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UNDERSTANDING ALGORITHMS IN DIFFERENT PRESENTATIONS

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Abstract: Within the framework of the Testing Algorithmic and Application Skills project we tested first year students of Informatics at the beginning of their tertiary education. We were focusing on the students' level of understanding in different programming environments. In the present paper we provide the results from the University of Debrecen, the Universitatea Babes-Bolyai, and the Sapientia Hungarian University of Transylvania in two tasks, which are based on the same algorithm but presented in different forms. We have found that students in Hungary tend to focus on the coding details while with the students in Romania there are only minor differences in the results of the two forms. This difference can be explained by the different acceptance methods of the universities in the two countries and/or by the methods applied in primary and secondary education to solve computer related problems. We can conclude that the approaches adopted by students of Informatics in Hungary may be an explanation for the high attrition rates in tertiary Computer Science education.

Key words: problem solving approaches, presenting algorithms, level of understanding

1. Introduction

The first testing period of the Testing Algorithmic and Application Skills (TAaAS) project – the academic years 2011/2012–2013/2014 – revealed that first year students of Informatics in Hungary starting their tertiary education "…can only think in algorithms in traditional programming environments. They do not regard the recent developments in IT as being driven by algorithms." [1]. We have also concluded that "…methods must be developed and introduced in primary and secondary education, which focus on the development of the students' algorithmic skills in different environments and in different computer related activities; the development of students' algorithmic skills should be independent of computer environments and computer related activities." [1]–[12]. The analyses of the students' results have also revealed that their level of algorithmic skills hardly exceeds that of 5th–8th grade students ([1], [13], Figure 1).

In the subsequent phase of the TAaAS project we invited universities outside Hungary to participate in the testing of first year students of Informatics at the beginning of their tertiary education. In the 2014/2015 academic year six further countries joined the project: Romania, the Czech Republic, Slovakia, Serbia, Poland, and France. In the present paper we provide the results of the Faculty of Informatics, University of Debrecen, Hungary and the two universities from Romania – Universitatea Babes-Bolyai and Sapientia Hungarian University of Transylvania. The specialty of these universities is that they accept Hungarian minorities. The focus of this testing period is on how students interpret counting problems presented in different forms.

2. Testing process

The results of two tasks of the 2014/2015 test are compared in the present paper. The algorithm of the two tasks is the same; however, their implementations are different. Both of the tasks are simple counting algorithms. The input array and the variable which contains the result are provided in both cases. The difference between the two tasks was the presentation of the problem. In one case a pseudo code was provided (Figure 1) [11], [12], while in the other a flowchart with smiles functioned as the items of the input vector (Figure 2).

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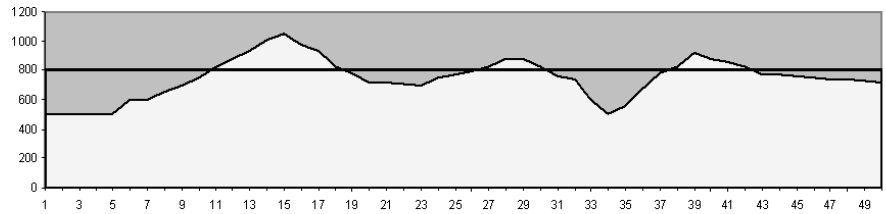
The pseudo code is borrowed from the first round of the 2008/2009 Hungarian Programming Contest for 5th–8th-grade students [13]. The flowchart originated in the TAaAS project. With the smiles and the flowchart, our aim was to present the algorithm in a form which is closely connected to the graphical programming enironments which are preferred in primary and secondary education.

What does the following program do? What is stored in variable DB?



