average importance by the lowest grade students and as very important by others. Also, the lowest grade students perceive exemplary problem solutions (H5) and the usage of CMS/Moodle for assigning and submitting assignments (E2) as very important, while others think of them as absolutely essential.

7. Conclusions

This paper described briefly the context, positioning, design and TEL support for introductory courses on OOP as implemented at bachelor level at three universities in three different countries. The main goal of this paper was to contribute to the discussion about appropriate TEL services for teaching OOP and their perception among students. We conducted a questionnaire survey in order to investigate students' views of the importance of various TEL services that are either currently used or are being planned to be employed in the educational processes at our institutions. Results showed that the students from our three institutions perceive the usage of TEL tools for organization and distribution of teaching material, assignment activities and announcements *as either very important or absolutely essential*. This is in accordance with results of previous studies, especially regarding distribution of course content. In the study by Govender and Govender (2010), students assessed highly the access to course material, syllabus and quizzes provided by the LMS used in a face-to-face programming course. In the study by Naveh et al. (2010), a significant correlation was found between course content and student LMS use and satisfaction.

On the other hand, the students in our three institutions *do not tend to use forums* provided by TEL tools *extensively*, although they consider them very important. Other studies have also highlighted the importance of forums for students, but they had not clearly stated whether the students actually use them, since the results were usually based on analyzing questionnaires and not on data regarding the actual usage of LMS. Naveh et al. (2010) have found that forums promote use and satisfaction regarding LMS, especially among first-year students that need more guidance in their initial steps in studies. However, a limitation of that study was the fact that the authors did not have the chance to actually record students' activity in the context of the one LMS utilized. In another study based on a

questionnaire survey and interviews, the discussion forum was considered by students as the most important feature of the LMS used to support a face-to-face programming course (Govender and Govender 2010). In alignment with the authors of the aforementioned study, we also consider forums very important, since they give the advantage of discussing problems at the moment they come to surface during problem solving, sharing knowledge and providing guidance to students. In an attempt to investigate further why students do not tend to use forums extensively despite recognizing their importance, ten students at UOM-TMD were informally interviewed. The students, who were not confident in their knowledge of programming, stated that they were not using forums because they were worried that they might post childish questions or questions that have obvious answers. Having this in mind, it would be interesting to study whether posting questions and answers in the forum anonymously would make any difference in actual usage of forums by students. The *low level of utilization* is also observed for communication with instructors using *instant messaging* tools. Explanatory questionnaire items related to the usage of communication services showed that students were quite satisfied with e-mail or personal communication with their teachers.

The analysis of questionnaire items related to TEL services that could be used in the future showed that students, regardless of the institutional group, show *very high interest in exemplary problem solutions and supplementary educational material* in the form of e-lessons. Example programs were also considered both by students and instructors as the most useful type of material in a study by Lahtinen at al. (2005). In fact, example programs were considered more important even than interactive visualizations. If the example programs are written and commented on both in terms of the underlying methodology and the source code, as proposed in the relevant question in our questionnaire, their anticipated importance is even greater, so instructors should consider devoting time and effort to devising educational material of this type.

Non-parametric statistical analysis of questionnaire data revealed that there is a *high similarity between UNS-PMF and MUNI-FI* students in their perception of importance of TEL services. On the other hand, students from UOM-TMD tend to give higher ratings to those services for which statistically significant differences among institutional groups are observed. The observed difference between UOM-TMD and the two other groups can be explained by the nature of study programs: the UOM-TMD computer science undergraduate program is more oriented towards technology management than computer science programs at UNS-PMF and MUNI-FI. UOM-TMD students are trained in an environment where a special emphasis is put on the development of technology-enhanced management systems, and consequently it can be expected that they are generally more aware of the importance of learning management tools and services. Our statistical analysis also revealed that the perception of *the importance of TEL services is mostly not affected by year of study*. At UOM-TMD students with the lowest average grade consider TEL services less important in comparison with students having higher average grades. Students with different average grades at UNS-PMF and MUNI-FI tend to find TEL services equally important. This result additionally signifies the similarity between those two independent institutional groups.

