Prof.dr.sc. Blaženka Divjak
Mirela Ostroški, MA
University of Zagreb
Faculty of Organization and Informatics
Pavlinska 2, Varaždin
blazenka.divjak@foi.hr
mirela.ostroski@foi.hr

Learning outcomes in mathematics: Case study of their implementation and evaluation by using e-learning

Abstract:

Learning outcomes are considered to be a key tool for student-centered teaching and learning. In implementation of learning outcomes both the top-down approach and the bottom-up approach need to be combined. Whereas the former takes into account the overall study program and the level of study, the latter departs from the level of a particular unit and course. In devising the instruction of mathematics for non-mathematics majors it is essential to recognize the role that mathematical tools and models play in such a study program. In doing so, students' pre-knowledge of mathematics should by no means be disregarded.

In our paper we aim to present a case study of implementation of learning outcomes in several mathematical subjects within the Information and Business Systems study program at the Faculty of Organization and Informatics of the University of Zagreb. In the first phase, after the learning outcomes have been recognized, they are harmonized with students' pre-competences, teaching methods, student workload (ECTS), continuous monitoring of students' achievements and their assessment, while taking into account different learning and motivation styles. During the second phase the learning styles evaluation model is elaborated and the relation and interactions between different elements of the learning and teaching process are verified.

The entire process is heavily supported by ICT and executed through blended e-learning and the use of social software such as wiki, e-portfolio, etc. Such a delivery mode does not only enhance student motivation for learning mathematics and the availability of teaching and learning materials but also improves communication between the student and the teacher, as well as that among the students themselves. In addition, it enables the teacher to store a lot of students' artifacts, which opens many possibilities for the evaluation of learning outcomes.

Key words: learning outcomes, mathematics, ICT, e-learning, taxonomy, e-portfolio

1. Learning outcomes and other elements of the curriculum

Institutional level

The prerequisite for the systematic and the consistent introduction of learning outcomes into the study programme is the project at the institution and the support of the management and the faculty board of the institution. In this matter, the project can be internal or it can have an external sponsor (grant). For example, at the Faculty of Organization and Informatics University of Zagreb the foundations for the implementation of learning outcomes have been set within the structure of the project entitled *Learning outcomes in interdisciplinary study programmes INTER-OUTCOMES* which were executed at the Faculty of Organization and Informatics (FOI) of the University of Zagreb in the period from February 2008 to February 2009, and which were financed by The National Foundation for Science, Higher Education and Technological Development of the Republic of Croatia. Partner institutions on the project were the Faculty of Science – Mathematical department of the University of Zagreb and the Faculty of Electrical Engineering and Computing of the University of Zagreb. The leader of the project was Blaženka Divjak from the Faculty of Organization and Informatics in Varaždin. The objective of the project was to develop the methodology of learning outcomes and their dissemination within the framework of the system for quality insurance in higher education and their implementation with the emphasis on interdisciplinary area of informatics. The three mentioned partner institutions were associated and had the aim to define, develop and compare the learning outcomes for the study programme of informatics, which necessarily includes computing science and mathematics. In this project, teachers were educated in the learning outcomes and this was the prerequisite for the agreement about methodology and for the implementation of learning outcomes. First we will continue with the basic theoretical precepts for the introduction of learning outcomes.

Learning is a complex process which enables the perception and understanding of the world and as such, it encompasses a high spectrum of the activities that include the mastering of reading and understanding of what has been read, as well as the understanding of abstract principles and mathematical evidence and the development of appropriate behaviour for specific situations (Fry and el, 2003).

Modern literature gives us different theories about how one learns. Today a constructivist theory of learning prevails, which postulates that it is the experience which leads us to formulate general concepts (constructs) that serve as the models of our reality. According to constructivism people participate actively in the development of their knowledge. The most significant representatives of constructivism of the twentieth century are Swiss psychologist Jean Piaget and American psychologist Jerome Bruner. In professional literature there is a fair number of the critics of constructivism and parallely some other theories are developing such as rationalism, behaviorism, cognitive science, etc. (Fry and el, 2003).

Implementation of learning outcomes

In professional public the topic of recognizing the key principles of teaching in higher education is widely discussed. Being inspired by (Ramsden, 2003) we give some more important principles in Table 1.

