Cross-Curricular Connections and Knowledge-Transfer Elements in Data Management

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Abstract: In this study, we present the items and the results of a complex task in which the data management knowledge of students was measured in the 2018 academic year. Our results obtained from statistical analyses are in line with previous studies that analyzed informatics/computer science coursebooks and concluded that current books favour surface-based approaches and consequently, are unsuitable for developing students' computional thinking skills. Furthermore, our study found evidence that contrary to Prensky's unproven claim, digital children also need teachers' support in spreadsheet environments to learn effective computer problem-solving strategies, avoid common spreadsheet errors, and acquire basic algorithmic and programming skills. Our results, clearly show that the widely accepted low-mathability approaches should be excluded from the teaching-learning process due to their ineffectiveness, and should be replaced by high-mathability approaches, which support knowledge-transfer, effective end-user computing, and introductory studies to "serious" informatics/computer sciences.

Keywords: Informatics; algorithmic skills; computational thinking; computer problem-solving; knowledge-transfer

1 Introduction

Informatics as a school subject is compulsory in grades 6-10, with one class a week. Additional lessons and courses in lower grades are optionally available. Previous measurements, classroom experiences, and teacher interviews have shown that the current National Base Curriculum and the Hungarian frame curricula in informatics contain several vague, difficult-to-understand terms that make teachers' planning difficult. We also found that informatics/computer sciences (ICT) education is surface-based since most ICT teachers focus on teaching interfaces instead of problem-solving [1] [2] [3]. Within the frame of this decontextualized [30] low-mathability approach [1], students carry out erroneous slow thinking [21] activities instead of highmathability [1] concept-based real-world problem-solving [3] with the right proporsion of fast and slow thinking [21] [28].

Computational thinking is mentioned as the fourth basic skill in the current Hungarian basic educational documents [4]-[15] along with Reading wRiting, and aRithmatic [16]. However, it is not clear from these documents how ICT education supports the development of an algorithmic approach, or cross-curricular and intra-ICT knowledge transfer [17].

In addition to subjective classroom experiences [18] and tool-centered low-mathability tests [28], we needed an objective high-mathability, contextualized measurement tool to ascertain or disprove students' behaviors and the presence or absence of knowledge elements associated with them, during classes and computer problem solving [18].

For this reason, we designed a mini-competence test to identify students' knowledge transfer elements and to measure students' computational thinking and algorithmic skills in traditional and non-traditional programming environments. The purpose of the assignments was to directly measure how students apply the knowledge acquired in other subjects and in other areas of informatics in new environments and how they recognize algorithms and common knowledge transfer elements.

2 Methodology

The essence of our mini-competence test is to measure the students' level of computational thinking skills which is in complete accordance with our high-mathability teaching-learning approach [44]. According to our knowledge transfer based method, the primitive data types are introduced in spreadsheet management accompanied with real world tables, and then this knowledge can be transferred to database management and "serious" programming.

3 Sample

Elementary and secondary students from the 7-10th grades completed the test all over Hungary. A total number of 8880 students from 93 schools returned the completed tests [19] [20]. A further 269 tests were returned from the 5-6th and the 11-12th grades (additional tests) (Table 1).

Table 1
The sample of the mini-competence test, measuring the students' knowledge-transfer skills

Grade	Sample
7	1561
8	1639
9	3059
10	2352
additional tests	269
total	8880

4 Hypotheses

In this study, we analyze students' basic knowledge transfer skills in data management and seek answers as to how different ICT topics prepare for data management studies. Our primary goal is to demonstrate how knowledge transfer tasks support schema construction through reliable, fast-thinking [21][21]. Taking all these aims into consideration, we have set up the following hypotheses related to the subject of data management:

[H1] In cases in which students recognize the integer correctly they recognize the real data type also correctly in a significantly greater extent.

[H2] In cases in which students recognize the largest number in a vector, they also recognize the smallest number also correctly in a significantly greater extent.

[H3] In cases in which students recognize both the integer and the real datatypes, they can also recognize the smallest and largest numbers in the vector also correctly to a significantly greater extent.

[H4] The students' results significantly improve by the end of 10^{th} grade.

The Description of The Task

Based on the current Hungarian ICT frame curricula, students can interpret data, and recognize different elementary and complex datatypes [5] [6] [7]. In accordance with the frame curricula, the DigComp 2.1 at Foundation Level 2 requires the same skills and emphasis as at Levels 3 and 4 (Figure 1).

