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E-LEARNING EDUCATION OF EDUCATIONAL TECHNOLOGIES IN FULL-TIME AND COMBINED STUDIES

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Abstract: The article focuses on research in the area of Educational Technologies, mainly on the comparison of ways, methods and processes of education in full-time and combined studies. The work was undertaken in the Pedagogical Faculty, Ostrava University, Ostrava, Czech Republic. The fundamental presumptions and hypotheses that the work intended to verify concerned the presupposed increase of efficiency of students' learning, as well as opportunities to model the transition of students in a relevant way through an e-learning course. The main research method used was a pedagogical experiment that, following several years' analysis, took place in the winter term of the 2008/2009 school year.

The important contribution is the methodology of generating Petri Nets that represent students' transition through an e-learning course. The models of real transition for students, through a course created by Petri Nets, confirmed the possibility to model tutorial processes in this way.

Key words: Petri Nets, e-learning, educational technologies, students' transition

1. Introduction

The subject of Educational Technologies is taught to students of Pedagogical faculty of University of Ostrava (Kapounova, 2004). It is aimed at providing knowledge and practical skills in the Information and Communication Technology (ICT) area, as well as their integration into a learning process — partly as a technical medium and partly as an example of modern methods and processes used in a learning process. The subject's tuition is supported by an e-learning course created in the Moodle learning environment in both full-time and combined studies (Turcani, 2008). Every year about 400 students complete the tuition.

Students solve about 15 practical tasks divided thematically into five blocks as part of the course. For each task, students find detailed instructions describing the way to resolve the particular task, including sample solutions. They create their own solution that they submit to be checked through the e-learning course.

Electronic support of the tuition of Educational Technologies allows the recording of information about students' activities while studying. In order to gain insight into the ways, methods and processes of students' learning in individual forms (full-time and combined), we used the data acquired from the Moodle learning platform module. We have processed this data using the methods of frequency and sequence analysis. On the basis of the acquired information we try to create a model of students' transition through an e-learning course by Petri Nets (Nagyova, 2008).

The idea of linking e-learning and Petri Nets isn't new. Petri Nets are used for the supervision of education (see Chang, 2008; Sanchez, 2008).

2. Students' study activities

In the school year 2008/2009 an extensive e-learning course was used to support the tuition of Educational Technologies. This course was created with the objective of acquiring maximum

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information about the movement and activities of students within the course. The course consisted of 195 learning materials and activities and 15 assignments.

The full-time studies were attended by 183 students and the combined studies by 277 students. The students are predominantly female; men represent only up to 10%.

In the Moodle learning platform module 121,349 activities were recorded by the full-time students and 147,501 activities by the combined students. It can be generally stated that the full-time students performed more activities during the course (on average 663 activities per student) than the combined students (on average 532 activities per student).

We only focus on the activities aimed at displaying the study materials (resource view) and inserting individual assignments (assignment upload) and their mutual interaction. Numbers of individual activities for full-time as well as combined students are shown in Table 1. The data indicates that the full-time students access the resource view more frequently, while the combined students, on the other hand, upload solutions for correspondence assignments more frequently, even repeatedly, worrying if they have been sent off and if the specified conditions have been met.

Table 1: *Count of recorded students' activities*

	Full-time studies	**Combined studies**
Resource view	46,434 (38%)	55,286 (37%)
Assignment view	2,994 (2%)	4,286 (3%)
Total	121,349	147,501

3. A model of students' transition through a course

The course of the Educational Technologies contains 15 correspondence assignments. We mark them with even numbers P_2, P_4, P_6 ... P_{30}. Each correspondence assignment consists of certain study materials, descriptions, instructions, sample solutions etc. We divided them collectively into 15 groups, which equal the number of assignments. As we suppose that the resource view is followed by solutions and assignment upload, we number individual groups of study materials with odd numbers, i.e. P_1, P_3, P_5 … P_{29}. P_1 indicates a group of study materials pertaining to the first assignment that is marked as P_2 etc.

