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EXAMINATION OF SOLUTION TIMES TO COMPUTER SCIENCE AND PHYSICS TASKS: A STUDY IN SLOVAK AND HUNGARIAN SECONDARY SCHOOL STUDENTS

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Abstract: *The paper is based on a wider empirical study which was performed as part of a project examining scientific, mathematical and algorithmic thinking of secondary school students in Slovakia and Hungary. Here, some results are presented, focusing on the evaluation and comparison of students' responses to computer science and physics tasks by considering the solution times. In all four computer science tasks, we found significant differences in response times between correct and incorrect answers, while in physics tasks, there was a significant difference only in one of the four tasks.*

Keywords: STEM, secondary education, computer science, physics, solution time

INTRODUCTION

In today's knowledge and information-based society, unsurprisingly, there is a high and still growing demand for specialists who have the necessary expertise and skills in STEM (science, technology, engineering and mathematics) areas. The importance of STEM education is widely recognized, and there are many publications and research projects worldwide dealing with this topic.

One of the main research objectives of a larger project realized at our university with financial support from the grant agency VEGA (Slovakia), was to identify the reasons for low interest in STEM subjects among Slovak and Hungarian secondary school students. The project studied the scientific, mathematical, algorithmic and problem solving thinking, understanding difficulties of students, and their learning styles and attitudes towards STEM sciences, including computer science (Juhász & Tóth, 2021; Szarka et al., 2021; Svitek, 2022). In this paper, we present some partial results of this larger project, focusing on the assessment of computer science tasks and physics tasks. We show data suggesting that analysis of solution times can provide additional insight into students' algorithmic and scientific thinking.

1. ALGORITHMIC AND SCIENTIFIC THINKING

In recent years, algorithmic thinking has received increased attention. It is an important core competency in computer science which together with problem solving, can be considered one of the basic pillars of computational thinking (Wing, 2006; Korkmaz et al., 2017). Moreover, some researchers regarded algorithmic thinking as the most susceptible part of computational thinking for being measured in educational research studies (Román-González et al., 2018). According to Futschek (2006), algorithmic thinking is a set of different abilities, and its fundamental purpose is to construct algorithms that can solve given problems.

Algorithmic thinking is a fundamental skill that should be incorporated into the curriculum at all levels – its importance in primary education as the basis of learning has been already recognized by many researchers (Futchek & Moschitz, 2011). Futschek (2006) emphasizes that problems fostering the development of algorithmic thinking should not be too simple, but the problem statements should be easily comprehensible. Programmable robots as well as online puzzle-based game learning systems can also enhance algorithmic thinking skills and puzzle-solving performance (Czakóová, 2020; Hsu & Wang, 2018).

Scientific thinking can be defined as a type of knowledge seeking which encompasses any instance of purposeful thinking that has the objective of enhancing the seeker's knowledge (Kuhn, 2002). It can be described by the following processes: analysis of phenomena and problems, formulation of questions and hypotheses, selection of methods, data collection, making observations, investigation, display and analysis of data, identification and control of variables, pattern recognition, design and execution of experiments, testing hypotheses, evaluation and interpretation of results, making inferences, and communication and presentation of results (Kuhn, 2002; Adey & Csapó, 2012; Szarka & Juhász, 2019).

Scientific thinking involves many cognitive capabilities including, but not limited to, analogical reasoning, casual reasoning, induction, deduction, and problem solving (Dunbar & Fugelsang, 2005). However, Kuhn (2002) emphasizes that science education does not necessarily involve scientific thinking. One recent and influential approach to science education is the inquiry-based learning approach. It is a teaching method that encourages students to ask questions and propose hypotheses, collect data that test the hypotheses, reach conclusions, and then reflect upon both the original problem and the thought processes they used to solve the problem (Dunbar & Fugelsang, 2005). A detailed analysis of inquiry-based learning in the context of STEM education can be found in (Morze et al., 2018).

