

# Use of Petri nets for evaluation modeling of the student transition through the web environment

Zoltán Balogh, Milan Turčáni, Martin Magdin

**Abstract**— The paper describes student transition evaluation modeling through LMS by the use of Petri nets. First, a universal student transition model had to be created through the LMS. This model created in Petri nets is modular. This means that a model could be added which evaluates the student on the bases of transition through LMS. According to these results, each states of the student could be simulated and on the bases of his steps it is possible to evaluate him. Petri net (PN) is a graphical and mathematical modeling tool that has such characteristics as concurrent, asynchronous, distributed, parallel, nondeterministic, and stochastic. Although, as an ideal system which would be close for every student is utopian for sure. It is still possible to approach the perfect personalization of teaching by means of correctly designed models by the use of Petri nets.

**Keywords**— Learning Management System (LMS), Modeling, Petri nets, Evaluation, Universal model.

## I. INTRODUCTION

THE introduction of ICT into practice has brought about changes in all areas of society and thus education. However, to the potential of these technologies used fully, it is necessary to adopt a new approach to the implementation of education. This in turn requires a new model for educational institutions and its processes will be changed by ICT. By retaining the existing educational process it is unlikely to achieve another learning outcome. The basis for making changes is generally creating a new business model (Fig. 1). Although the meaning of business is not quite the same as the meaning of that term in the commercial sector; in terms of changes in education and the implementation of ICT in education such an approach is desirable [1]. Educational institutions should behave as an organization providing education services.

The rating or evaluation is an integral part of the process development of each system. The evaluation of educational resources must therefore be part of the process of creating

learning resources. In this case, the evaluation has two levels - evaluation of technological resource lists and evaluation of the educational content of the resource. Evaluation of technological aspects is relatively simple, based on checking and evaluating the implementation of the requirements set for the source, such as meeting technology standards, appropriate size of the file used in the labeling, source structure and so on. When evaluating the educational content, application levels of pedagogical principles are detected in the learning resources. Creation of learning resources does not only require expertise in issues of educational content but also pedagogical and psychological disciplines [2].

With the growth and evolution of the internet, online systems have increased. The education was not left behind and e-learning tools and platforms started to appear allowing managing educational process or even getting qualifications online [3]. With the development of Computer Based Training and Web Based Training, the distance learning provides the novel learning way different from traditional education and has become one of the important styles of modern education [4] [5]. Learning Management System (LMS) is a kind of web-based system that aims at supporting educational activities in distance or presence modalities. Currently various LMS platforms have been developed and made available, and also have been largely used in both distance learning and traditional classes [6]. Nowadays electronic learning systems provide the possibility of saving all information about student's activities in one place. Teacher could monitor the student's activities after his login into system. Systems offer submission of the file, testing the control of the communication and cooperation too. LMSs facilitates teacher to keep his methodical portfolio dynamic and offer electronic students' portfolio in every moment [7] [8]. An LMS provides the platform for the web-based learning environment.

The paper focuses on the evaluation modeling of the student passing the LMS. The scoring and assessment model of the student crossing the e-course was created into the universal model constructed in Petri nets [9].

## II. MODELING STRUCTURE OF THE UNIVERSAL MODEL

When modeling the correct LMS system, it is useful to know as much information as possible. This means get to know its behaviour in certain situations, requirements for control, physical or other restrictions of the given system. Then it has to be clearly determined what the system has to