Table 1. Teaching principles in higher education

Principles	Instruments
Clear goals and intellectual challenge	Learning outcomes and goals
Interest and understanding	Good teaching and appropriate literature
Concern and respect for students and student learning	Appropriate student's workload (ECTS)
Appropriate assessment and feedback	Implementation of taxonomy

Development of generic skills	Learning outcomes
Learning from students	Quality assurance and enhancement of teaching

In theory, as well as in practice, we distinguish between three basic approaches to teaching. The first one, often called traditional, is the one in which the teacher is at the centre of the teaching process. Moreover, the teacher can also appear as the one who organizes the activities directed to learning. The third approach puts the student at the centre of the teaching and learning process. In Table 2. we give basic characteristics of these three approaches. The table has been taken from (Ramsten, 2003, p.115).

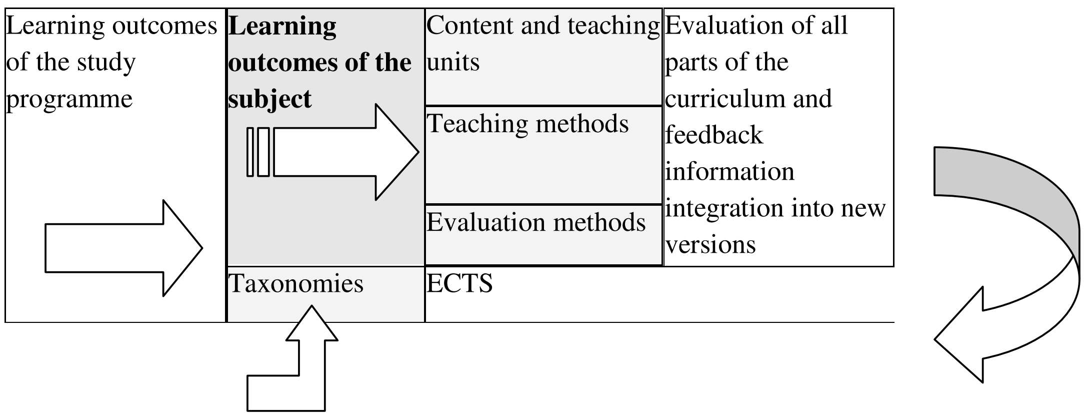
Tablica 2. Theories of university teaching

	Teaching as telling	**Teaching as organising**	**Teaching as making learning possible**
Focus	Teacher and content	Teaching techniques that will result in learning	Relation between student and subject matter
Strategy	Transmit information	Manage teaching process; transmit concepts	Engage; challenge; imagine oneself as the student
Actions	Chiefly presentation	"Active learning"; organising activity	Systematically adapted to suit student understanding
Reflection	Unreflective; taken for granted	Apply skills to improve teaching	Teaching as a research-like, scholarly process

Teaching planning should in fact deal with the organization of the teaching process. Thus, we should bear in mind the students' pre-knowledge, the goals of the study programme and the role of a single subject in the programme. Furthermore, we should be aware of different learning, organizational – technical possibilities which we have at our disposal and also of available teacher resources. In the end, it should be clear how this affects student workload, i.e. students' activities should be expressed in ECTS points. This helps us to formulate learning outcomes for the study programme or the subject. The constructing of objectives and learning outcomes calls for conscious decisions about a great number of challenges and problems in the teaching and learning process on the part of the teacher and the institution.

Let us emphasize that learning outcomes are statements about what is expected of the student to know, to understand, to do and to evaluate as a result of the learning process. They are connected with measurable level descriptors in national and European qualifications framework. In the literature there are many discussions about differences between objectives, outcomes and competences. Learning objectives determine what the teacher wants the student to learn and to understand, so those who support the student–centered learning prefer using learning outcomes in the organization of the teaching process. Lately, in the professional literature there is more discussion about learning outcomes than teaching objectives, although the objectives can be formulated in a way that they reflect the modern approach to teaching. Moreover, by achieving learning outcomes through the process of studying, the student acquires competences necessary for finding employment and self-employment.