N=50, measured values: 500, 500, 500, 500, 500, 600, 600, 650, 700, 750, 820, 880, 930, 1010, 1050, 980, 930, 830, 780, 720, 720, 710, 700, 750, 770, 790, 820, 880, 880, 820, 760, 740, 600, 500, 560, 670, 780, 820, 920, 880, 860, 820, 770, 770, 760, 750, 740, 740, 730, 720.

```
DB:=0
Loop from i=1 to N
   If X(i)>800 then DB:=DB+1
End loop
```

Figure 1. The pseudo code of a counting algorithm

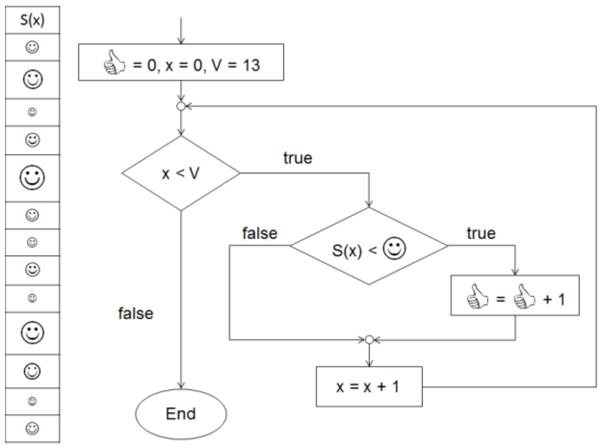


Figure 2. The flowchart of a counting algorithm

3. The sample

The three universities offer similar courses in Informatics. However, there are differences which we have to take into consideration. First of all, the acceptance methods are different in the two countries. In Hungary, students are accepted to the university based on their results in the high school graduation process. The calculating method is detailed in [14]. Here, we must note that entering higher education courses in Informatics does not require any knowledge or any exam qualification in Informatics. Even, if students take a graduation exam in Informatics, they do not have to complete programming tasks. At intermediate level there is no such task, while at advanced level it can be ignored. On the other hand, in Romania there is an entrance exam in Informatics or Mathematics at several universities, which focuses on the students' knowledge in problem solving. The Universitatea Babes-Bolyai accepts students based on their written entrance exam, either in Informatics or Mathematics, or their results in UBB Math-Informatics competitions [15], while the acceptance method at the Sapientia Hungarian University of Transylvania is similar to the Hungarian system, based on the results of the high school graduation exam [16]. We must also note here that the most popular university in Romania offering courses in Hungarian is the Universitatea Babes-Bolyai, while courses in Romanian are available at several other institutes around the country [17], [18]. Consequently, majority students have more options in selecting a tertiary institute than minority students [18].

The other obvious difference between the institutes in Hungary and Romania is the language. In the tested universities in Romania, Hungarian is the minority language; however, they offer courses in Romanian, which is the majority language of the country, and also in English and German. We must note here that the University of Debrecen also offers courses in Informatics in English. However, the foreign language courses are attended by students who arrive mostly from underdeveloped countries in Africa and Asia, whose backgrounds are not known; for these reasons they are not included in this phase of the test.

The test was completed by all the different courses and sites at the universities. At the University of Debrecen four courses were tested: Software Engineering (UD_SOE), System Engineering (UD_SYE), Business Informatics (UD_BI), and Library and Information Sciences (UD_LIS). At the Universitatea Babes-Bolyai students were distinguished by the language in which they study. Based on the languages, four groups of the students are identified: Hungarian (UBB_HU), Romanian (UBB_RO), English (UBB_EN), and German (UBB_GE). At the Sapientia Hungarian University of Transylvania (Sapientia University, SU), the sites of the campuses was different. Here we were able to distinguish two groups: one in Targu Mures (SU_TM) and one in Miercurea Ciuc (SU_MC). Table 1 presents the number of students participating in the test and their results in the decoding of the pseudo code (PSC) and the flowchart (FCH) tasks.

Table 1. The number of students involved in the present phase of the TAaAS project and their average results based on the SOLO categories of understanding [19]–[21]

	Sample	Pseudo code (PSC)	Flowchart (FCH)
	University of Debrecen (UD)		
UD_SOE	117	3.62	2.34
UD_SYE	89	2.65	1.93
UD_BI	86	1.66	1.30
UD_LIS	9	1.00	1.11
	Universitatea Babes-Bolyai (UBB)		
UBB_HU	105	4.68	4.17
UBB_RO	295	2.36	1.72
UBB_EN	166	2.39	1.71
UBB_GE	29	1.00	1.00
	Sapientia Hungarian University of Transylvania (SU)		
SU_TM	136	2.58	2.18
SU_MC	45	1.26	1.15