2. METHODOLOGY

Conducted in September and November 2021 with the financial support of a project VEGA, the survey involved 1517 first and second year secondary school students from Slovakia and Hungary. In Slovakia, a total of 18 secondary schools took part in it, of which 12 were with Hungarian teaching language, one with Slovak teaching language and 5 schools were with both teaching languages – Hungarian and Slovak depending on the class. In Hungary, the survey involved five secondary schools. The sample distribution by gender was as follows: 628 male students (41.4%) and 888 female students (58.6%), one participant did not provide the gender.
In the survey, the following five measurement instruments were used: background questionnaire, STEM assessment test, logical thinking test (Raven, 2000), inductive reasoning test, and Kolb's learning style questionnaire (Kolb, 1984). The most extensive measurement tool was the STEM assessment test with 20 tasks, which contained 4–4 tasks (items) from school subjects such as physics, chemistry, biology, mathematics, and informatics. The test items were chosen from elementary school curricular materials, taking into account that part of the participants were first year students who have just begun their secondary school studies. Data acquisition was performed on computers and tablets under the personal supervision of a project team member. Participants completed the measurement instruments online using a specifically designed and previously tested framework (Tóth et al., 2021), which allowed test-takers to securely log in with a unique pre-generated username and password. This online measuring system displayed only one test item at a time, and the students were not allowed to return to a previously solved task. Since the system allowed the measurement of the time students spent on solving each item, it became possible to examine their responses taking into consideration the elapsed solution time, which is usually not available in traditional paper-based surveys. Thus, in this study, we have formulated the following research questions:

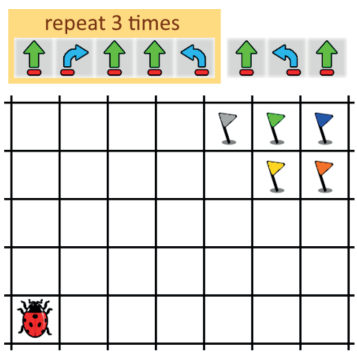
RQ1: Are there any solution time differences between correct and incorrect answers on computer science and physics tasks?

RQ2: How the number of responses changes if only answers provided over a specified time are taken into account? What can we conclude from this change?

2.1. Computer science tasks of the STEM assessment test

Task CS1 (*queuing*)**:** Estimate the minimum number of adjacent swaps that are needed if we want to reverse the order of 12 animals.
Description: There are animals standing in a row, arranged from the tallest to the shortest. We can only swap two adjacent animals at a time. If we have 3 animals, then at least 3 adjacent swaps are needed to reverse their order, while in the case of 6 animals, 15 swaps are required, and in the case of 9 animals, 36 swaps are necessary.
Answer choices: a) 45 b) 55 c) 66 d) 78 e) 91.
Task CS2 (*river crossing*)**:** How can the soldier get to the other side so that after the crossing the boys and the boat are on the initial bank of the river? Give a correct sequence of river crossing steps.
Description: A soldier reaches the river he has to cross. The river is deep and there is no bridge nearby. There are two boys with a rowboat on the river bank. However, the boat is so small that it can either hold two boys or the soldier (each person can row the boat and each of the boys can pass by himself).
River crossing steps:
The boy in the yellow shirt rows the boat across the river.
The boy in the blue shirt rows the boat across the river.
Both boys row the boat across the river.
The soldier rows the boat across the river.

Task CS3 (*ladybug robot*)**:** Which color flag will the ladybug robot reach, if it executes the sequence of instructions in Figure 1?



F i g u r e 1. Task CS3 (ladybug robot)
S o u r c e: Own work.

Description: The ladybug robot knows three basic instructions: it goes forward by one square using , turns right by 90 degrees using , and turns left by 90 degrees using .
Answer choices: a) grey b) green c) blue d) yellow e) orange

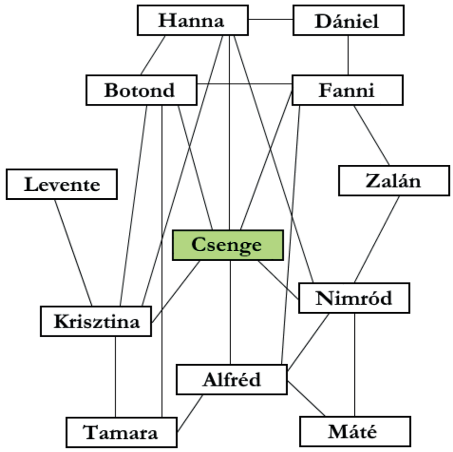


Figure 2. Task CS4 (social network)

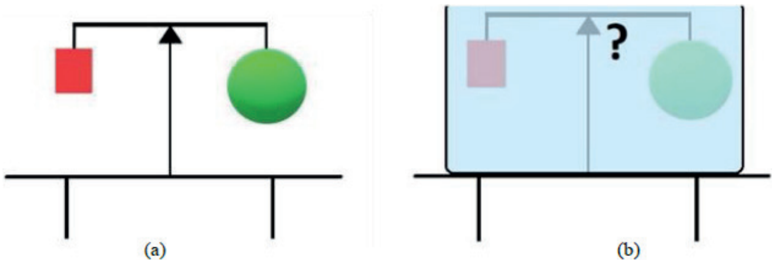
Source: Own work.