3.1 Full-time studies

Full-time students take place in regular tuition of 2 lessons per week (i.e. 26 hours per term) within the Education Technologies course. As part of this tuition they submit individual correspondence assignments. In case they aren't sure what to do, they can use study materials from the e-learning course or they can ask their teacher for help. After finding out how the students go through the course, we will focus our attention on the assignment upload (correspondence tasks handover) and resource view (study of materials).

Table 2 represents an interaction matrix (Chrastka, 2007) related to the assignment upload by the full-time students. Individual cells of this matrix (a cell in *i* row and *j* column) correspond to the frequency of the upload of the P_j assignment after the P_i assignment. Maximum frequencies in one row are highlighted in grey (in a given column).

The interaction matrix shows the following:

- The interaction matrix confirms that students on average worked on the assignments gradually, from P_2 to P_{30}. Individual places follow one another in the assumed order, P_2, P_4, P_6 … P_{30}.
- The P_2 assignment was mostly done first, only in 41 cases was it uploaded after the P_4 assignment

- The maximum number in the matrix (number 142 in the first row) shows the frequency of the P_4 assignment upload after the P_2 assignment upload. This corresponds to the situation when students usually prepared their pictures (task P_2) and consequently used them while creating a bigger animated picture (task P_4). High frequency of the assignment upload (137) can be also found in the transition between the places P_6 and P_8, i.e. the students usually continued, after the proposal of the work list, to realise this proposal practically.

Table 2: *The interaction matrix of the assignment uploads: full-time studies*

	P2	**P4**	**P6**	**P8**	**P10**	**P12**	**P14**	**P16**	**P18**	**P20**	**P22**	**P24**	**P26**	**P28**	**P30**	**Total**
P2	0	142	27	10	2	2	0	1	0	2	1	0	0	0	2	189
P4	41	0	103	23	5	8	0	0	0	0	3	0	0	0	0	183
P6	2	1	0	137	43	16	3	4	3	0	1	0	3	0	0	213
P8	3	1	49	0	119	12	7	5	1	1	2	1	1	0	1	203
P10	5	2	17	22	0	102	9	10	6	1	5	0	2	0	1	182
P12	1	1	4	6	1	0	91	58	2	2	4	0	1	0	0	171
P14	0	0	1	2	1	11	0	82	33	8	9	2	11	2	4	166
P16	1	0	4	2	7	11	46	0	61	15	7	6	3	1	2	166
P18	0	0	0	1	0	0	1	3	0	104	14	4	11	3	1	142
P20	2	0	1	2	2	0	3	3	15	0	73	18	19	6	14	158
P22	0	0	0	0	1	2	2	0	3	6	0	111	36	8	1	170
P24	0	0	1	0	1	2	0	3	13	11	30	0	65	15	21	162
P26	1	0	0	1	0	2	0	0	5	6	9	13	0	115	10	162
P28	1	0	1	0	2	5	3	1	5	11	16	13	10	0	62	130
P30	0	0	1	1	0	1	3	0	4	8	0	3	2	2	0	25
Total	57	147	209	207	184	174	168	170	151	175	174	171	164	152	119	
PI		0,97	0,49	0,66	0,65	0,59	0,54	0,48	0,4	0,59	0,42	0,65	0,4	0,76	0,52	**58%**

The maximum values in the rows and columns of the interaction matrix (marked in grey) show the most frequent transitions between the corresponding places. The situation is optimal if these numbers are close to the row or column totals. In this case, the transition of the students through this course is the same; the tuition is organised in such a way that it leads students to the same study processes that we may consequently try to manage. Therefore, it appears to be advantageous to organise the tuition in such a way so that the maximum number of study activities are realised in the most frequently shown orders, i.e. so that the given interaction matrix of the course transitions showed the maximum transition index.

Definition 3.1: (transition index)

The transition index (marked *PI*) for the relevant interaction matrix can be defined as the average of a percentage formulation of the most frequent columns' interactions.

Example:

The last row of the interaction matrix represents a probability of the most frequent columns' interactions. In the second column these are interactions from P_2 to P_4 (142 interactions). The total of this column is 147. Of these, 142 interactions represent almost 97% of the total sum in the column (see number 0.97, at the bottom). The average of such acquired percentage data in all columns is 58, i.e. the transition index of this matrix is 58%.