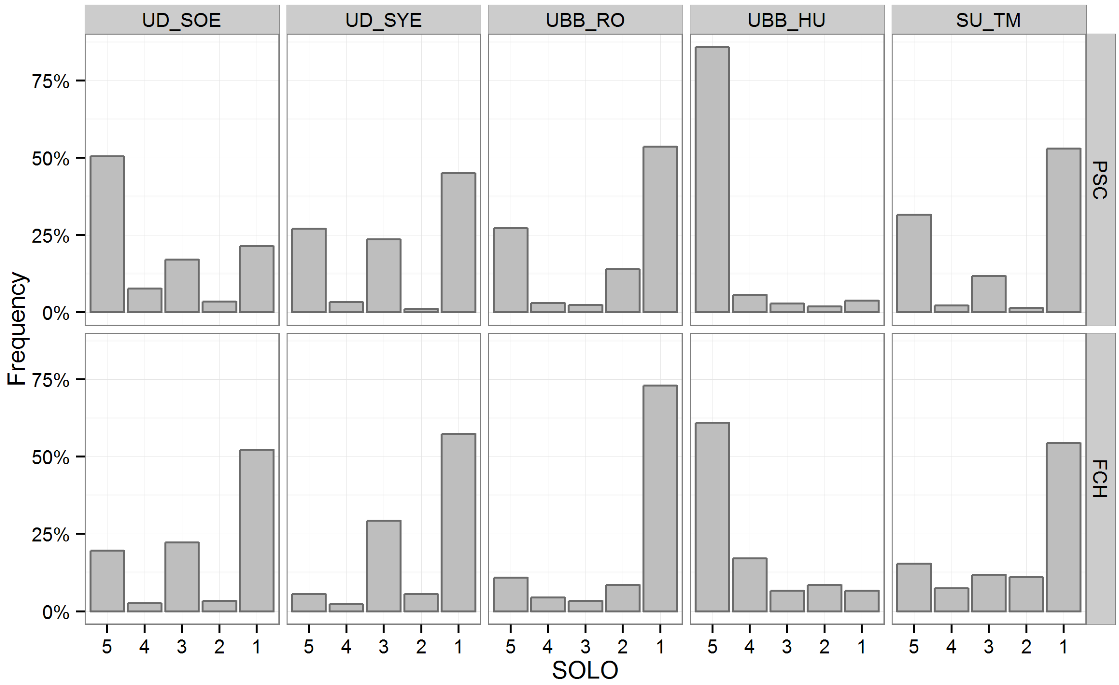


Figure 3. The frequency of the results of the students in the two counting tasks where the evaluation is based on the SOLO categories of understanding [19]–[21]