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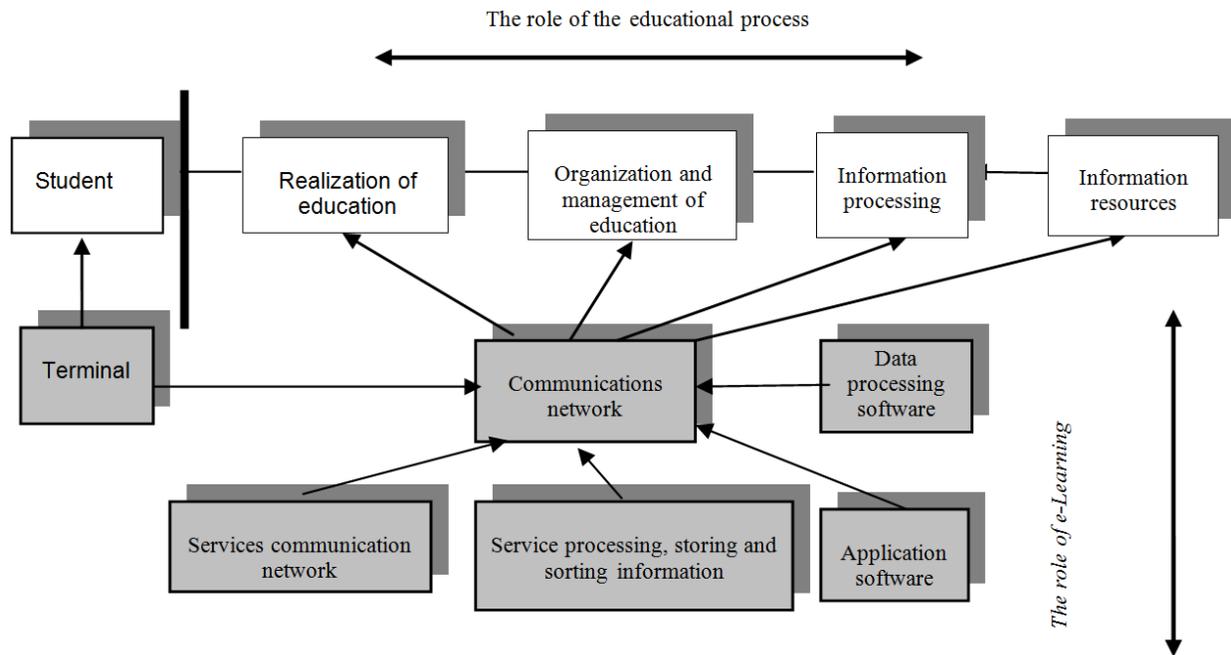


Fig. 1 Business model of the educational institution providing e-learning service

perform and which are the primal actions to avoid collisions. The aim of the requirements is to have the best universal model which describes the dynamics of the given system [10].

With similar universal models similar e-learning courses would be created. The creation and construction of the universal model has already been described in some papers [9].

Petri nets were used to create the universal model of the student passing the LMS. Process models can be also created using UML diagrams [11]. The structure diagram of the universal model is shown in Fig. 2. To better understand the modeling and simulation concept it is essential to acquire the basic notions [12].

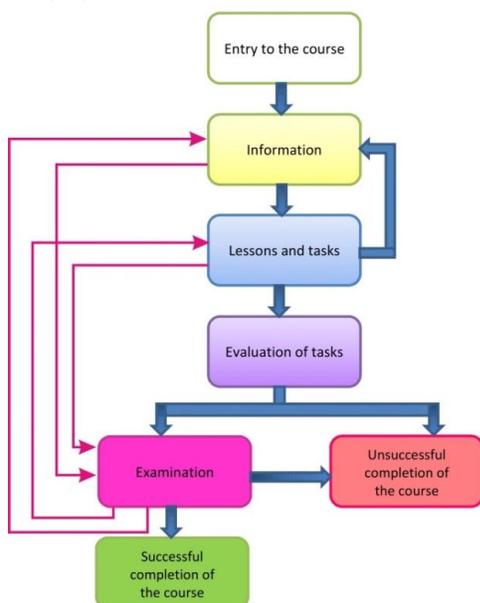


Fig. 2 The structure diagram of the universal model exam

A. Petri Net Formalism used in modeling

Petri net theory was introduced by Dr. Carl Adam Petri in 1962. The Petri net (PN) is a graphical and mathematical modeling tool that has such characteristics as concurrent, asynchronous, distributed, parallel, nondeterministic, and stochastic. It can be used to model and analyze various systems. With the raise of the complexity in the PN system, the description of the ordinary PN becomes more and more complicated. Its extended Petri nets include colored Petri net [13, 14], timed Petri net [15] [16], fuzzy Petri net [17], high-level fuzzy Petri net [18].

Petri Nets are bipartite, directed multi-graphs which are used to model systems in which regulated flow of objects and information occurs. Petri Nets offers a powerful modeling tool with a very wide application area. In many engineering systems and disciplines, computer networks, communication systems, manufacturing plants, command and control systems, real-time computing systems, logistic networks and work flows are some of the application fields of the Petri Nets [19].

Being a combination of mathematical theory and a graphical representation method Petri Nets is a convenient instrument for both practitioners and theoreticians. Graphical aspect of Petri Nets provides a powerful tool for visual communication such as flow charts, block diagrams and networks, while the mathematical aspect allows one to analyze and develop a mathematical model of the system.