In order to model a real transition of students through the course we have tried to define the Petri Net based on the compiled interaction matrix. From the graphic point of view *The Petri Net* (Brauer and Reisig, 2006) can be characterised as a bipartite oriented multi-graph. It contains two types of vertices:

- places (shown as rings): static elements with the possibility of memory in expressed by symbols (tokens);
- transitions (shown as rectangles): active elements expressing possible changes of status.

The edges of the Petri Net can only connect such pairs of vertices where each of them belongs to a different group. The oriented edge may lead from the transition to the place or from the place to the transition. The graph's edge (of the Petri Net) is illustrated graphically using arrows in the corresponding orientation. The graph may contain parallel edges, i.e. edges connecting the same pair of vertices with the same orientation. The exact mathematical definition of the Petri Nets can be found in Reisig (1992).

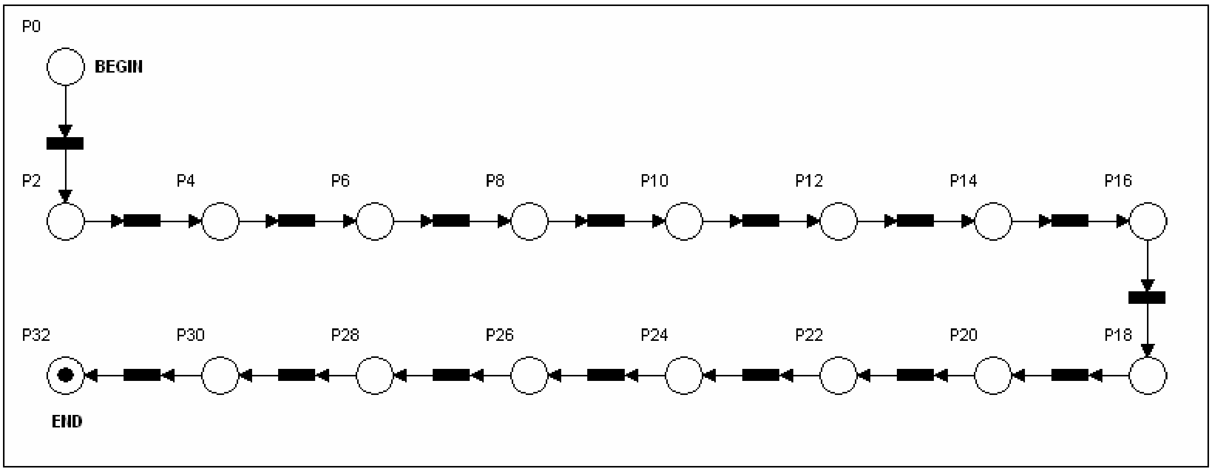

Figure 1: *The Petri Net of the assignment upload: full-time studies*

The Petri Net is composed from the interaction matrix according to the following rules:

- We only focus on the cells of the interaction matrix that correspond to the highest frequency of the occurrence of the transitions in question — the maximum values in rows and columns — so that after the assignment upload it would be possible to continue in the course. As stated before, these represent the most frequent transitions between the corresponding places.
- We define individual places of the Petri Net (P_2, P_4, P_6 … P_{30}, including the beginning marked P_0 and the end marked P_{32}) and specify individual edges so that they reflect the data in the interaction matrix in the best possible way, i.e. individual transitions are added to enable the movement of the tokens as per the marked (maximum) cells of the interaction matrix.

The Petri Net corresponding to Table 2 is shown in Figure 1 (all Petri Nets were created by HPSim computer programme, see Anschuetz (2002)). The Petri Net is linear, portraying the fact that students were uploading individual assignments in sequence, one after another.

The situation is more complicated if we monitor the students' learning process. Table 3 shows an interaction matrix of the full-time students. The first glance indicates that while studying the materials, descriptions, viewing sample solutions etc. the students were not proceeding in a linear way as it was when they uploaded the assignments. During their learning process they often returned to read necessary parts or to view the upcoming sections to see what was coming next. The grey boxes in Table 3 show the most frequent interactions within the course.