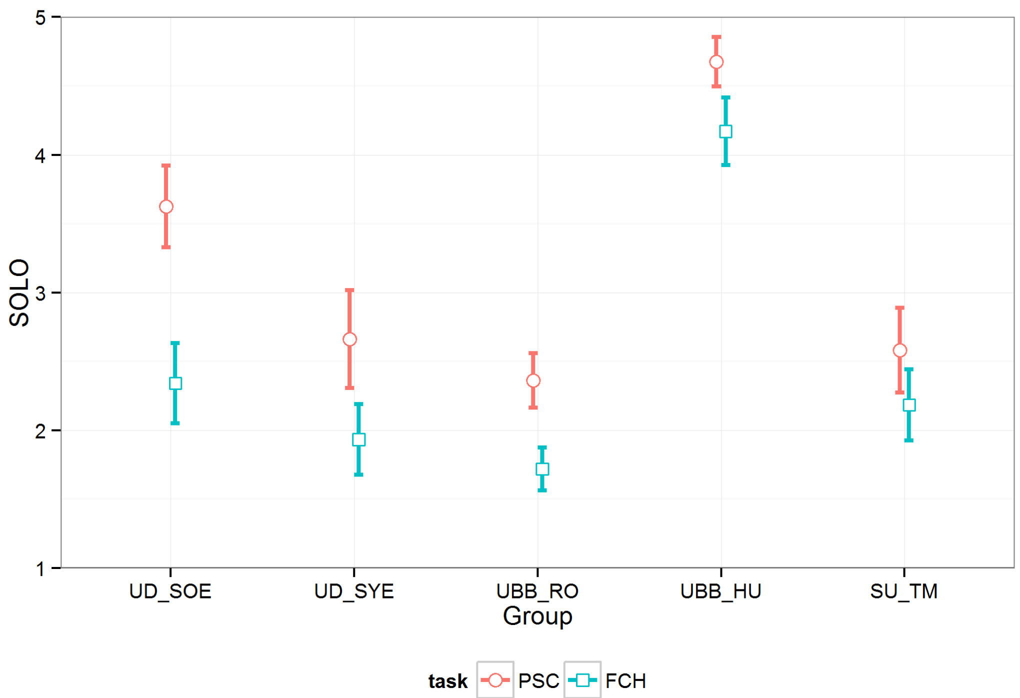


Figure 4. The average results of the students in the two counting tasks

4. The evaluation

To evaluate the students' answers we used the SOLO categories of understanding [19]–[21]. Matching these categories to our tasks we were able to distinguish five categories.

- Ignored (1), those who did not work on the task.

- Prestructural (2), mainly those students who focused on the details of the language and loop, instead of the problem.
- Unistructural (3), those who considered only one aspect of the problem.
- Multistructural (4), those who understood more than one aspect but were not able to form a complete answer.
- Relational (5), those students who gave a correct answer.

Due to the circumstances of the test, the extended abstract SOLO category is left out, since it has no relevance [1].

Based on the SOLO results we were able to calculate the averages of the students' results in the different groups (Table 1, Figure 3–4 and Table 7, Figure 5–6). In the preliminary analysis the averages and the confidence intervals revealed that in the UD_BI, UD_LIS, UBB_GE, and SU_MC courses most students were not able to complete either of the tasks. Consequently, we were not able to compare their results in the two tasks, and they are left out of the detailed analyses. From this point on the following five groups were analyzed: UD_SOE, UD_SYE, UBB_HU, UBB_RO, and SU_TM.

5. Hypotheses

The previous analyses of the results of the TAaAS project have already suggested that students of Informatics in Hungary start their tertiary education with a lower level of computational thinking and algorithmic skills than it is expected by university standards. Based on these results we formed our hypotheses, expecting that the international testing would reveal some reasons for this discrepancy.

H1: There is a connection between the two tasks. We have the methods and the tools to measure the results of the algorithm presented in the two different forms.

H2: There is a significant difference between the results. The result of the FCH task is better than the PSC. The FCH form of the algorithm fulfils the spatial-visual-stimuli-preference of students in the digital age.

H3: There is a significant difference between the groups in both tasks.

6. Results

6.1. All the participating students

The results of the different institutes in the two tasks were compared with the Kruskal-Wallis test. First of all, it was found that there is a significant difference between the analyzed groups in both tasks (in both Kruskal-Wallis tests the group served as the independent variable and the PSC and the FCH as the dependent variable in each test, $p<0.001$). The order of the institutes, based on the results, is similar in the two tasks. In both tasks the best results are from the Hungarian students of the Universitatea Babes-Bolyai (UBB_HU), followed by the SOE students of the University of Debrecen (UD_SOE), with the Romanian students of the Universitatea Babes-Bolyai (UBB_RO) coming last. In the third and fourth position, however, there is a change between the SYE students of the University of Debrecen (UD_SYE) and the TM students of the Sapientia University (SU_TM).

The Kruskal-Wallis post hoc test revealed that the results of the UBB_HU group are different from all the other groups. The UD_SOE group is also different from the other groups. However, there were no significant differences found between the other three groups. In the FCH task another pattern was recognized. The result of the UBB_HU is different from all the other groups. The UBB_RO students, who have the lowest results in this task, differ from the second and third best – UD_SOE and SU_TM students – but not from the UD_SYE group. In no other cases was any significance difference found.

It is also clear from Table 1 and Figures 3 and 4 that the results of decoding the pseudo code (PSC) are higher than the flowchart (FCH) in all the analyzed groups. However, it is remarkable that the difference between the two tasks of the UD_SOE students is much higher than that of other groups. A similar tendency can be found in the UD_SYE group, which explains the switch in the third and fourth positions in the comparison of the two tasks (Figure 4).