Task CS4 (*social network*)**:** Csenge wants to upload a photo on the social network, but she does not want Alfréd to see it. Mark the correct answer!
Description: Csenge and his friends have registered to a social network. Each contact is illustrated in Figure 2, the line means that the two people know each other (e. g. Nimród and Csenge are friends, but Tamara and Csenge are not). If someone on the network shares a photo with a friend, his or her friends will also see this photo.
Answer choices:

a. Csenge can share the photo with Hanna, Krisztina and Fanni.
b. Csenge can share the photo with Hanna, Krisztina and Nimród.
c. Csenge can share the photo with Botond, Krisztina and Alfréd.
d. Csenge can share the photo with Botond, Nimród and Fanni.
e. Csenge can share the photo with Botond, Hanna and Krisztina.

2.2. Physics tasks of the STEM assessment test

Task PH1 (*Archimedes*)**:** What will happen? Choose the letter of the correct answer.
Description: According to Archimedes' principle, when a body is placed in a liquid, the body will be subjected to a buoyancy force that depends on the density of the liquid and the volume of the body below the liquid level (immersed in the liquid). The experiment shown in the Figure 3 is performed at the school. A red cube is suspended at one end of a metal bar supported in the middle and a green sphere at the other end of the bar. In the open air, there is a balance between the two bodies shown in Figure 3 a), and then the bodies shown in Figure 3 b) are placed in a vessel filled with water so that the whole system is completely immersed in the water. What will happen?



F i g u r e 3. Task PH1 (Archimedes)
S o u r c e: Own work.

Answer choices:

a. The final result depends on the mass of the bodies.
b. The red cube rises.
c. The green ball rises.
d. Balance is maintained.
e. I do not have enough information to predict the outcome of the experiment.

Task PH2 (*density*)**:** Put the steps of the experiment in the right order.
Description: The density of a solid can be determined by dividing its mass by its volume. The volume of regular geometric solids (cubes, rectangles, spheres, etc.) can be calculated. Tamara, on the other hand, was given the task of determining the density of an irregular solid, a stone. Yes, but Tamara has only been given a list of the tools she needs, but she does not know the exact order in which to carry out the experiment.
Required tools: scale, graduated cylindrical measuring flask, stone
Help Tamara and put the steps of the experiment in the right order by assigning a number to them! The first step is given to help.
Experiment steps:

- Find the density of a stone as the ratio of its mass to its volume.
- Fill the cylindrical measuring flask with an adequate amount of water and read the volume of water.
- Measure the mass of the stone. – 1.
- Read off the rise in the water level on the measuring cylinder flask, this is equal to the volume of the stone.
- Carefully put the stone into the measuring cylinder flask.

Task PH3 (*circuit*)**:** Which statement is true? Mark its letter.
Description: The two most common ways to connect loads are in series and in parallel. A series circuit has elements connected in series, or one after the other without the wire branching. The current flowing through all elements connected in series is the same, no matter how many resistors are encountered along the way. If one load breaks down, the circuit breaks. A parallel circuit has elements connected in parallel – that is, one point in the circuit branches, with wires going to two different elements, and then the branches rejoin again. The voltage across each element connected

in parallel is the same. The voltages on each load depend on its resistance. If one load breaks down, the others will continue to work regardless.
On Christmas Eve, Peter is reading his favourite book by the light of a table lamp with the Christmas tree lights on, when one of the lights burns out. What will happen?
Answer choices:

a. The table lamp will glow brighter.
b. The Christmas tree lights and the table lamp will stay lit.
c. The Christmas tree lights will go out.
d. The other Christmas tree lights will stay lit.
e. The table lamp will also go out.

Task PH4 (*sound*)**:** Choose the letter of the correct answer.
Description: The speed of sound depends on the density of the medium through which it is travelling. In medium with higher density, the sound propagates faster. The density of iron is higher than the density of air, so…
Answer choices:

a. the sound propagates more slowly in the iron.
b. the sound propagates faster in the air.
c. the sound propagates at the same speed in iron and air.
d. the sound propagates faster in the iron.
e. the sound does not propagate in iron.