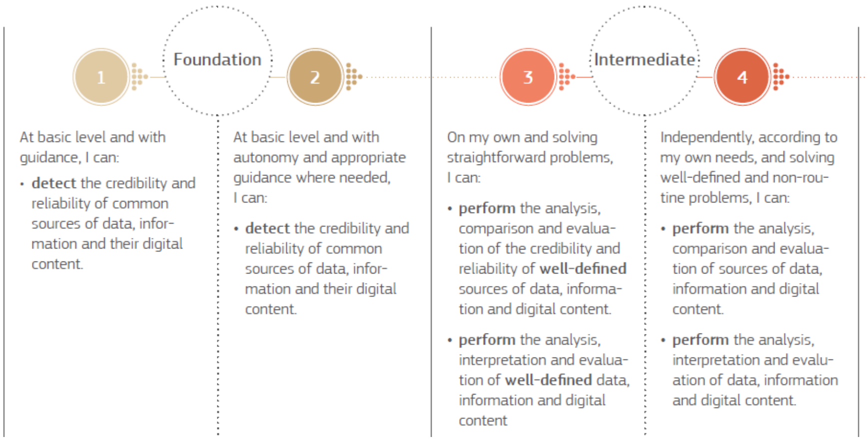


Figure 1

DigComp 2.1, Competence area 1: Information and data literacy 1.2 Evaluating data, information, and digital content. To analyse, compare and critically evaluate the credibility and reliability of sources of data, information and digital content. To analyse, interpret and critically evaluate the data, information; and digital content. Proficiency Levels 1-4.

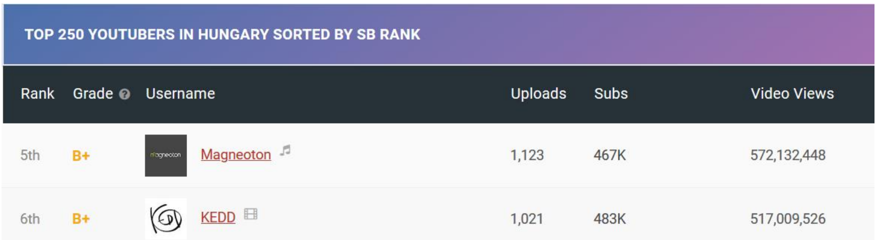
To measure the above-mentioned basic data management skills, our test consists of a task considering the datatypes, the number of data records in the table, and the minimum and maximum values.

	A	B	C	D
1	Username	Uploads	Subs	Views
2	VamosART	484	1,107,555	226,195,766
3	Videómánia	338	833,23	254,545,702
4	PamKutya	120	809,866	223,441,355
5	LetsGoMartin	176	725,638	162,798,559
6	TheVR	1,062	592,675	213,550,948
7	luckeY	1,183	561,13	150,341,428
8	Peter Gergely	100	548,241	79,713,757
9	Scribble Netty	159	546,049	74,234,471
248	Szilvaglam	87	61,899	3,918,538
249	rance flow	524	61,863	53,275,385
250	KIS GRÓFO (official)	9	61,65	30,712,031
251	KODIAK	736	61,467	14,599,194

Figure 2

DigComp-compatible task for detecting the credibility of sources of data, information, and their digitial content, performing the analysis, interpreting, and evaluating well-defined data, information, and digital content

To complete the items of the task, an adapted spreadsheet table was provided, converted from the "Top 250 YouTubers Channels in Hungary" webtable [24] [24] [22]. In the teaching-learning process, the use of authentic and adapted data sources plays a crucial role since tables with real contents have a motivating effect on students [25] [25]. On the other hand, it has also been shown that the teaching of informatics and spreadsheets is rather interface and tool-oriented, and applies decontextualized data [26] [28] [29] [30]. Measuring the effectiveness of these contradictory approaches and proving how they support the development of students' computer problem-solving strategies and computational thinking skills are the aims of the present paper.


TOP 250 YOUTUBERS IN HUNGARY SORTED BY SB RANK

Rank	Grade	Username	Uploads	Subs	Video Views
5th	B+	Magneoton	1,123	467K	572,132,448
6th	B+	KEDD	1,021	483K	517,009,526

Figure 3
Top 250 YouTubers Channels in Hungary

The complexity of this task derives mainly from the semantics of the comma; whereas in English the comma functions as a thousand-separator character, in Hungarian the comma stands for the decimal character. Although the country on the SocialBlade website can be selected, the syntax of the content does not follow this selection, nor does it match the rules of the selected language. The Uploads column contains the number of uploads and the Video Views the number of views, which are integers, considering the semantics of these data.