The three institutions that participated in this study have several similarities, as well as differences in the programming tools, LMS and teaching approaches utilized. Despite these differences, it was established that students from different institutions share the same perceptions of several TEL services that seem to be of great importance to them. An interesting extension of this study would be to investigate the true impact of these TEL services in students' performance and factors that shape their performance, such as completion of assignments, grades in activities carried out with the utilization of TEL services, discussion forums and general didactical issues handled by instructors through the aforementioned TEL services.

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	UOM-TMD	**UNS-PMF**	**MUNI-FI**
Course	Object-oriented Design and Programming	Object-oriented programming	Programming in Java
Bsc duration	8	8	6
Prior Programming experience	Imperative-procedural programming (C based)	Imperative programming (Pascal, Modula-2 based)	Imperative paradigm (either C or Python-based)
Semester	3	3	3 (mostly)
Duration (weeks)	13	13	13
Lectures (hours/week)	2	2 and 2 for theoretical exercises	2
Labs (hours/week)	2 hours/week, groups of 25-30 students	2 hours/week, groups of 10-15 students	2 hours/week, groups of 16-20 students
Homework	Weekly programming assignments	None	None
Evaluation (Grading)	Homework & lab assignments (20%), middle-term (20%) and final exams (60%)	Practical assignments (30%), three interim theoretical tests (30%), oral exam (40%)	In-lab tasks (36%), in-lab quizzes (9%), two midterm practical tests (28%), final exam (27%).
Teaching approach	Use of a microworld and an educational IDE. Project-driven, iterative approach based on BlueJ. Objects-first (within the course). Active learning.	Blended learning. Several practical assignments, from simple to more complex. Objects-first (within the course). Learner-centered.	Project-driven, semi-constructivistic approach, development in BlueJ. Objects-first (within the course).
Programming env./Tools	objectKarel, BlueJ, JCreator/Eclipse	Web-based tutoring system, BlueJ, Jeliot	BlueJ, NetBeans (for the most advanced students)
Utilization of TEL tools	Built-in Course Management System with E-learning features	Moodle, Svetovid in-house submission system.	E-learning and study administration facility of the in-house developed Information System

Table 1. Comparison of OOP in the three institutions

	UOM-TMD	UNS-PMF	MUNI-FI
LMS and Tutoring Systems	In-house LMS	LMS Moodle, Web-based tutoring system	In-house LMS and study administration system (IS MU)
Programming Environments and Tools	objectKarel BlueJ JCreator/Eclipse	BlueJ Jeliot	BlueJ (NetBeans)
Assessment tools	LMS tool for assignment, submission and management of programming projects. Correction of assignments, midterm and final exams is done manually.	LMS Moodle as a tool for testing students' theoretical knowledge (using *Quiz* module) and small tests for self-evaluation. In-house *Svetovid* system for assessing students programs. Use Moodle for administration of all points and final grades.	LMS tool for assignment and submission ("vaults"). Correction of midterm and final exams is done manually. Correction of tasks may be in some groups done semi-automatically.
Communication and cooperation	Announcement tool with integrated e-mail system & discussion forum of the LMS	Usually e-mails. Students intensively use LMS Moodle: discussion forums, instant messages, chat sessions, e-mail.	Announcement tool with integrated e-mail system & discussion forum of the LMS