Consequently, after determining the levels of the study programme and agreeing about professional competences, learning outcomes of the study programme are developed. Learning outcomes at the subject level take into consideration learning outcomes of the programme obtained in such a way, and their expression is based on a chosen taxonomy. With this, one should be aware of the specific quality of the observed subject and initial students' competences. Afterwards, learning outcomes at the level of teaching units are detailed and appropriate methods of teaching and assessment are chosen. Further, we should bear in mind that all the activities in the subject can be recognized and measured in the student workload expressed in ECTS points. Finally, in order to reach the system improvement, evaluations of all parts of the curriculum should be done regularly, as well as those relating of learning outcomes at all levels, and information obtained in this way should be integrated in the system (Picture 3).



Picture 3. Learning outcomes context

Learning outcomes evaluation

Having developed learning outcomes at a certain levels, the regular periodical evaluation of their achievement and relevance has to be done. This procedure should be a part of internal assurance the quality of teaching. On the other side, it shall be evaluated by external professionals in the framework of external evaluation process.

The validation of learning outcomes should comprise that kind of the evaluation process and it should also consist of regular students' feedback information about whether specific outcomes are achieved and whether all the outcomes are covered. Furthermore, study verification based on learning outcomes is needed. In this context, the connections between learning outcomes, teaching methods and knowledge testing should be checked, and one should also assess how set outcomes influence the student workload. Finally, there is also a question of teaching literature and e-learning material which will enable students to learn in order to gain set learning outcomes.

As a result of such evaluations, learning outcomes should be revised at the end of each year or semester at all necessary levels. The easiest is to introduce changes at micro levels (teaching units and partially subjects). Unfortunately, innovations in the curriculum demand certain verification on the part of the faculty and university councils, the senate, and often of the National Council for Higher Education. Periodical repetition of this step leads towards the improvement of students' knowledge and employability.

We shall continue with presenting a few examples of learning outcomes implementation and evaluation by using e-learning. First, we explain how to test efficiently students' knowledge and pre-knowledge by using taxonomy. Furthermore, we give some examples of the social software use, specifically e-portfolio, then how to test students' understanding and how to evaluate learning outcomes of the subject. In the end, we shall show the use of survey and the work diary on the subject in order to get feedback information about fulfilling learning outcomes and student workload.

2. Case study of implementation and evaluation of learning outcomes

Blended learning of mathematics and implementation of learning outcomes

At the FOI, for some years, we have been considering e-learning as an unavoidable and a very important element of the teaching process at our institution and which essentially contributes to the quality of the teaching process and especially to the accessibility of the teaching materials. The result of such approach is the acquired E-learning strategy of the Faculty of Organization and Informatics (the E-learning Strategy of the FOI), which relies on the E-learning Strategy of the University of Zagreb (the E-learning Strategy of the UniZg). The fundamental guidelines of the strategy are:

- E-learning is a legal and a desirable way of learning and teaching at the University of Zagreb, and also at our faculty
- The level of e-learning introduction into the teaching process at our faculty is guided by pedagogical needs, and not exclusively by the imperative of modern technology application
- Different aspects of e-learning represent the area of scientific research at the faculty, since they are directly connected with information science.

By introducing and actively using e-learning, FOI intends to improve the quality of the teaching process and learning outcomes, render students (future citizens of the society of knowledge) capable for a lifelong learning, enable a widening participation to higher education and ensure visibility of the faculty on the international educational market.

In the framework of the strategy the blended learning has been chosen as the most appropriate one for the needs of teaching at our faculty, and conforming to this, three levels of blended learning have been determined.

Students have also recognized the possibilities and advantages of blended learning in relation to classical learning. In the survey, which was done in the academic year 2007/2008 and in which 240 students of the first year participated, we asked: „ Do you prefer when teaching is done: a) mostly with the support of a computer b) in a classical way with oral teacher's lecture c) with a combination of the first two ways.“ 69% of the questioned students prefer blended learning, 24% classical way, and 7% computer-supported teaching.

Taxonomies in mathematics

In order to construct more successfully the learning outcomes according to “depth of knowledge”, we observed several taxonomies created for mathematics. All observed taxonomies define the „depth“ of the mathematical content, that is, they do not dwell only on the content defining. Bloom's taxonomy (Bloom, 1956) is the most frequently used taxonomy in creating the learning outcomes. It consists of 6 categories (knowledge, comprehension/understanding, application, analysis, synthesis and evaluation).