Despite the higher flexibility of the students while studying, the interaction matrix shows a higher transition index of 66%. It can be assumed that the model of the Petri Net created as per the interaction matrix, will correspond to the studies of approximately 66% of students. The generated Petri Net is in Figure 2.

Table 3: *The interaction matrix of the resource view: full-time studies*

	P1	P3	P5	P7	P9	P11	P13	P15	P17	P19	P21	P23	P25	P27	P29	Total
P1	0	523	35	16	35	5	5	3	7	4	3	2	4	6	6	654
P3	500	0	81	18	180	24	12	7	23	74	18	4	5	4	19	969
P5	22	25	0	441	556	32	7	7	31	13	10	1	4	4	6	1159
P7	17	26	310	0	392	39	10	6	7	5	2	3	4	2	7	830
P9	30	86	639	297	0	117	17	5	16	32	10	0	4	1	12	1266
P11	7	13	15	14	23	0	327	73	29	36	8	1	5	1	8	560
P13	3	11	10	10	8	186	0	217	48	42	12	3	4	1	19	574
P15	1	8	5	3	13	61	124	0	64	51	5	2	4	0	14	355
P17	8	33	26	5	14	29	25	16	0	474	53	6	24	21	53	787
P19	8	78	12	7	19	28	11	11	467	0	93	16	30	17	67	864
P21	5	9	7	3	2	8	8	4	39	56	0	306	94	42	178	761
P23	2	5	1	3	2	1	0	0	9	16	200	0	141	38	80	498
P25	4	7	5	3	1	7	8	1	10	12	55	82	0	320	77	592
P27	4	8	3	4	3	5	5	2	13	19	66	36	192	0	222	582
P29	11	29	10	8	11	20	19	4	33	33	232	47	92	145	0	694
Total	622	861	1159	832	1259	562	578	356	796	867	767	509	607	602	768	
PI	0,88	0,61	0,89	0,89	0,90	0,54	0,57	0,61	0,67	0,55	0,68	0,60	0,55	0,53	0,52	**66%**

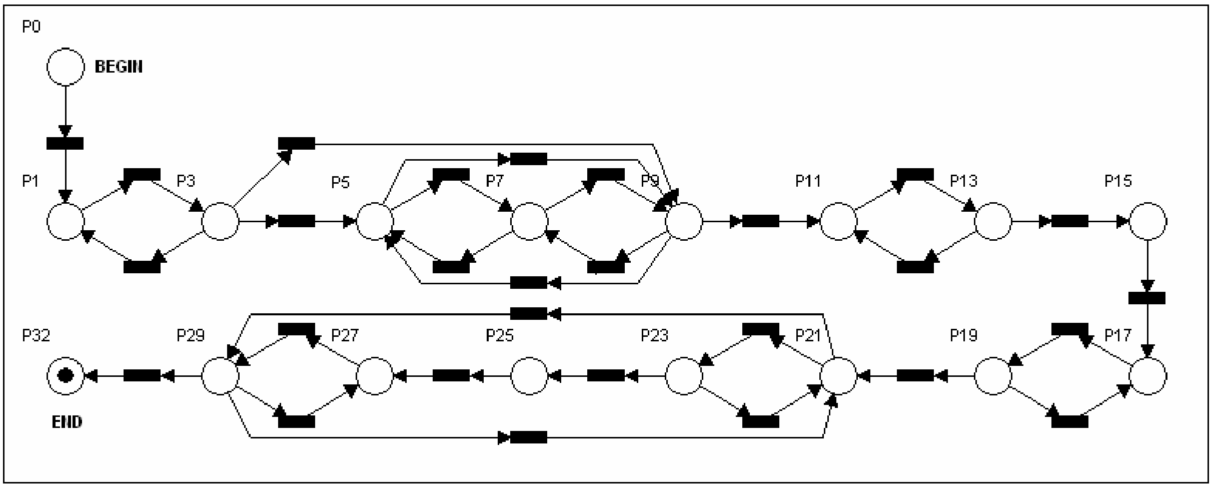

Figure 2: *The Petri Net of the resource view: full-time studies*

The model Petri Net of the real transition of the students through the e-learning course (Figure 2) is valid, and has a start and end point that are reachable in the end time, while random transition is ensured.