Task-Solving with Datatypes

In Excel and most modern spreadsheet environments, datatypes can easily be recognized based on the default alignment settings. According to these arrangements, the following default alignments are widely accepted (Table 2).

Table 2
The default datatype-alignments in spreadsheet programs

datatype	alignment
text	left
integer	right
real number	right
logical	center
errors	center
datatype	alignment

The appearance of graphical interfaces has undoubtedly simplified the use of computers for those who do not have advanced IT skills. However, the interpretation of these graphic "messages" requires competencies that can be significantly accelerated in well-organized and planned educational environments. A further aim of our testing was to investigate whether it is necessary to teach data management in spreadsheet environments [30] [32] [22] or it is sufficient to allow students to explore and operate alone in the graphic interfaces, bringing their native knowledge with them [33] [34].

	Integer	Real	Text	Logical	Date	None
Column A	☐	☐	☒	☐	☐	☐
Column B	☒	☒	☐	☐	☐	☐
Column C	☐	☒	☒	☐	☐	☐
Column D	☐	☐	☒	☐	☐	☐

Figure 4

The first item of the task: selecting the datatypes of each column of the presented the table

Based on the adapted table (Figure 3), the datatypes of Columns A-D are presented in Figure 4. Column A is the simplest since it consists of the name of the youtubers; consequently, the datatype is text in this column. Considering the semantics of Columns C-D, the datatypes should be integers. However, one comma turns these integers into real numbers, while two commas are into strings. Consequently, Column B has both integers and real numbers, Column C a string and real numbers, and Column D strings, exclusively, due to the two commas.

The largest number in Column B is: ....

The smallest number in Column B is: ....

Figure 5

The items regarding the recognition of the minimum and the maximum values in column B

There are two other items related to the recognition of datatypes and contents, asking the minimum and maximum values in column B (Figure 5). The purpose of this open-ended task was to filter out random answers in the previous multiple-choice item.

The correct solution to the problem is that the values shown in column B have a maximum of 736 and a minimum of 1,062 in Hungarian and European Excel (Figure 6) (1.062 in English Excel).

	A	B	C	D
1	Username	Uploads	Subs	Views
2	VamosART	484	1,107,555	226,195,766
3	Videómánia	338	833,23	254,545,702
4	PamKutya	120	809,866	223,441,355
5	LetsGoMartin	176	725,638	162,798,559
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Figure 6

The lowest (red) and highest (green) values in column B

The next question in the test focuses on the identification of the data records in the table. The table has 251 rows, of which the first row contains the field names, so the number of data records is 250, of which Rows 10-247 are hidden (Figure 7).

How many data rows (records) are in the table?..

Figure 7

To identify the data records in the table

Datatypes as the Knowledge-Transfer Elements of the Task

One of the most important cross-curricular knowledge-transfer elements of the table is the semantics of the comma, a problem that arises in the conversion process from webtable to datatable [26] [24] [35] [22]. The concept of datatype can also be considered an intra-informatics knowledge-transfer element because if students learn datatypes in a spreadsheet environment, this knowledge is transferable to further studies in database management and programming since in spreadsheet environments, due to their informative graphical interfaces, the subject of datatypes can be introduced effectively [26] [36] [37] [38]. It has also been proved that the combination of the functional language of spreadsheet programs and high-mathability approaches to spreadsheeting would serve as an introduction to programming [39] [40] [41]. Programming in spreadsheet environments combines the benefits of both the functional languages and the graphical interfaces, providing a programming tool for non-professional IT end-users.

A further cross-curricular relationship to mathematics is recognizable, as the set of natural numbers are extended to integers in elementary school in the 5th grade, to decimal fractions in the 6-7th grades, and to irrational numbers in the 7-8th grades, thus introducing the concept of real numbers [42] [43].

5 Results

The number of answers considering the datatypes in Columns A-D is presented in Table 2. It was found that 65% of the students marked the datatype correctly in column A (5774 students). 3722 and 3374 students answered correctly that there are integers and real numbers in column B, respectively. In column C, 3711 and 1201 students marked correctly the real number and string datatypes. In column D, 1159 students answered correctly that the datatype is a string (Table 3).