Following that we compared the five groups, considering the differences in the results of the two tasks. In this respect, significant differences were also found between the groups (Kruskal-Wallis test, p<0.001, Table 2 and 3).

Table 2. The results of the multiple comparison test after Kruskal-Wallis in the PSC task

Pairs of groups	Observed diff.	Critical diff.	Is it significant?
UD_SOE-UD_SYE	107.16	84.63	TRUE
UD_SOE-UBB_RO	132.47	65.74	TRUE
UD_SOE-UBB_HU	115.37	80.88	TRUE
UD_SOE-SU_TM	114.72	75.87	TRUE
UD_SYE-UBB_RO	25.31	72.76	FALSE
UD_SYE-UBB_HU	222.53	86.69	TRUE
UD_SYE-SU_TM	7.56	82.03	FALSE
UBB_RO-UBB_HU	247.85	68.37	TRUE
UBB_RO-SU_TM	17.75	62.36	FALSE
UBB_HU-SU_TM	230.10	78.16	TRUE

Table 3. The results of the multiple comparison test after Kruskal-Wallis in the FCH task

Pairs of groups	Observed diff.	Critical diff.	Is it significant?
UD_SOE-UD_SYE	40.12	84.63	FALSE
UD_SOE-UBB_RO	79.76	65.74	TRUE
UD_SOE-UBB_HU	210.81	80.88	TRUE
UD_SOE-SU_TM	16.00	75.87	FALSE
UD_SYE-UBB_RO	39.64	72.76	FALSE
UD_SYE-UBB_HU	250.92	86.69	TRUE
UD_SYE-SU_TM	24.10	82.03	FALSE
UBB_RO-UBB_HU	290.57	68.372	TRUE
UBB_RO-SU_TM	63.74	62.36	TRUE
UBB_HU-SU_TM	226.83	78.16	TRUE

Based on the Kruskal-Wallis tests we can conclude that the results of the UD_SOE students are significantly different from all the other groups, except for the SOE_SYE group.

The distribution of the SOLO results in both tasks suggests a merging of the middle three categories (Figure 3). By merging the three middle categories we arrive at a three-phase scale:

- Ignored (I)
- Partially correct (P)
- Correct (C)

With the three-phase scale we can carry out a loglinear analysis of the connections among the results of the two tasks. The variables considered are the groups (G) (5), task PSC (3), and task FCH (3).

Based on the corresponding 5H3H3 contingency table, the following loglinear model fits our data: GHPSC GHFCH PSCHFCH, Khi-squared(16)=11.59, p=0.7714.

The variables are connected considering the pairs; however, there is no ternary interaction. The lack of ternary interaction means that the connection between tasks PSC and FCH does not differ significantly within the groups. We must emphasize here that this result does not contradict the results mentioned previously, since there it was not the connection between tasks PSC and FCH which was tested, but the differences in the results.

The connections among the pairs revealed by the loglinear model are shown by the parameters of the model, but the results can clearly be seen in the cross-reference tables (Tables 4–6).

There is a strong connection between the two forms of the algorithm, which is independent of the groups. Table 4 shows that with an increase in the results of the PSC task an increase can also be detected in the results of the FCH task. We can conclude that solving the two tasks requires similar skills.

Table 4. The crossreference table of the three-phased solutions of the two tasks

PSC \ FCH	I	P	C	Total
I	257 85.7%	38 12.7%	5 1,7%	300 100%
P	73 50%	60 41.1%	13 8.9%	146 100%
C	78 26.4%	91 30.7%	127 42.9%	296 100%
Total	408 55%	189 25.5%	145 19.5%	742 100%

We can read from Table 4 that there is a high probality that the results in task PSC maximize the results in task FCH. Considering the connections between the groups and the results obtained in the tasks, we can observe that the result of the UD_SOE group, whose result is the second best in task SCP, dropped considerably, so its result equals that of the merged sample.

Tables 5 and 6 show the connections between the groups and the tasks. In the rows of the table the distribution of the results is presented in absolute numbers and in percentages. In the PSC task the most frequent category is C in the UD_SOE, UBB_HU groups, while in the FCH task this is only true for the UBB_HU group. In all the other groups the most frequent category was I.