The Petri Net also shows that its individual places P_1, P_3, P_5 … P_{29} were divided into groups. Within these groups we find cyclic repetition of certain activities, such as a cyclic repetition of the places P_5 and P_7 or places P_7 and P_9, or also a larger cycle between P_5 and P_9. If we focus on the content of study materials within individual cycles, we discover that the created cycles correspond exactly to the thematic units into which the individual places of the Petri Net (corresponding study materials and correspondence assignments) within the e-learning course are divided.

3.2 Combined studies

The combined students take part in one five-hour tutorial as part of the Education Technologies course. Within this tutorial they get acquainted and solve tasks from the last (the hardest) thematic block, P_{22} … P_{30}. During their work they also get acquainted with sound and sound formats (tasks P_{12}, P_{14} and P_{16}).

Table 4 represents an interaction matrix of the assignment upload for the combined students. The matrix shows that the starting task is P_{22}. The total of the values in the corresponding column is the lowest and there is no higher number in it. This assignment is not connected with any other assignment through any previous interaction.

P_{20} is the last task to be resolved; the total of the values in the corresponding row is the lowest and the only remarkably higher value in this row only shows a frequent return of the students to task P_{18}. Tasks P_{18} and P_{20} create a small local cycle.

The transition index of the interaction matrix in question is 51%, therefore lower than in the case of the full-time students. This shows a higher variety in methods and processes of the combined students' learning.

Table 4: *The interaction matrix of the assignment upload: combined studies*

	P2	**P4**	**P6**	**P8**	**P10**	**P12**	**P14**	**P16**	**P18**	**P20**	**P22**	**P24**	**P26**	**P28**	**P30**	**Total**
P2	0	178	18	7	3	3	4	27	1	2	6	3	4	4	4	264
P4	19	0	85	32	18	10	17	24	12	17	7	1	9	4	2	257
P6	1	4	0	123	63	3	2	7	17	9	2	2	3	0	2	238
P8	7	3	50	0	126	5	4	13	14	10	1	0	4	3	0	240
P10	8	12	23	46	0	16	8	21	45	36	3	2	4	0	8	232
P12	9	2	3	2	2	0	136	26	2	4	8	7	24	3	18	246
P14	14	11	10	4	3	22	0	76	10	5	17	7	24	3	25	231
P16	37	16	21	5	9	17	31	0	20	16	24	9	11	10	12	238
P18	2	6	8	4	8	2	3	4	0	107	1	2	3	4	5	159
P20	3	4	10	11	13	7	2	5	72	0	7	4	5	3	10	156
P22	6	2	1	0	1	23	6	2	2	2	0	198	32	6	8	289
P24	17	7	4	3	1	71	5	6	3	1	45	0	94	9	7	273
P26	15	3	3	2	0	2	1	4	0	5	6	11	0	181	22	255
P28	12	6	6	3	2	31	2	4	6	5	7	9	20	0	121	234
P30	79	10	7	5	6	16	12	19	16	15	4	5	18	8	0	220
Total	229	264	249	247	255	228	233	238	220	234	138	260	255	238	244	
PI	0,34	0,67	0,34	0,5	0,49	0,31	0,72	0,32	0,53	0,46		0,76	0,46	0,76	0,5	51%

The Petri Net, created as per the mentioned interaction matrix, is shown in Figure 3. It starts in P_{22} and finishes in P_{20}. It is more or less linear and corresponds to the process and organisation of the combined students' learning. We find a small cycle only in the case of the interruption of the tutorial learning, with the information related to the work with sound (P_{12}, P_{14} and P_{16}).

The Petri Net of the real process, showing how the combined students were solving and uploading their assignments, was originated only on the basis of the data recorded in the Moodle learning environment. In spite of that, it almost truly reflects the methods and processes of the students' learning and learning organisation. The transition index, moreover, confirms the higher variability in the learning of these students; not all of them take part in the tutorial, and the independent work of each student depends on his/her entry knowledge and skills.