3. RESULTS

This section presents the evaluation of computer science (CS) and physics (PH) tasks by considering the time consumption. The percentage distribution of correct and incorrect answers given by students to the three computer science multiple-choice tasks and three physics multiple-choice tasks is shown in Table 1. As the table implies, at least one student selected each of the answer choices for all tasks. Evidence that students used all five of the answer choices suggests that the distractors are functioning as intended. It can be stated for all computer science tasks and physics tasks PH3 and PH4, that the majority of students was able to mark the correct answer. Task PH1 proved to be the most difficult one, with a very low success rate of 18.7%, which implies that Archimedes' principle is a topic difficult for lower grade secondary school students to understand and apply in solving tasks.
During our study, we examined the amount of time students spent on solving test tasks. The online system continuously measured the time (in seconds) for each participant attending the survey. The measurement of time began with starting a new task and ended with the entry of the answer, which automatically opened the next task. Thus, the time required for solution of a task also includes the time needed for reading and understanding the text. For a given task, a very small amount of time could indicate that the student simply marked the answer without reading the question and task description. Contrarily, a large amount of time could imply that the student found this task to be difficult. Table 2 summarizes the basic statistical indicators of time consumption for each task.

Table 1. Percentage distribution of correct (in bold) and incorrect answers to multiple-choice tasks

Task	N	Answer choices				
		a	b	c	d	e
CS1 – queuing	1517	10.4	20.0	**42.0**	24.1	3.5
CS3 – ladybug robot	1514	18.8	**45.0**	7.5	14.9	13.8
CS4 – social network	1513	11.6	6.6	5.2	8.0	**68.6**
PH1 – Archimedes	1517	34.9	11.3	**18.7**	21.0	14.1
PH3 – circuit	*1514*	*3.6*	*18.6*	**59.2**	*16.7*	*1.9*
PH4 – sound	1514	4.4	8.4	9.4	**61.4**	16.4

Source: Own work.

Upon analyzing the data presented in this table, it can be stated that students spent visibly longer time solving the computer science tasks. The mean solution time was the highest in task CS1, which is not surprising, because students have to read the longer text of the task, they have to understand the process of reversing the order of the animals, and then they have to estimate (or calculate) the requested minimum number of adjacent swaps based on the known data. In tasks CS2 and CS3 we observed roughly similar mean solution times. Task CS4 with mean time consumption of 121.7 seconds also managed to attract the attention of participating students. We assume that the popularity of the topic plays a role in this, since the vast majority of secondary school students actively uses social networking sites.

Table 2. Basic statistical indicators of time consumption by tasks

Task	Statistical indicator				
	N	Mean	SD	Rel. SD	Median
CS1 – queuing	1517	197.1	123.9	0.629	175
CS2 – river crossing	1510	147.9	83.7	0.566	134
CS3 – ladybug robot	1514	145.2	89.2	0.614	130
CS4 – social network	1513	121.7	65.5	0.538	117
PH1 – Archimedes	1517	107.4	51.0	0.475	99
PH2 – density	1517	100.3	52.6	0.524	92
PH3 – circuit	1514	*97.5*	*69.1*	*0.708*	*89*
PH4 – sound	1514	53.2	35.1	0.660	46

Source: Own work.

In physics tasks PH1, PH2 and PH3, the mean solution times are roughly equal, the difference between them is within 10 seconds. Task PH4 has the least solution time among all tasks, with mean time consumption of less than a minute. It is important to emphasize that the length of the task description was the shortest in this test item. As presented in Table 2, in all computer science and physics tasks, the median value is lower than the mean value. Comparing the solution times, there are remarkable

differences between students, as shown by high standard deviation (SD) values. High SD rates imply considerable personal differences (Tóth et al., 2021). To compare the differences between the tasks, a relative standard deviation was calculated for each task. The high relative standard deviation values of tasks PH3, PH4, CS1 and CS3 imply that these tasks had a more difficult text to understand.
For each task, the difference in the solution time values between the groups of students who did and did not solve the given task correctly were analyzed using a non-parametric test, because solution times do not distribute normally, a finding consistent with the literature (Lasry et al., 2013). Normality testing was performed using the Shapiro–Wilk test. The results of the Mann–Whitney U-test are summarized in Table 3. The obtained data show that in computer science tasks CS1, CS2 and CS4 correct answer solution times are significantly longer ($p<0.05$) than the time taken to give incorrect answers. Longer solution times suggest that students spend more time reading the text of the tasks, understanding the question, and thinking about the solution. In task CS3, however, the incorrect answer solution time proved to be significantly longer ($p<0.05$) than the correct answer solution time. This result indicates that the distractors are not automatic choices for participating students. Furthermore, the lower proportion of correct answers to this task suggests that cyclical execution of several consecutive instructions is a serious challenge for many students in the lower grades of secondary schools.