Table 5. The distribution of the results of the PSC task in the five groups. The shaded cells show the highest frequency in the groups.

G \ PSC	I	P	C	Total
UD_SOE	25 52.9%	33 28.2%	59 50.4%	117 100%
UD_SYE	41 46.1%	24 27%	24 27%	89 100%
SU_TM	72 52.9%	21 15.4%	43 31.6%	136 100%
UBB_HU	4 3.8%	11 10.5%	90 85.7%	105 100%
UBB_RO	158 53.6%	57 19.3%	80 27.1%	295 100%
Total	300 40.4%	146 19.7%	296 39.9%	742 100%

Table 6. The distribution of the results of task FCH in the five groups. The shaded cells show the highest frequency in the groups.

FCH / G	I	P	C	Total
UD_SOE	61 52.1%	33 28.2%	23 19.7%	11 100%
UD_SYE	51 57.3%	33 37.1%	5 5.6%	89 100%
SU_TM	74 54.4%	41 30.1%	21 15.4%	136 100%
UBB_HU	7 6.7%	34 32.4%	64 61%	105 100%
UBB_RO	215 72.9%	48 16.3%	32 10.8%	295 100%
Total	408 55%	189 25.5%	145 19.5%	742 100%

6.2. Students who worked with the tasks

In the following, we present the results of those students who worked with the problems. We must note here that we do not have reliable information about the students' reasons for ignoring the tasks. However, informal interviews revealed that there are at least two reasons: they did not know the answers, or they did not take the test seriously.

Table 7. The number of students working with both tasks and their average results based on the SOLO categories of understanding

	Sample	Pseudo code (PSC)	Flowchart (FCH)
	University of Debrecen (UD)		
UD_SOE	53 – 45.29%	4.51	3.85
UD_SYE	32 – 35.96%	4.06	3.34
	Universitatea Babes-Bolyai (UBB)		
UBB_HU	96 – 91.43%	4.84	4.42
UBB_RO	61 – 20.68%	4.34	3.80
	Sapientia Hungarian University of Transylvania (SU)		
SU_TM	50 – 36.76%	4.42	3.90

Table 7 shows the number of students who worked with both tasks, while Figure 5 illustrates the distribution of their SOLO-results, and Figure 6 the average of these results. Ignoring the uncompleted tasks, we have a significant difference between the groups in the PSC task (Kruskal-Wallis test, $p<0.001$). However, the comparison of the pairs revealed that this difference is due to the difference between the best and the weakest groups, UBB_HU and UD_SYE, respectively. There was no significant difference found between the other groups. In task FCH, a significant difference was also noted between the groups. In this task, on one hand, similar to task PSC, the best and the weakest groups' results proved to be significantly different. On the other hand, we have found a significant difference between the two groups from the UBB, the Hungarian and the Romanian students, respectively.

As was mentioned earlier, these results can be explained by the distribution of the Romanian and the Hungarian students in the tertiary institutes in Romania [18]. However, there might be another explanation which is strongly supported by the results of research into minorities. This research has found that "minority parents … urge their children to study harder…" "…realizing the importance of higher education studies, they try to do their best in any way they can to support their children in becoming successful students." [22].