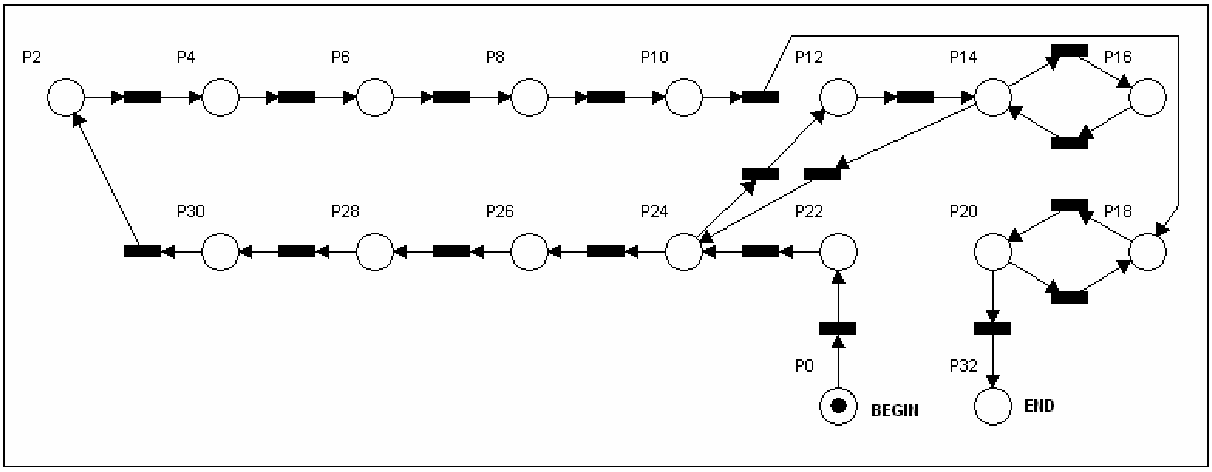

Figure 3: *The Petri Net of the assignment upload: combined studies*

If we focus on the methods and processes of the combined students' learning, on the resource view of study materials, descriptions and sample solutions, we find out they are almost totally consistent with the full-time students (see the interaction matrix in Table 5). The course parts that the students passed during the tutorial can be seen in the matrix in the lower row and column totals relating to the corresponding study materials (P_{21} … P_{29}, P_{11}, P_{13} and P_{15}). The progression of the learning process stays, with the exception of the time arrangement of the taught topics, the same as in the case of the full-time students. The same cells of the interaction matrix are highlighted in grey. The corresponding Petri Net is therefore identical to the Petri Net of the full-time students (see Figure 2).

Table 5: *The interaction matrix of the resource view: combined studies*

	P1	**P3**	**P5**	**P7**	**P9**	**P11**	**P13**	**P15**	**P17**	**P19**	**P21**	**P23**	**P25**	**P27**	**P29**	**Total**
P1	0	604	38	17	49	11	14	14	16	19	28	4	8	7	12	841
P3	530	0	181	52	227	28	24	29	65	97	34	16	22	28	41	1374
P5	29	88	0	1083	767	30	22	23	84	70	17	6	12	15	30	2276
P7	18	47	946	0	579	19	10	18	67	62	9	4	8	7	9	1803
P9	25	120	803	524	0	60	28	24	93	123	14	4	14	17	43	1892
P11	21	38	14	3	20	0	210	61	19	40	9	5	16	11	19	486
P13	15	28	14	7	21	134	0	145	30	46	10	4	13	8	32	507
P15	22	33	20	9	18	44	86	0	32	64	17	3	17	8	20	393
P17	19	62	84	40	56	24	17	19	0	632	29	13	19	31	41	1086
P19	34	114	70	45	89	37	32	33	618	0	35	13	22	20	85	1247
P21	17	38	18	5	16	28	6	5	19	29	0	198	70	38	138	625
P23	9	19	10	3	4	22	8	7	14	16	122	0	102	34	47	417
P25	20	25	19	3	14	13	13	4	17	12	44	55	0	200	67	506
P27	20	29	22	9	15	6	14	7	24	22	41	45	123	0	125	502
P29	29	78	36	10	31	20	26	6	41	51	170	42	62	95	0	697
Total	808	1323	2275	1810	1906	476	510	395	1139	1283	579	412	508	519	709	
PI	0,66	0,55	0,85	0,89	0,83	0,41	0,41	0,37	0,57	0,49	0,56	0,48	0,44	0,39	0,37	55%

The transition index of the interaction matrix of the resource view is 55%, again much lower than in the case of full-time students.