Petri Nets, as a mathematical and graphical tool, enables one to work and study information processing systems which are described as being concurrent, asynchronous, distributed, parallel, nondeterministic and/or stochastic.

Informally, Petri Net has three basic items, places, transitions and arcs. The arcs connect the places and transitions to each other. Transitions symbolize actions or events and places represents states or conditions to be satisfied

before an action or event can be carried out. The places may contain or may not contain tokens. The presence or absence of a token in a place can indicate whether a condition associated with this place is true or false [19].

A Petri Net is formally defined as a 5-tuple;  
 $N = (P, T, I, O, M_0)$

In Equation;

$P = \{p_1, p_2, \dots, p_m\}$  is a finite set of places;

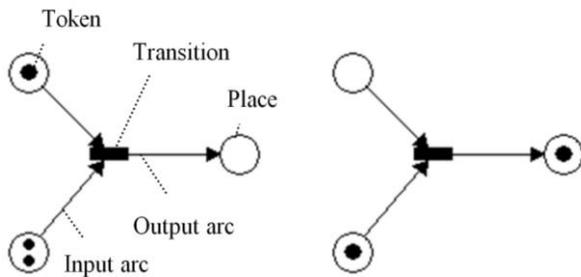
$T = \{t_1, t_2, \dots, t_n\}$  is a finite set of transitions, such that  $P \cup T \neq \emptyset$ , and  $P \cap T = \emptyset$ ;

$I: P \times T \rightarrow N$  is an input function that defines directed arcs from places to transitions, where  $N$  is a set of nonnegative integers;

$O: T \times P \rightarrow N$  is an output function that defines directed arcs from transitions to places;

$M_0: P \rightarrow N$  is the initial marking, an  $M$  dimensional vector whose components correspond to the places A Petri Net,  $N$ , with an initial marking of  $M_0$  is denoted by  $(N, M_0)$ .

Initial marking represents token distribution into the places, and distribution expresses a state of the system. Graphically, places are depicted by circles, transitions are depicted by bars or boxes, arcs are depicted by arrows and the tokens are represented by dots. The arcs connect places to transition and in the same way they can connect transitions to places. In general, arcs are marked with their associated weights. An arc with a weight of 'k' can be considered as a k-way arc. Weight of an arc represents the number of tokens transported through that arc. If an arc is directed from place P to transition T, the arc defines place P as an input place of transition T and similarly if an arc is directed from transition T to place P, the arc defines that place as an output place of transition T.



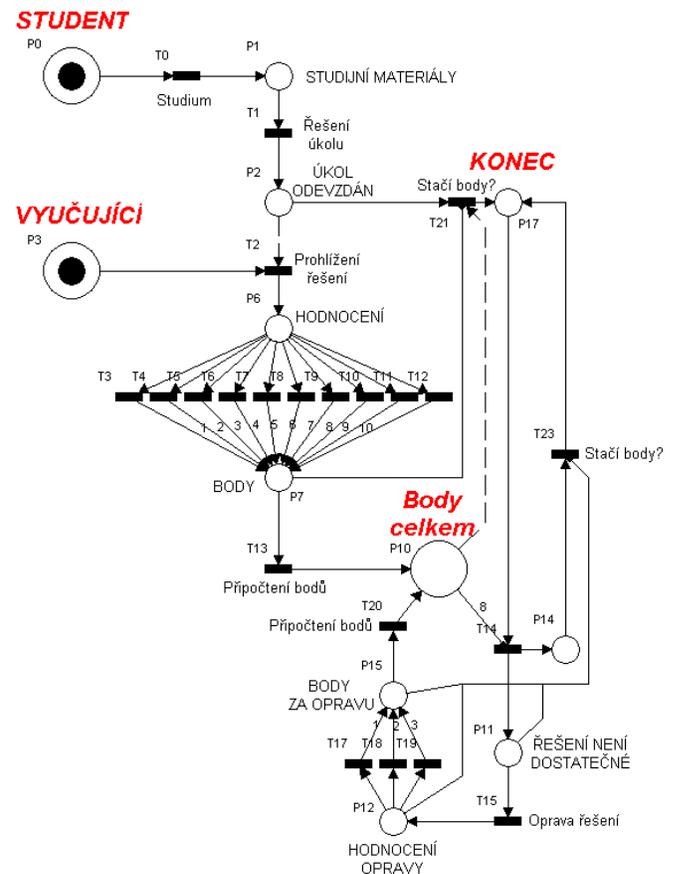
a) Before the transition firing      b) After the transition firing  
 Fig. 3. Simple Petri Nets

A transition T is said to be enabled if its input places contain minimum number of tokens that are determined by the weight of the corresponding arcs. If a transition is enabled it can fire when a transition fires, tokens are removed from each of its input place and token are deposited to each of its output places. The numbers of tokens that will be removed or deposited are determined by the arc weights.