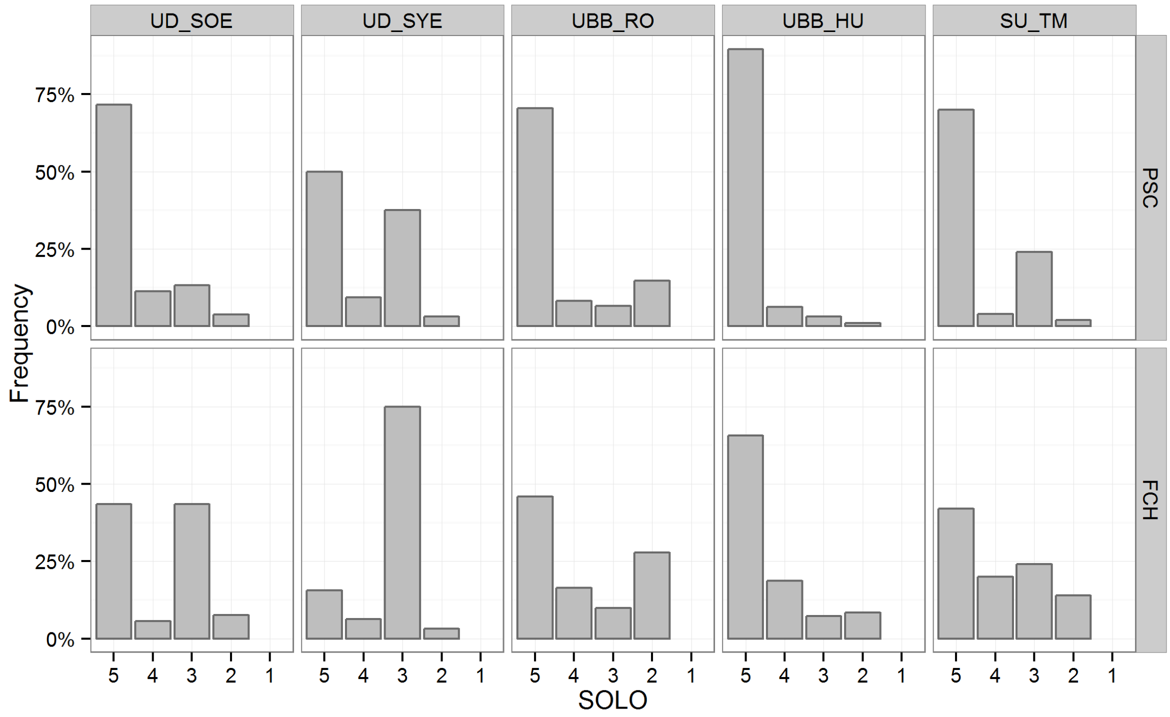


Figure 5. The frequency of the results of the students who worked with the problems, based on the SOLO categories of understanding

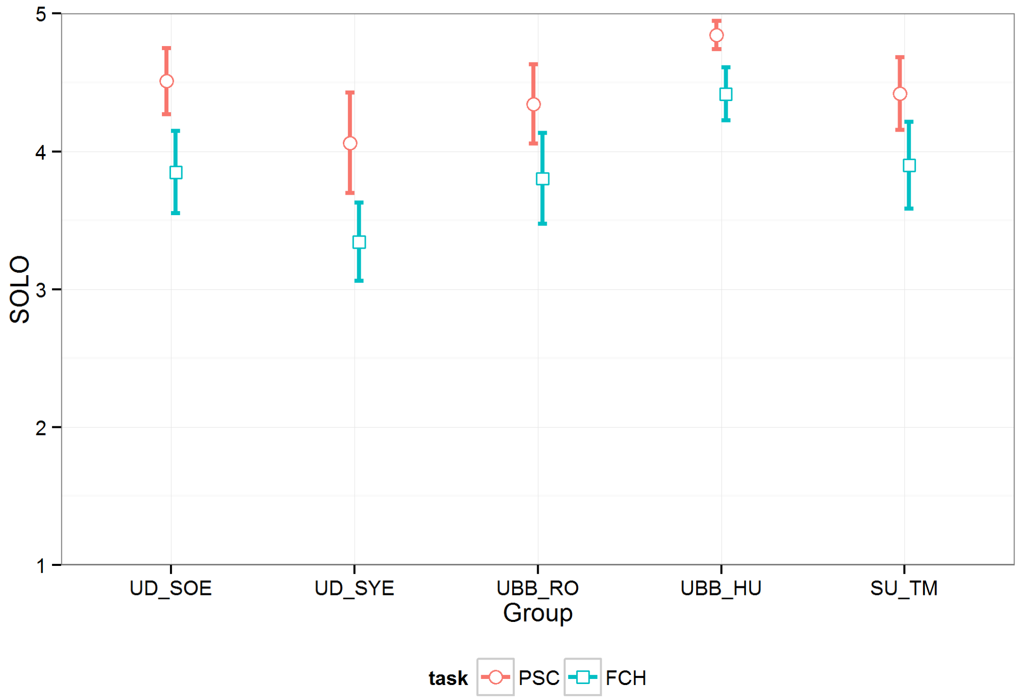


Figure 6. The average results of the students who worked with the problems

When comparing the differences between the results of the two tasks completed by the groups no significant difference was found (Kruskal-Wallis test, p = 0.573). In this sense none of the groups are different from the others. Leaving out those students who did not complete the task reduced the differences between the groups. Consequently, the results of the students who did not complete the tasks would shed light on the lack of algorithmic skills, problem solving approaches, and attitude.