Table 3
The number of responses to the datatypes in each column

	Integer	Real	Text	Logical	Date	None
Column A	642	485	5774	284	138	372
Column B	3722	3374	860	437	206	259
Column C	2138	3711	1201	793	311	392
Column D	2370	2596	1159	1078	290	650

In the minimum-maximum item, several students wrote 1183 for the largest and 9 for the smallest number (Table 5). Considering the incorrect answers, we can conclude that these students were unaware of the semantics of the comma; they recognized the comma as the thousand-separator character and did not realize the change in its role. The minimum value in column B was correctly answered by 865 students, which is 10% of the sample, and the maximum by 963 students, 11% of the sample.

Considering the number of data records, 17% of the students answered incorrectly that there are 251 data records, while 357 answered 12, 365 answered 13, and 954 answered 3 or 4 (Table 3).

The correct number of data records was answered by 822 students, which is only 9% of the sample (Table 4). We also must call attention to the high number of students who skipped this task.

Table 4
The number of responses to the data records

	Number of records					
Answer	250	251	12	13	3 or 4	ignored
Marked	822	1500	357	675	959	4567
%	9	17	4	8	11	51

Those students who answered 251 realized that there are hidden rows in the table, but did not separate the row of field names from the data records. Those who answered 12 are aware of the concept of data record and field name but did not notice that there are hidden rows in the table. In contrast, those who responded 13, neither noticed the hidden rows nor the row of the field name. All they did was count the number of rows in the sample table presented. Those who answered 3 or 4, did not know the definition of either a data record or a field name.

Table 5
The number of responses to the lowest and highest values

	Maximum			Minimum		
Answer	736	1183	ignored	1,062	9	ignored
Marked	963	4908	3009	865	5010	3005
%	11	55	34	10	56	34

As presented in Figure 8, there are 933 students who recognized both the integer and the real number datatypes in column B, while 815 students found the minimum and maximum values correctly. The comparison of the pairs revealed that there are only 154 students who recognized both the datatypes and the minimum and maximum values. This result shows that only 154 students were able to combine all the knowledge elements required to complete the task – integer and real datatypes, the syntax and sense of the comma in numbers in Hungarian –, which is 1.7% of the sample.

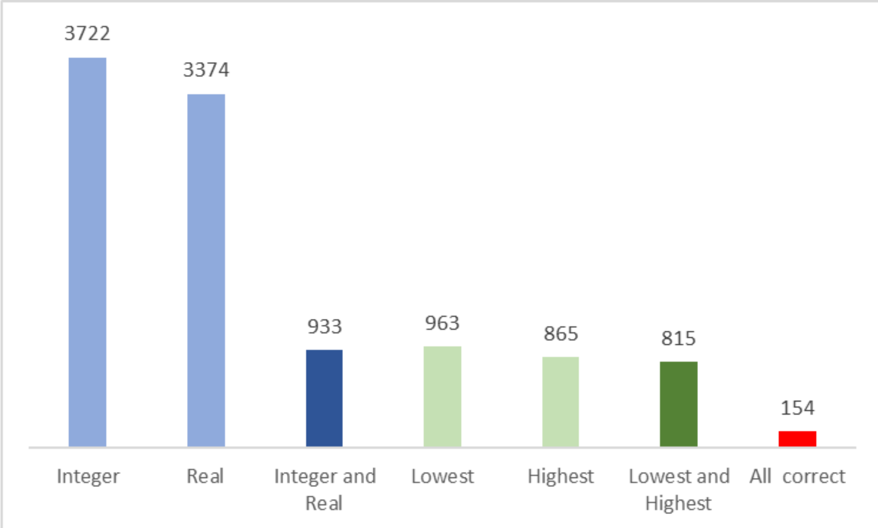

Figure 8

The number of students who correctly recognize the datatypes, the extrema in the datatable

We performed an independence and homogeneity test to reveal the relationship between the recognition of integer and real numbers, and found that they make errors symmetrically, which means that if they recognize one datatype, there is no guarantee that they also recognize the other (Table 6). Based on this outcome, we must reject hypothesis H1.

In the comparison of the results of the different age groups, we found that there is only a minimal improvement by the end of grade 10 ($p < 0.001$). This result failed to validate hypothesis H4.

Table 6

Testing independence in SPSS: those who marked the integer also marked the real datatype

		B_real		Total
		not marked	marked	
B_real	not marked	2714	2441	5155
	marked	2788	3374	3721
Total		5502	3374	8876

To confirm hypothesis H2, in cases in which students recognize the smallest value in Column B, they also recognize the largest. We made an independence test with the Chi-square test. Based on the result of the cross-table, we can say with a probability of 0.85 that hypothesis H2, due to the asymmetry of the matrix, is proved ($p < 0.001$) (Table 7).