**B. The scoring and assessment**

The scoring model of a written task is a calculable function. Its input is the beginning of the work of a given task (student's study of materials and the teacher's waiting time for task submission). The output (the value) is the number of points gained by the student for solving the given task [20].

Fig. 4 shows the scoring Petri nets of a written task. The maximum of points gained are 10 points with the requirement of gaining at least 8. At the moment of submitting the task (place P2) the T2 transition is implemented and the teacher may do the assessment of the task. Then he chooses a relevant number of points – are simulated by the choice of one from the transition T3 to T12. Thus in the place P7, 1 to 10 tokens appear, which consequently ascribe to the total number of points (place P10). As long as the student has not gained at least 8 points (the inhibitory arc conducting from the place P10 to transition T14 is testing it) he has to correct his solution (transition T15). The teacher decides how many points from 1 to 3 the student gains for his correction (again, choice from the transition T17 to T19). The points are ascribed to the total number of points (place P10). If the students number of point is still not sufficient (required 8 points), the situation is repeated – the students corrects his task and the teacher ascribes relevant points [20].



STUDENT – STUDENT, VYUČUJÍCÍ – TEACHER, Body celkem – Total Scoring, KONEC – END

Fig.4 Scoring model of one written task [20]

This model is a precise image about task scoring and according to this model it is possible to create a similar construction of scoring model which can be composed to the already created universal model.

### III. MODEL OF STUDENT ASSESSMENT IN LMS

If the student wants to pass the exam, he needs to fulfill two major requirements. First, he has to do all the tasks, submit them. Then he has to gain a sufficient number of points from them (in this case, 75% of points). There are four tasks in the model with the total number of points of 40. From this number, the 75% minimal limit is calculated which are 30 points. The availability of the student to the exam is based on the two facts. By the inhibitory arcs, it is verified whether the lessons have already been opened (whether a token exists in the places P800, P820, P830, P840, P850) and whether all the tasks have been submitted (whether exists a teacher token in the places P822, P832, P842, P852). All these inhibitory arcs connect with one transition (T870) at the same time (Fig. 5). The inhibitory arcs work conversely than the normal ones, and enable the transition to realize when the places connected to it does not contain any token. This means that if all the given places above are empty, the tasks are already submitted. Inspection is needed here to avoid “unsuccessful end of course” before submitting all the tasks. When submitted, in the place P870 a token appears which provides availability of the place P514 from each lesson (from the end of information sector and each lesson through the transitions T160, T260, T360, T460, T560). It is the place of task assessment. If the point gain is sufficient inhibitory arc of P700 activates the transition T561, thus gets to the place P664 meaning unsuccessful end of course (Fig. 5). The inhibitory arc has a value of 30, taking the place P700 as empty until it reaches the number of 30 tokens (points).

If the limit of 30 points has been reached, moving ahead to the exam through transition T562 is available. The transition checks up the place P700 (Fig. 6) by testing arc with the weight of 30, whether the 30 points exist there, and whether the teacher declassified the exam (whether the place P860 has a token). A testing arc was used instead of a normal one to keep the points gained from the tasks in the place P700. According to the place, it is possible to check up the correct system work anytime, even during the simulation. In the requirements, the form of the exam has not to be defined (whether it is an online testing, a written exam or a classic form of examination). The designed universal model contains an exam with a scoring from 2 to 20 points. The scoring was solved the same way as the task assessment. The token is waiting in the place P601 until the examination and the assessment end and the token in the place P602 starts the scoring of the exam by burning one of the 10 transitions from T662 to T680. In the place P604 points gained from the exam occurred. Originally, we got from P601 to P602, so no token has been left there. The new solution was made to not to unite the student activity simulation part (visible for the student) with the mathematic and the logical part (what is happening in the background, what is the LMS and the teacher doing). Thus their natural and original performance/behaviour has been maintained.