Table 2. TEL in OO courses in our institutions

Item	Question
How important do you consider the support provided by each one of the following tools in the teaching and learning of programming?	
E1	Use of Course Management Platform (CMS)/Moodle for the organization and distribution of didactical material
E2	Use of CMS/Moodle for assigning and submitting (weekly) assignments
E3	Posting all the "Announcements" for the course to CMS/Moodle and automatic notification at students' email
E4	Ability to post questions regarding lectures and (weekly) announcements at the course's "Forum" and interaction with classmates/instructor
E5	Did you use "Forum" in the context of programming courses?
E6	I didn't use "Forum" because a) I did not know about the existence of this possibility b) I did not want other enrolled students to see my questions c) I had difficulty in expressing explicitly my questions d) I only wanted to read posts e) I did not need it f) Other:
E7	Did you use any instant messaging tools like Skype, ICQ, GTalk, or similar to directly communicate with the instructors?
E8	I didn't use them because a) The option was not explicitly offered by the instructors b) The instructors were not available online when I needed their attention c) I prefer to post questions on "Forum" d) I approached the instructors by e-mail e) I approached the instructors personally f) I did not need it g) Other:
How important do you consider the support that *could be provided* by the following tools?	
H1	Online self-evaluation quizzes regarding your knowledge of the programming concepts from each lesson (unit)
H2	Supplementary educational material in the form of e-lessons, repository of papers, video material, etc.
H3	Ability to adapt the content of e-lessons (e.g. presentation of the content and selection by the student of the units to be studied)
H4	Tracking the students' learning style through an online questionnaire or an intelligent adaptive system and adaptation of the way of presenting the available material (the same material – i.e. theory, questions, examples – is presented in different order/amount according to each student's learning style)
H5	Exemplary problem solutions with comments regarding the solution (methodology) and the source code

Table 3. Questionnaire used to obtain students' opinions about importance or utilization of TEL tools employed in teaching process.

	UOM-TMD			UNS-PMF			MUNI-FI		
Sample size	93			113			80		
Incomplete questionnaire	7 (7.5%)			5 (4.4%)			5 (6.2%)		
Distribution of respondents by year of study (missing – respondents that have not provided year of study, NR – the number of respondents)	**Year**	**NR**	**[%]**	**Year**	**NR**	**[%]**	**Year**	**NR**	**[%]**
	Missing	17	18%	**Missing**	63	56%	**Missing**	7	9%
	1	26	28%	**1**	28	25%	**1**	9	11%
	2	11	12%	**2**	14	12%	**2**	40	50%
	3	9	10%	**3**	5	4%	**3**	11	14%
	4	20	22%	**4**	3	3%	**4**	10	13%
	5	10	11%				**5**	3	4%
Distribution of respondents by average grade (missing – respondents that have not provided avg. grade, NR – the number of respondents)	**Grade**	**NR**	**[%]**	**Grade**	**NR**	**[%]**	**Grade**	**NR**	**[%]**
	Missing	24	26%	**Missing**	68	60%	**Missing**	11	14%
	5	6	6%	**6**	1	1%	**1**	7	9%
	6	28	30%	**7**	8	7%	**2**	21	26%
	7	22	24%	**8**	16	14%	**3**	24	30%
	8	12	13%	**9**	15	13%	**4**	12	15%
	9	1	1%	**10**	5	4%	**5**	5	6%

Table 4. Size and demographic characteristics of samples.

Item	**UOM-TMD**				**UNS-PMF**				**MUNI-FI**			
	N	**Med**	**Mod**	**IQR**	***N***	**Med**	**Mod**	**IQR**	***N***	**Med**	**Mod**	**IQR**
E1	93	**5****	**5**	1	113	**4***	**5**	2	76	**4***	**4**	2
E2	93	**5****	**5**	1	113	**4***	**4**	2	76	**4***	**4**	2
E3	93	**5****	**5**	1	113	**5****	**5**	1	76	**4***	**5**	2
E4	92	**4***	**4**	1	112	**4***	**4**	2	78	**4***	**4**	2
E5	92	1	1	1	112	2	2	2	80	3	2	2
E7	93	1	1	0	109	1	1	1	78	1	1	0
H1	92	**4***	**4**	1	113	3	3	2	80	3	4	2
H2	92	**4***	**4**	2	113	**4***	**4**	1	80	**4***	**4**	1.5
H3	91	**4***	**4**	2	113	3	3	1	77	3	3	1
H4	92	**4***	**5**	2	113	3	3	2	77	3	3	2
H5	90	**5****	**5**	0	113	**4***	**5**	2	80	**5****	**5**	1

Table 5. Descriptive statistics of analyzed samples: *N* (number of respondents), Med (median), Mod (mode) and IQR (Inter-quartile range). One star indicates high importance/utilization, while two stars indicate very high importance/utilization.