7. Revisiting our hypotheses

In our test, we have presented two tasks based on the same counting algorithm. The only difference between the tasks was their appearance. The pseudo code tends to follow the form of coding typical of high level programming languages, so there was a choice between the smiles with the flowchart to reveal whether the students prefer the spatial-visual stimuli to the code based form [23]. Considering our hypotheses we have come to the following conclusions.

Hypothesis H1 was formulated considering the similarities of the two tasks. In accordance with our hypotheses, there is a connection between the two tasks, so when an increase is detected in the result of the PSC task a similar tendency is found in the FCH task. It was also found that there is a significant difference between the two tasks. However, the results are better in the pseudo code than in the flowchart task, in all the analyzed groups. Based on this result we must reject the second half of our H2 hypothesis. Students of Informatics prefer the form which is closer in appearance to the coding used in high level programming languages to the visualized input. When comparing the groups we found significant differences between them.

However, in the two tasks different connections and differences were recognizable. It is clear that the Hungarian students of UBB are significantly better in both tasks than the other groups. H3 hypothesys is found true. The SOE students are significantly different from all the other groups in the pseudo code task, but not in the flowchart task. In this task they are different from the best and the lowest results. A similar tendency is detected in the other group of SYE students in Hungary. These results suggest that students in Hungary are more code-dependent than students in Romania. They tend to focus more on the coding details than on the algorithm.

Apropos of this circumstance, one can surmise that the better results of the Hungarian students are related to the fact that they are an ethnic minority in Romania, and so performing well in a Hungarian-language programme of the most prestigious Romanian state university may also mean protecting and asserting the national identity of that minority. Their learning habits and knowledge-management can perhaps relate to strategies of identity management that Erzsebet Dani discusses in her book on the identity dramas and intercultural strategies of Hungarians in Romania [17].

8. Conclusion

In the Testing Algorithmic and Application Skills (TAaAS) project we tested the level of algorithmic skills of first year students of Informatics. In the present paper we have provided the results of five groups of students from three universities: University of Debrecen, Universitatea Babes-Bolyai and Sapientia Hungarian University of Transylvania.

The tasks of the test were to measure how the students recognize an algorithm if it is presented in two different forms. To decide on the level of understanding and students' algorithmic skills the SOLO categories were applied. Both tasks were a counting algorithm, once given in the form of a pseudo code with numbers, and in the other case in a flowchart with smiles of different sizes. This latter form was selected to prove the theory that students in the digital age prefer spatial-visual stimuli to character-based sources.

The best results were achieved by the Hungarian students of the Universitatea Babes-Bolyai, followed by the SOE group of the University of Debrecen, while the worst were the Romanian group of the Universitatea Babes-Bolyai. It is remarkable that in all the groups the results were better in the pseudo code task than in the flowchart. Significant differences can be detected in the size of the differences. This difference caused the change in the order of the results between the SYE students of the University of Debrecen and the students of the Sapientia University. The greatest difference between the two tasks was found in the SOE students of the University of Debrecen.

Based on the results of our analyses we have come to the conclusion that the students of the universities in Romania were able to recognize the algorithm in the two different forms better than the students in Hungary. The students' results in Romania did not change significantly when they were faced with a non-character based presentation of an algorithm. Using the SOLO categories and the comparison of the results of the two tasks we have found the level of understanding of the students in Hungary is lower than that of the students in Romania.

This can be explained by the different acceptance methods of the students and/or the approaches the students take to studying programming and problem solving in primary and secondary education. In general, we can conclude that students in Romania start their tertiary education in Informatics with a higher level of understanding than students in Hungary.

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