According to our laws a student has the right to have three

attempts of examination. This means that such a net have had to be created in which it is possible to save the results of all attempts. The model counts the student's attempt passing the exam, saves the gained points, shows the results, how the course ends. The student may study the desiderative lessons, materials, prepare himself for the next attempt, and again, be examined. The token in the place P603 shows, how many times the student has already been examined.

The testing arcs are connected with three transitions where each arc has a different weight (1, 2, 3 – numbers of attempt). The testing arcs provide that the token does not disappear from the place, and the place may count the attempts. When the place P603 gets the first token, the one-weight testing arc activates the transition T621 and gets the tokens into places P621 and P631. A token got to the place P621 and consequently it opened a possibility of saving the results of the first attempt from the place P604. Result savings makes the transitions T611, T612 and T613. They need to know which one of them has to save the results and they have to fulfil the requirements:

- they need to have points from the place P604,
- they need to have a token from the place P62X, where X is a number of the current experiment (with the use of testing arc),
- they need to have an empty place for the next experiment (with the use of inhibitory arc). If the next place is not empty, it means that another experiment has been implemented and the next transition has to save the points. It is a crucial condition which, in fact, protects the results of the previous experiment.

If the transition T611 has been implemented, the number of points is presented in the place P611. Then if the half of the total number of points has been reached in an exam, the testing arc with the weight of 10 and the student's token from P601 activates the transition T661. Thus the place P661 is reached, what is the first place of a successful end of the course. If on the exam the points do not reach the number of ten and in the place P611 there are less tokens than 10, the inhibitory arc activates the transition T631, and the token gets into the place P641. The transition T641 is connected to the place P601. The token in the place P601 represents the student's action. It moves according to whether the student passed the exam (through the transitions T651, T652, T653 it gets to the state of successful end of the course) or he got a token from the place P641 (or P642), which means that he did not pass the exam and he may return to his materials and study again (T641, T642). Or in the case that the student did not pass the exam the third time, he finished the course unsuccessfully (T643).

Through the transition T641 (T642) he gets to the place P609, he can choose from the lessons by the transitions T6X0 where the X represents the number of a sector, or return to the exam. If the student's token returns to the exam sector, the