Item (I)	Kruskal-Wallis H, df = 2	Significance	H_2
E1	33.49	< 0.0001	Rejected
E2	41.33	< 0.0001	Rejected
E3	16.23	0.0003	Rejected
E4	0.56	0.7556	**Accepted**
E5	47.71	< 0.0001	Rejected
E7	46.39	< 0.0001	Rejected
H1	7.18	0.0275	Rejected
H2	3.59	0.166	**Accepted**
H3	16.52	0.0003	Rejected
H4	23.18	< 0.0001	Rejected
H5	27.9	< 0.0001	Rejected

Table 6. Results of Kruskall-Wallis ANOVA tests for statistically significant differences in students' perceptions of TEL aspects across all institutional groups ($\mathbf{H_2}$ hypotheses).

Item (I)	MWU test				KS test		$H_1(I, G_1, G_2)$
	Z	Sig.	|PS – 0.5|	Difference	D	Sig.	
E1	-5.07	< 0.001	0.21	Large	0.32	< 0.001	Rejected
E2	-5.09	< 0.001	0.20	Large	0.33	< 0.001	Rejected
E3	-3.96	< 0.001	0.16	Medium	0.26	< 0.01	Rejected
E4	0.68	0.49	0.02	Insignificant	0.06	> 0.1	**Accepted**
E5	6.59	< 0.001	0.27	Large	0.50	< 0.001	Rejected
E7	-0.63	0.52	0.01	Insignificant	0.02	> 0.1	**Accepted**
H1	-1.79	0.07	0.07	Small	0.14	> 0.1	**Accepted**
H2	-1.23	0.21	0.05	Small	0.07	> 0.1	**Accepted**
H3	-3.61	0.0003	0.15	Medium	0.33	< 0.001	Rejected
H4	-4.42	< 0.001	0.19	Medium	0.28	< 0.005	Rejected
H5	-2.09	0.036	0.07	Small	0.14	> 0.1	**Accepted**

Table 7. Results of MWU and KS tests ($\mathbf{H_1}$ hypotheses) for $\mathbf{G_1}$ = **MUNI-FI** and $\mathbf{G_2}$ **= UOM-TMD**.

Item (I)	MWU test				KS test		$H_1(I, G_1, G_2)$
	Z	Sig.	|PS – 0.5|	Difference	D	Sig.	
E1	-0.49	0.62	0.02	Insignificant	0.06	> 0.1	**Accepted**
E2	0.45	0.65	0.01	Insignificant	0.04	> 0.1	**Accepted**
E3	-2.82	0.004	0.11	Medium	0.20	< 0.05	Rejected
E4	0.63	0.52	0.02	Insignificant	0.04	> 0.1	**Accepted**
E5	3.19	0.001	0.13	Medium	0.23	< 0.025	Rejected
E7	-5.28	< 0.0001	0.17	Medium	0.34	< 0.001	Rejected
H1	0.61	0.54	0.02	Insignificant	0.08	> 0.1	**Accepted**
H2	0.57	0.57	0.02	Insignificant	0.05	> 0.1	**Accepted**
H3	-0.47	0.63	0.01	Insignificant	0.06	> 0.1	**Accepted**
H4	-0.39	0.69	0.01	Insignificant	0.10	> 0.1	**Accepted**
H5	3.10	0.002	0.11	Medium	0.23	< 0.025	Rejected

Table 8. Results of MWU and KS tests ($\mathbf{H_1}$ hypotheses) for $\mathbf{G_1}$ = **MUNI-FI** and $\mathbf{G_2}$ **= UNS-PMF**.

Item (I)	MWU test				KS test		$H_1(I, G_1, G_2)$
	Z	Sig.	|PS – 0.5|	Difference	D	Sig.	
E1	5.09	< 0.0001	0.19	Medium	0.31	< 0.001	Rejected
E2	6.06	< 0.0001	0.23	Large	0.36	< 0.001	Rejected
E3	1.24	0.21	0.04	Insignificant	0.096	> 0.1	**Accepted**
E4	-0.07	0.94	0.003	Insignificant	0.06	> 0.1	**Accepted**
E5	-4.67	< 0.0001	0.18	Medium	0.365	< 0.001	Rejected
E7	-5.18	< 0.0001	0.16	Medium	0.32	< 0.001	Rejected
H1	2.64	0.008	0.10	Medium	0.18	0.058	Rejected
H2	1.84	0.065	0.07	Small	0.12	> 0.1	**Accepted**
H3	3.45	0.0006	0.13	Medium	0.27	< 0.005	Rejected
H4	3.97	< 0.0001	0.16	Medium	0.28	< 0.001	Rejected
H5	5.04	< 0.0001	0.18	Medium	0.30	< 0.001	Rejected