The categories are also arranged according to weight. According to Bloom, the highest level of taxonomy includes a very complicated level of cognitive thinking. However, Bloom's taxonomy is not suitable for creating learning outcomes in mathematics because it is too complicated for everyday use, especially if the teacher wants to use it to test the students' knowledge. Moreover, we studied the following taxonomies: the MATH taxonomy (Smith and others, 1996), the TIMSS (Chrostowski and O'Connor, 2001) and the MATH-KIT (Cox, 2003) and we finally decided for the MATH-KIT. We have to mention that good results in implementation in mathematics (Chick, 1998) were given by the SOLO taxonomy (Structure of the Observed Learning Outcomes) which was developed by Biggs and Collis in 1982, where the evaluation of the students' progress was shown in five levels, so it correlates with the grade scale that we use in Croatia (from 1 to 5). However, for our needs of preparing the data base of questions and problems, five levels are too much for effective work.

Cox's taxonomy ensures the creation of the teaching process following the learning outcomes, it is simple for the classification of the depth knowledge, suitable for assessment purpuses, and especially assessing homework (tests) via web. Taxonomy defines classification in three categories:

- K (Knowledge) – basic knowledge. It implies concept defining and understanding, knowing examples, use of concepts and facts, use of theorems and formulas in tasks which demand a simpler application, a practical use of calculation techniques.
- I (Interpretation) – interpretation: comprehension, understanding, analysis and synthesis. It implies the fact that the student can reproduce the learned theorem, understand it and know some consequences and limitations, deduce heuristic evidence, adjust set problem so that the theorem can be applied.
- T (Transfer) – translating knowledge into a new context, application, creation, synthesis. It implies the fact that the student can apply and observe the theorem in the new and unfamiliar context, correlate the set material with other aspects of mathematics, develop new and improve the existing models, formulate hypothesis.

Task base according to taxonomy

The first example of the learning outcomes implementation by using of e-learning is given in subjects Mathematics 1 and Mathematics 2 in the first year of undergraduate study Information and business systems. More about the methodology of teaching in these subjects is described in (Divjak & Erjavec, 2006). Besides classical ways of knowledge assessment through preliminary exams, we also use on-line knowledge self-testing in the e-learning system Moodle.

All forms of testing and knowledge assessment in Moodle and in classical tests are prepared according to Cox's taxonomy. For example, self-testing in Moodle is a test in electronic way that a student does individually and the moment he hands the test he gets the information about his success. Having finished the test each student not only gets an insight into the correct answers but also feedback information about the solution, especially if the self-test consists of the tasks of the highest level in terms of taxonomy (type T).

In the subjects Mathematics 1 and Mathematics 2 we have created a number of self-tests and homework tasks in Moodle that have been done according to Cox's taxonomy. For each homework or self-test we have created the data base of questions that has three groups (K, I and T). For example, in homework associated with determinants in each of the three groups there are 30 tasks, totally 90 tasks for each homework. To each student Moodle generates his set of questions/tasks by taking out predetermined number of questions/tasks from each group. In this way we have achieved that each student gets a test of a defined knowledge width and depth in advance. For Mathematics 1 we have a base of totally 300 questions and tasks, and for Mathematics 2 a total of 532 questions and tasks. The reason for greater number of tasks in Mathematics 2 is that its material deals with calculus (functions, limits, derivations, integrals) so it is easier to do more calculation tasks than in Mathematics 1, which mainly includes linear algebra (matrices, determinants, linear equations systems). However, Cox's taxonomy is not the only key according to which categories of questions within the task base for these two subjects have been developed. Single self-tests have been created so that they are mainly graphic or geometrical. The objective of this kind of testing is to strengthen the sense for geometrical cognition of a problem, to encourage interest for mathematics and to popularize topics which are not popular among our students (relations and sets in Mathematics 1, or derivations and integrals in Mathematics 2), but which are important for their professional competences.

It should be emphasized that on-line tests do not have a big influence on forming a pass grade (D), since students do them mainly in uncontrolled conditions but they have a motivational role in the teaching process.