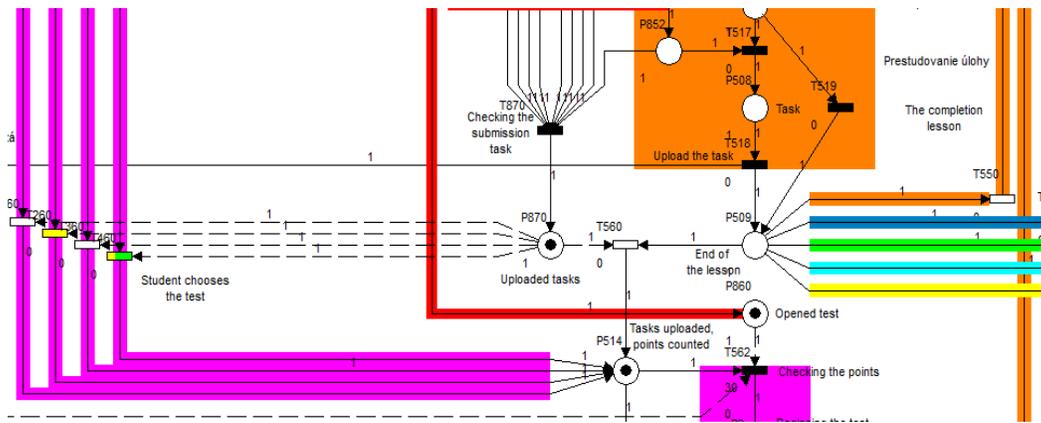


Fig. 5 Before exam

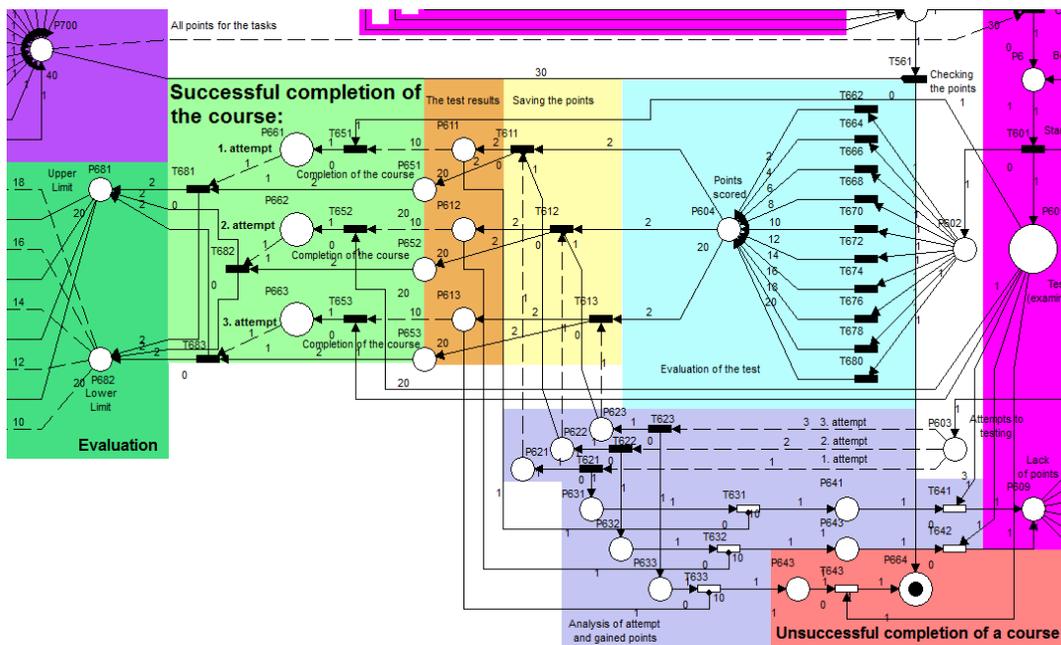


Fig. 6 Exam progress model

transition T601 sends a token to the abacus P603 which activates the transition T622 with the testing arc with the weight of 2. Then it sends tokens to the places P622 and P632 and thus activates the point savings of the second experiment (T612). If the student reaches a sufficient number of points, he has the possibility to return to the lessons and materials. If the student does not pass the exam the second time, he may return to the same ways and try it the third time. After saving the points of the third attempt to the place P613, the only way is to end the course successfully, or through the transition T633 get to the place P644 where he ends the course unsuccessfully.

The testing arcs from the places P621, P622 and P623 have an interesting function. In these places, there is no need of tokens just to save points from the exam to the right place. The tokens are not necessary because they are the activation condition of transitions T611, T612 and T613 as it was in the condition of the teacher to open the lessons in the places

P8X1. It is necessary to block the operation of testing arcs and the transition T62X because if after his unsuccessful examination the student returns to the lessons, the token from the place e.g. P63 would be removed. The testing arc from P603 would send another token to this place through the transition T62X which would also get to the lessons and it would be repeated again and again until the whole model would fill up with tokens. As long as there are tokens in the places P62X, the transitions T62X do not let any token to the places P63X even if it is empty.

#### IV. STUDENT EVALUATION

When modeling the student's transition through the system, there is a visible part of the already presented exam model with an added function of assessment. The function has its own principles, as an input, just a solution of a successful exam is needed. The possible scoring evaluation has to be set

according to the fact, how many points it is possible to gain on the exam.

In Fig. 7 there is the model of grading according to semestral performance. The function's basis is the same, but it was necessary to add points gained from the tasks. Then the place P700 had to be duplicated which means that the content had to be copied into places P721 and P722. The purpose was to keep the role of this place and meanwhile to figure in its content to the points gained on the exam.

Attention had to be paid when adding points gained in the tasks to the total number of points. It was crucial for the student to pass the exam first and then add the points gained in tasks by the use of transitions T684, T685, T686. In this version of the model the number of gained points is much more. That is the reason, why different point numbers are added to each place.

Deterministic transitions have to be used for correct function of grading in transitions T69X in order to start the grading only when the points gained have already been counted.

this term, educational institutions intend changes which may occur in the provision of education by applying information and communication technologies. Providers of information and communications services intend to use technology in education. Implementation of two different approaches should be combined in a common solution so that the implementation of ICT would contribute to education development and its quality.

System modeling is an activity which on the bases of acquired knowledge enables thinking about the real world and thus consciously influences it. The notion of a system usually represents an abstraction of reality while the focus is on those facts which are relevant for this research. The modeled system has a certain structure, it is composed of elements (entities of the system) among which relations exist. In a dynamic system, the relations and the system set of elements may change [21].

In the sense of research technology, the core of the modeling is a substitution of the examined system by his model (a modeled system). The aim is to gain information about the original examined system by experimentation with the model [22].