Table 3. Comparison of the solution time values between successful and unsuccessful students

Task	Mean solution time		Median solution time		Mann–Whitney U	p value
	correct answers	incorrect answers	correct answers	incorrect answers		
CS1	210.5 (N=637)	187.3 (N=880)	187	168	252301.5	**0.001**
CS2	152.1 (N=938)	141.5 (N=572)	138	127	237356.5	**0.000**
CS3	137.6 (N=682)	152.1 (N=832)	118.5	137	251499.0	**0.000**
CS4	132.8 (N=1040)	98.1 (N=473)	124	94	163498.5	**0.000**
PH1	108.0 (N=283)	107.3 (N=1234)	98	99	170216.5	0.508
PH2	100.7 (N=774)	100.0 (N=743)	91	93	285637.5	0.823
PH3	*96.9 (N=897)*	*98.5 (N=617)*	*90*	*87*	*257736.0*	**0.023**
PH4	52.8 (N=930)	53.9 (N=584)	45	48	271285.5	0.974

Source: Own work.

Table 3 also shows, that in physics tasks PH1, PH2 and PH4, there are no significant differences in solution times between correct and incorrect answers. In task PH3, the incorrect answer solution time proved to be slightly significantly longer ($p<0.05$) than the correct answer solution time.

Table 4. Mean solution time taken (in seconds) for correct (in bold) and incorrect answers in multiple-choice tasks

Task	N	Answer choices				
		a	b	c	d	e
CS1 – queuing	1517	166.0	184.5	**210.5**	194.2	219.4
CS3 – ladybug robot	1514	157.3	**137.6**	135.8	157.2	148.3
CS4 – social network	1513	113.0	103.4	67.5	91.7	**132.8**
PH1 – Archimedes	1517	106.4	105.1	**108.0**	109.1	108.5
PH3 – circuit	*1514*	*83.6*	*102.4*	**96.9**	*89.3*	*168.9*
PH4 – sound	1514	45.6	48.8	51.6	**52.8**	60.0

Source: Own work.

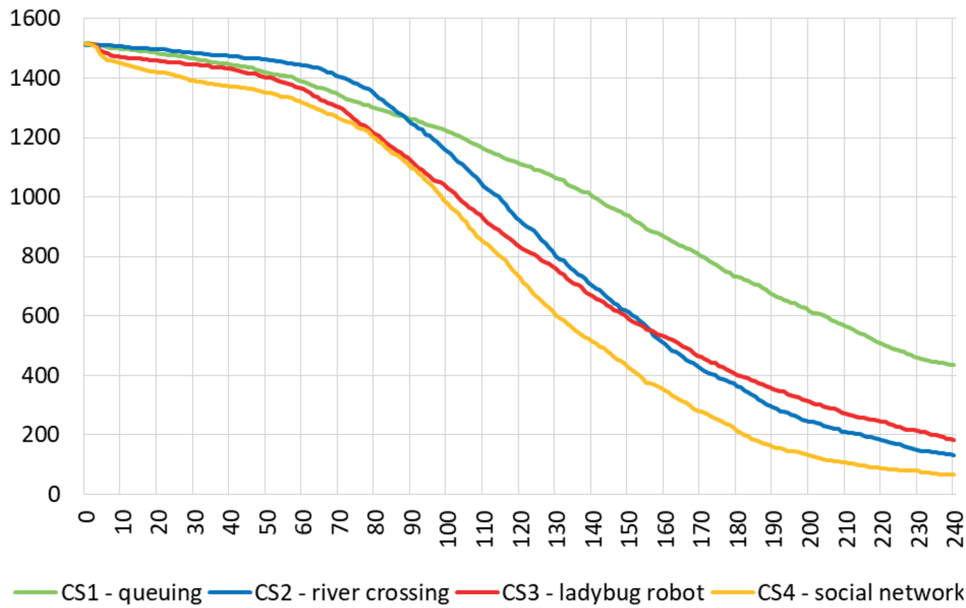


Figure 4. Decreases in the number of responses to computer science tasks depending on the number of answers provided over the specified solution time

Source: Gubo & Végh, 2022.