Table 9. Results of MWU and KS tests ($\mathbf{H_1}$ hypotheses) for $\mathbf{G_1}$ = **UOM-TMD** and $\mathbf{G_2}$ **= UNS-PMF**.

Item (I)	G = UOM-TMD			G = UNS-PMF			G = MUNI-FI		
	KW H	Sig.	$H_3(I, G)$	KW H	Sig.	$H_3(I, G)$	KW H	Sig.	$H_3(I, G)$
E1	3.06	0.55	**Accepted**	7.62	0.05	**Accepted**	3.08	0.54	**Accepted**
E2	3.27	0.51	**Accepted**	8.03	0.04	Rejected	4.79	0.30	**Accepted**
E3	5.72	0.22	**Accepted**	6.69	0.08	**Accepted**	0.34	0.98	**Accepted**
E4	3.63	0.46	**Accepted**	5.39	0.14	**Accepted**	10.81	0.02	Rejected
E5	5.21	0.27	**Accepted**	3.64	0.30	**Accepted**	1.70	0.79	**Accepted**
E7	11.08	0.02	Rejected	5.71	0.13	**Accepted**	0.75	0.94	**Accepted**
H1	1.77	0.78	**Accepted**	0.09	0.99	**Accepted**	9.27	0.05	**Accepted**
H2	2.51	0.64	**Accepted**	1.54	0.67	**Accepted**	1.62	0.80	**Accepted**
H3	8.95	0.06	**Accepted**	0.66	0.88	**Accepted**	3.30	0.51	**Accepted**
H4	5.82	0.21	**Accepted**	5.95	0.11	**Accepted**	5.66	0.23	**Accepted**
H5	17.98	0.001	Rejected	0.41	0.94	**Accepted**	0.45	0.98	**Accepted**

Table 10. Results of Kruskall-Wallis ANOVA tests for statistically significant differences in students' perception of TEL services for students with different year of study ($\mathbf{H_3}$ hypotheses).

Item (I)	G = UOM-TMD			G = UNS-PMF			G = MUNI-FI		
	KW	Sig.	$H_4(I, G)$	KW H	Sig.	$H_4(I, G)$	KW	Sig.	$H_4(I, G)$
E1	3.82	0.43	**Accepted**	5.58	0.23	**Accepted**	6.02	0.19	**Accepted**
E2	12.21	0.02	Rejected	3.23	0.52	**Accepted**	1.54	0.82	**Accepted**
E3	5.53	0.24	**Accepted**	4.18	0.38	**Accepted**	9.69	0.04	Rejected
E4	5.14	0.27	**Accepted**	11.05	0.02	Rejected	1.59	0.81	**Accepted**
E5	0.46	0.98	**Accepted**	8.09	0.08	**Accepted**	2.59	0.63	**Accepted**
E7	3.81	0.43	**Accepted**	1.79	0.77	**Accepted**	5.03	0.28	**Accepted**
H1	9.66	0.04	Rejected	1.34	0.85	**Accepted**	8.34	0.08	**Accepted**
H2	11.01	0.03	Rejected	1.10	0.89	**Accepted**	7.31	0.12	**Accepted**
H3	6.65	0.15	**Accepted**	0.57	0.97	**Accepted**	2.65	0.61	**Accepted**
H4	11.54	0.02	Rejected	2.09	0.72	**Accepted**	3.37	0.49	**Accepted**
H5	17.65	0.001	Rejected	4.31	0.37	**Accepted**	4.09	0.39	**Accepted**

Table 11. Results of of Kruskall-Wallis ANOVA tests for statistically significant differences in student perception of TEL services for students with different average grade ($\mathbf{H_4}$ hypotheses).