Table 7

Chi-square test in SPSS: those students who found the smallest value could find the largest value, too

		minimum	
		ignored	marked
maximum	ignored	99.4%	0.6%
	marked	15.4%	84.6%

We can conclude that students who recognized one of the datatypes did not necessarily recognize the other. On the other hand, the analysis proved that if one of the extrema is found, so is the other. Based on these findings, hypothesis H1 is rejected, while H2 is proved. However, at this phase of the evaluation, it was not clear what the connection is between the datatypes and the extrema.

In hypothesis H3, we assumed that if the students recognize both datatypes, they are also able to tell the minimum and maximum values in column B. To prove or reject this hypothesis, we performed a Chi-square test. We found that a greater proportion of students recognized the extrema in cases in which they recognized the datatypes; however, no relation was found between the two variables ($p<0.001$) (Figure 9).

Figure 9 presents the results of the extremum-item in connection with the students' recognition of datatypes. Students not recognizing any of the datatypes have the lowest results in finding the extrema. Of those who recognized one of the datatypes, 10.6% recognized the minimum and 11.9% the maximum. Of those who recognized both datatypes, reached 18.1% and 19.3% in the minimum- and maximum-item, respectively.

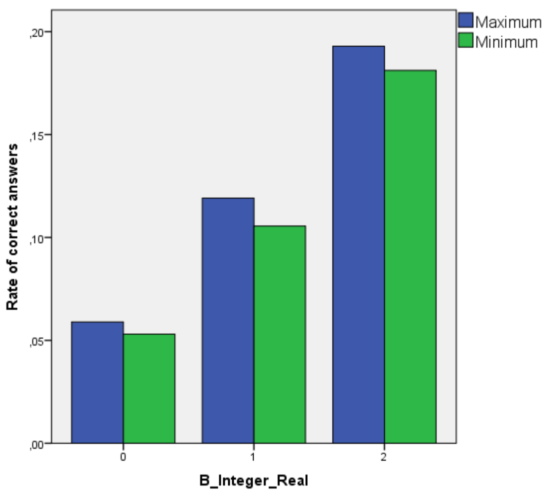

Figure 99

The percentage of students recognizing 0, 1, and 2 datatypes and solving the maximum (blue) and minimum (green) items correctly

6 Summary

Based on our testing procedure, we were able to prove that students make errors symmetrically in recognizing datatypes. This means that even though they recognize one datatype, the other will not necessarily be recognized. With this result, hypothesis H1 is rejected, so the recognition of one datatype does not imply the recognition of another.

An independence test was performed with the Chi-square test, which shows that, with a probability of 0.85, if students recognize the largest number in a vector, they also recognize the smallest number ($p<0.001$), thus confirming our H2 hypothesis.

Only 154 of the 8880 students can recognize both the datatypes and the minimum and maximum values, representing only 1.7% of the sample. We performed a Chi-square test to determine whether there was a relationship between the student's recognition of datatypes and extrema. It is not possible to draw a clear conclusion from the result, due to the low number of answers, but the tendency shows that after recognizing the datatypes, the students could determine correctly the lowest and highest values. However, we cannot prove our hypothesis with this test, so further measurements are needed for this purpose.

Conclusions

In this study, we presented the items of a task and their solutions, from a test focusing on the knowledge-transfer skills of 7-10th grade Hungarian students.

One aspect of the data management knowledge of students was tested in a spreadsheet environment since previous studies proved that high-mathability spreadsheet approaches would serve to teaching introductory data management and programming effectively and efficiently [39] [39] [44].

The results of our test, however, proved that low-mathability approaches to and self-taught experiences of spreadsheeting do not help students' understanding of datatypes and the problems connected to them [45]. These findings are in complete accordance with previous studies which claimed that decontextualized, interface- and tool-centered approaches do not help develop computational thinking skills, and consequently, effective problem-solving abilities [26] [36] [37] [38].

Our results, based on the students' performance in this knowledge-transfer focused test, might call attention to the lack of students' knowledge in end-user computing, especially in data management. Furthermore, it is also clearly shown that the widely accepted low-mathability approaches should be excluded from the teaching-learning process, and should be replaced by high-mathability approaches, which support knowledge-transfer, effective end-user computing, and introductory studies to "serious" informatics/computer sciences [46] [47].

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