Students' pre-knowledge

It is important to evaluate initial students' competences (pre-knowledge) in every subject and to compare them with output competences, in order to evaluate the students' progress in a specific subject. It is clear that this evaluation is not an easy or unambiguous procedure. Initial competences are described through a prerequisite in the form of whole subjects, but also as a set of necessary pre-knowledge that should be acquired through the previous formal, non-formal and informal learning. In the first year of the undergraduate study initial competences for some subjects are tested by an entrance exam, but it is also necessary to conduct a test of pre-knowledge for individual study groups in order to prepare the teaching process more effectively, but also to give students usable feedback information about possible deficiency in their competences. For this purpose, in the subjects *Mathematics 1 and 2* we do the pre-knowledge testing and we use taxonomy for classifying tasks and students' success.

The test at the beginning of the second semester consists of 12 questions divided in three groups (according to K, P and T taxonomy) in a way that each of the four units (quadratic equation, Pythagoras' theorem, logarithmic function, trigonometric functions) expands through these three levels. The objective of this testing is to determine the pre-knowledge which is necessary in order to follow the lectures in Mathematics 2, not only in width but also in depth.

Since we have been following students' pre-knowledge for the last three years, it has been determined that all three generations lack in knowledge and that some tasks are rarely or never solved. These are mainly graphical or geometrical tasks which relate the function to the practical problem, or the graph of a function with properties of the function. In order to lessen these lacks in the pre-knowledge, tutorial classes have been organized where older students help those attending specific subject classes, then frequent teacher consultations (6 hours per an assistant and 4 per a professor) and extra material for revision in the e-learning system. To stimulate students to do graphic tasks and to achieve better results we have created a great number of self-testing tasks in Mathematics 1 and 2, with graphical tasks and problems, for example the self-test 3 in Mathematics 2 (Table 3).

Table 3 shows the tasks solubility for groups (K, I, T) in Moodle for two self-tests and for the test which is done at the beginning of the second semester in the last three academic years. In the academic year 2008/09, 240 students did the test at the beginning of the semester, and the analysis of solubility was based on two seminar groups, i.e. on totally 62 students. The test analysis in 2006/2007 was also based on two seminar groups (i.e. on 80 students out of total of 324 who did the test that year).

In the academic year 2008/2009, 234 students did the self-test 3 in Mathematics 1, and 146 students in the year 2006/2007 (Table 3). We should note that one of the reasons for such a low response in self-testing in 2006/2007 was the fact that, in that year, e-learning was introduced for the first time in the subjects Mathematics 1 and 2 and all self-tests and tasks show a low students' response than in later years. This self-test includes linear algebra material (determinants and systems of linear equations) and these are the types of questions: true-false, multiple answer questions, linking, short answer (the student needs to write the correct answer). All questions are put in groups K, I and T (each group has 17 questions). The distribution of tasks solubility in these self-tests confirms the good distribution of tasks according to depth (K, I, T) and the justification of introducing taxonomy in subjects. One of the reasons why similar distribution of solubility does not occur in the test done at the beginning of the semester lies in the fact that it examines pre-knowledge from secondary school, and self-testing examines acquired knowledge during the semester and this is also an indicator that students who come to our faculty do not have some basic knowledge which we consider that they should have upon finishing secondary school.

The self-test 3 in Mathematics 2 (Table 3) is a test that has graphical and geometrical tasks from the area of function derivations and derivation application. In the year 2006/2207, 244 students solved the test and this academic year the test will be done only in the second part of the semester. The results from the year 2006/2007 show that students solve geometrical tasks better than those algebraic (self-test 3 in Mathematics 1), which we did not expect, if we consider the results from the beginning of the semester in which graphical and geometrical tasks were poorly done.