3.3 Differences in the learning of full-time and combined studies

We will define the identity index that will express a level (percentage) of mutual compliance of the two interaction matrices, or Petri Nets. We will obtain a gauge of mutual compliance of the model Petri Net with the real Net acquired, based on the interaction matrix.

Definition 3.2: (link)

Between P_i a P_j of the Petri Net in question there is a link at the moment when we can find T_k transition showing that (P_i, T_k) and (T_k, P_j) are edges of the Petri Net.

Definition 3.3: (identity percentage)

The identity percentage (marked *PT*) of the place P_i of the Petri Net PN_2, as per the Petri Net PN_1, is given by percentage of identical links leading to this place in both nets.

The identity percentage can be calculated in the following way:

$$PT(P_i) = \frac{a_i}{x_i} * 100\%$$

where a_i is a number of identical links leading to P_i in both nets PN_1 and PN_2, and x_i is a number of links leading to P_i of the Petri Net PN_2.

In the event that only identical links lead to P_i of the Petri Net PN_2 as in the Petri Net PN_1, the compliance is absolute (100%). If none of the links leading to P_i of the Petri Net PN_2 is present in the Petri Net PN_1 the compliance is zero (0%).

Definition 3.4: (identity index)

We suppose that the Petri Nets PN_1 and PN_2 contain the same number of n places. The identity index (marked *IT*) for the Petri Net PN_2, as per the Petri Net PN_1. is calculated by the average of the identity percentage for individual places of the net PN_2.

Example:

We will calculate the identity index of the Petri Net PN_2 for the method of the assignment upload for full-time students ((Figure 1; interaction matrix Table 4) as per the corresponding Petri Net PN_1 for combined students (Figure 3; interaction matrix Table 2). We will calculate the identity percentage for individual places:

- No link in the net PN_2 is leading to P_2, so we will not use this place for other calculations.
- In both nets only one link is leading to P_4 (from P_2); compliance is 100%. Similarly, in the case of P_6, P_8 and P_{10}.
- No link is leading to P_{12} in the net PN_1; compliance is zero.
- Similarly, we proceed in other places of the Petri Net PN_2; compliance is always either absolute (one hundred per cent) or zero.

The average of all identity percentages for individual places of the Petri Net PN_2 is 78.6%, i.e. the Petri Net PN_2 corresponds to approximately 79% of the Petri Net PN_1. A similar calculation can be applied to the identity index of the Petri Net PN_1 as per PN_2; 75%. The high identity index proves a remarkable concurrence in methods of the assignment upload by full-time and combined students.

If we focus our attention on the resource view, the concurrence among the students of both forms is even higher; the identity index reaches 97%. It has been generally shown that by preparing the e-learning course and its usage in full-time tuition, with the learning ways and methods of full-time students was extraordinarily close to the learning methods of the combined students.

4. Conclusion

The important contribution is the methodology of generating Petri Nets that represent students' transition through an e-learning course. The models of real transition for students through a course created by Petri Nets confirmed the possibility of modelling tutorial processes in this way. Monitored characteristics of the Petri Nets (transition index *PI* and identity index *IT*) confirmed that a comparison of the conditions for students of full-time and combined studies, supported by e-learning, led at the same time to the merger of learning forms, and full-time students used the advantages of a combined curriculum.

Assignment upload and resource view are not two separate activities in reality, as we have addressed it here. Within the course, they intertwine mutually; students usually study first and only then solve the correspondence assignments. The indicated analysis could be extended further to a mutual confrontation of these activities within the course.

The Educational Technologies course focuses on practical skills. Gained experiences should be followed by another verification of the method by applying it to other courses, mainly in courses focused on theoretical knowledge. Other elaborations of the Petri Nets methodology would surely enable its expansion towards the control and adaptive management of tuition.

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