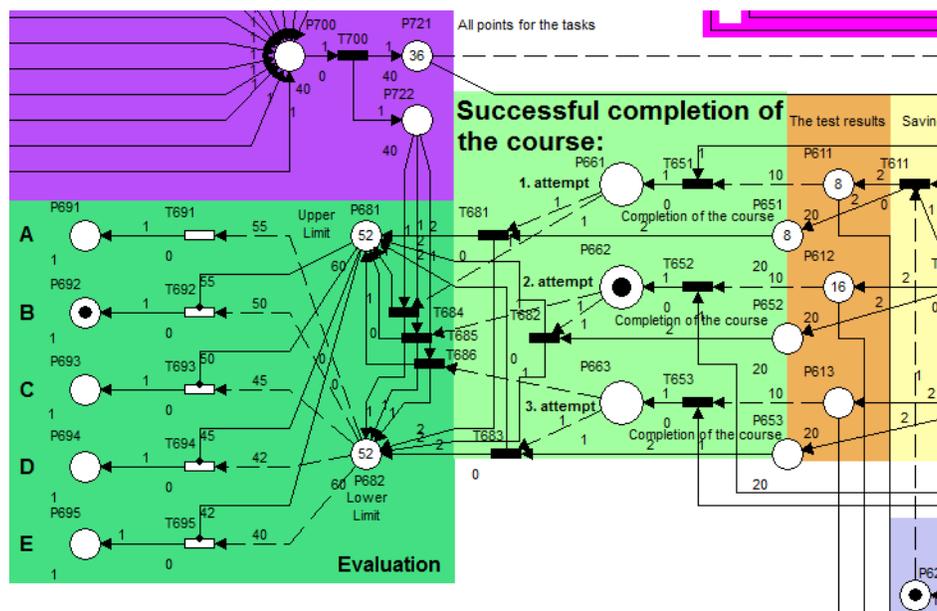


Fig. 7 The model of grading according to semestral performance

## V. DISCUSSION

Integration of ICT in education brings changes in many ways. One of them is the need to change the current model of teaching - teacher and a group of students at the same time in the same place with new possibilities of using ICT. Whether it enforces the study of the form of e-learning or blended format called blended learning or not, shows time. However, the electronic education support is part of the strategy of each higher educational institution. Such support should ensure that students' knowledge and skills were the most utilizable in practice and that their learning was the most effective.

The concept of e-learning is used not only in the case of changes in education, but also in the classifications of services provided by electronic communication networks. Nevertheless, the approach is different from each point of solution. Under

Thus is system defined as a really or abstractly existing object to be examined, while during his existence it may develop and cooperate with other systems which form his surroundings [23].

As long as system modelling is concerned, it is represented in a different environment (e.g. in a language or form understandable for the computer) where it is crucial to think about the internal characteristics such as reciprocal interaction between the system and its environment [24], [25].

## VI. CONCLUSION

When creating the materials, authors starts to deal with only the technical improvements in the area of Web-based education, but also accentuate the implementation of pedagogical and psychological concepts into planning the

electronic forms of education, such as learning, recurrence curve and curve of forgetfulness. Although, an ideal system which would be close for every student is utopian for sure. But it is possible to approach the perfect personalization of teaching by means of correctly designed models by the use of Petri nets.

In the paper, the model of student scoring and evaluation by the use of Petri nets is described. It was necessary to model the scoring evaluation of each task, test, final work, and exam. Since the scoring model depends on the type of the given task, a solution had to be found which is flexible and easily modifiable according to arbitrary requirements. In this case, also human factors play a big role: how the teacher images the course, how strict he is, whether he counts all the points gained through the semester, or he grades just the final exam, etc. When considering subject ending with an exam, it cannot be forgotten that the students has the rights for two correction terms. It means that together he has 3 attempts to pass the exam successfully. It may happen that after passing the exam, the student is not satisfied with his grade and he wants to correct it. But what happens if he gets a worse grade on his second attempt? Is it possible for him to keep the older and then better one? All these events, cases, and details are not possible to summarize into one model without losing overview. In this case, alternative versions (moduls) may be done. By the use of a universal model with relevant moduls created in Petri nets, it is possible to create practical electronic courses which will take into account all the aspects of a functional model.

The created e-courses by the designed universal model can be then checked up (evaluated) by the use of various statistical methods [26] [27] [28].

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