Table 3. Results of self –testing in Moodle and the test from the beginning of the semester

		2006/07	**2008/09**
Mathematics 1, Self-test 3 in Moodle	**K**	64.8%	82.73%
	I	52.7%	67.03%
	T	40.6%	43.82%
Mathematics 2, Test at the beginning of the 2nd semester	**K**	79.95%	48.79%
	I	23.1%	16.33%
	T	28.3%	18.68%
Mathematics 2, Self-test 3 in Moodle	**K**	73.9%	
	I	64.3%	
	T	44.3%	

Learning outcomes evaluation by using e-portfolio

We introduced e-portfolio in the subject *Selected chapters of mathematics* (4^{th} semester of the undergraduate study) in order to monitor students and evaluate the learning outcomes. The portfolio represents systematic, multidimensional and organized collection of evidence about students' knowledge, skills and attitudes. With e-portfolio this collection is available in electronic way or on-line. „In a nutshell, portfolio assessment is considered an effective means of measuring the change sin students' cognition and learning process, involvement and interaction, and assessing higher-order cognition abilities and attributes." (Frankland (ed), 2007). We use the open source e-portfolio system Mahara.

For each chapter (out of 6) the students have to make one artefact (homework, test, presentation exercise, model, to describe a possible application, systematized lecture notes) and reflection on learned material, acquired skills and their entire progress.

Therefore, the e-portfolio role in the subject Chosen mathematical chapters is dual.

- *Reflection on the subject*, *the students' activities in the subject and their execution*. The subject is described by its role in the programme, application, learning outcomes and etc. Moreover, there is a discussion about difficulties and success, explanation of the subject concepts and their correlation with other subjects as well as opinion on mathematical modelling and its role in the ICT profession. On one side, the activity related to e-portfolio represents a contribution to the use of technology in teaching, and on the other side, it serves to raise students' awareness of their own work and progress on the subject. This progress is monitored by the means of emphasizing the personal choice of the best artefacts on the subject and reflecting about the material and progress that is written in a free form.
- *Evaluation of learning outcomes of the subject*. This activity will mainly be done by the teachers on the basis of students' e-portfolio. The results of such evaluation will give valuable information for the analysis of learning outcomes achievement, but also about the subject role in the study programme. Since there are more than 300 students on the subject, and more than 200 of them have chosen e-portfolio activity as a part of constant monitoring, we believe that the sample will be statistically significant.

Learning outcomes evaluation by using the survey and the diary

The last example we give is related to the subject *Project cycles in research and development* which is taken in the postgraduate doctoral study program of *Information sciences*. The subject has been delivered for three years consecutively and the total of 45 students took it. We have to mention that these were very serious and mature students, and therefore the methodology of work and monitoring of students' progress had to be done very cautiously and in an elaborated way. You can find more about the learning outcomes and teaching methodology of the subject in (Divjak & Kukec, 2007).

With the purpose of learning outcomes evaluation two methods were used. The first one is the survey method in which we ask students, among other things, to what extent set learning outcomes have been achieved. The answers showed that 90% of students assessed that the learning outcomes were completely achieved and the remaining 10% answered that the learning outcomes were achieved rather well. Since these are very responsible students, their quantitative and qualitative answers can be considered relevant.

The second method of evaluation of learning outcomes, which is at the same time estimation of student workload during subject execution and exam preparation, is through a learning diary that is written by students in the e-learning system. The qualitative analysis of these artefacts shows to what extent a single student, with given initial competences, has managed to achieve required learning outcomes and how much effort he/she needed to fulfil specified learning goals. Average diary has a length between one and two A4 pages and contains very useful information for improvement of quality of teaching and learning as well as data on students' pre-knowledge and motivation for the study.

Conclusion

Information and communication technologies (ICT) and the need for the lifelong learning represent an unavoidable reality of the present age. Our task is to use the technology with the purpose of improving the teaching process quality and insuring the accomplishment of the learning outcomes, bearing exclusively in mind the pedagogical needs and not the imperative of the application of modern technologies. In this article we have presented some new examples of the e-learning use with the purpose of better implementation and evaluation of the learning outcomes. First, we described the use of the data base for testing created in the taxonomy in order to serve the needs of self-testing, and afterwards, the use of taxonomy to determine the students' initial competences. The example of the e-portfolio use follows, and on one hand, it serves for students' reflection on their own progress in the subject, and on the other hand, it enables the teacher to evaluate the learning outcomes achievement. In the end, we showed the example of learning outcomes evaluation and student workload by keeping the learning work in the subject. We conclude that it is very important to adjust methods of evaluation of learning outcomes to the study level, to the specific subject as well as to the students' characteristics and combine them with the evaluation of the other elements of the teaching and learning process.

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