Table 4 presents the mean time consumption in seconds measured for multiple-choice computer science and physics tasks of the STEM assessment test broken down to individual answer choices. Upon analyzing the data presented in this table, it can be stated for all six tasks that students who gave the correct answer have spent enough time for reading and understanding the text of the given task. In task CS4, there were some students who marked answer choice c) in a visibly shorter time. They probably did not understand the question correctly, as this answer choice also includes the name Alfréd, who should not see the photo shared by Csenge. Furthermore, in task PH3, those students who selected answer choice e), spent much longer time solving this task. After eliminating the three outliers, the mean solution time decreases to 88 seconds, approximately to the level of the mean solution time of the other answer choices.

The chart in Figure 4 illustrates for computer science tasks, how the number of students decreases if only answers provided over a specified time shown on the horizontal axis are taken into account. We assume that attentive reading the entire text of these tasks may have taken students at least 30–40 seconds.

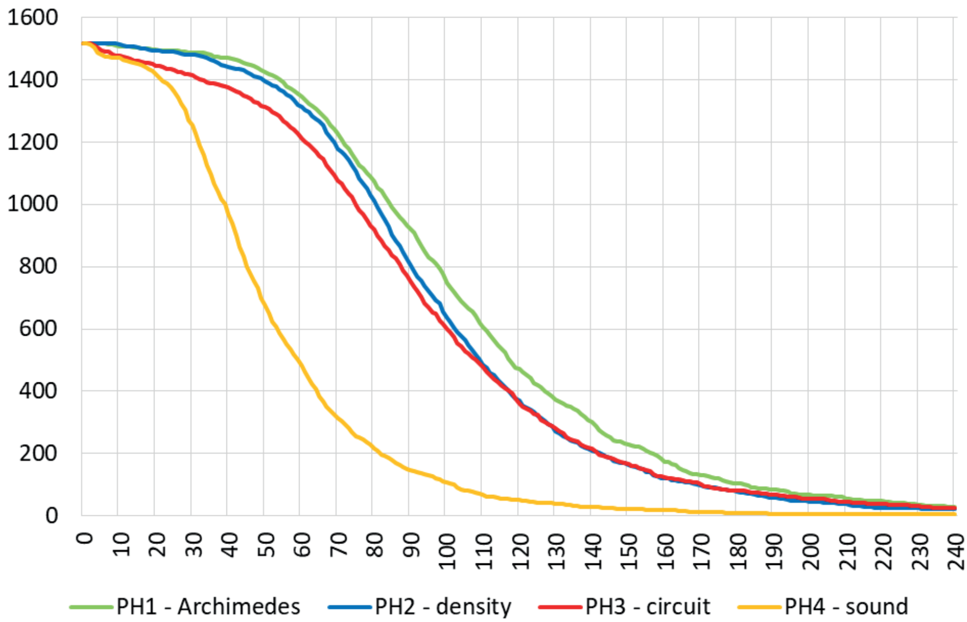


Figure 5. Decreases in the number of responses to physics tasks depending on the number of answers provided over the specified solution time

Source: Own work.

The smallest decrease was observed in task CS1, which proved to be the most time consuming task, where some of the distractors were already difficult to exclude clearly. In other three computer science tasks, around 70–80 seconds on the horizontal axis, the curves begin to slope more steeply downwards. This means that the majority of students needed at least this amount of time to read, understand and solve these three tasks. The most noticeable decrease can be seen in task CS4, which is not surprising, as after reading the text and analyzing the graph displaying acquaintances more than two third of the students solved the task correctly. It is also clearly noticeable that around 190 seconds the curves begin to flatten out again. From this, we can conclude that students rarely spent more than this amount of time to solve the tasks.

Figure 5 shows similar decreases in the number of student responses to physics tasks. We assume that in tasks PH1, PH2 and PH3 the attentive reading of the text requires at least 1 minute, while in task PH4 at least 30 seconds. From this chart, we can observe that in tasks PH1, PH2 and PH3 the shape of the curves are roughly similar – they begin to slope more steeply downwards around 50 seconds solving time, and begin to flatten out again around 120 seconds. In task PH4, the greatest decrease among all 8 examined test tasks can be observed. It is not surprising, as this task has the shortest description length and more than 60% of the respondents was able to provide the correct answer.

Based on the obtained results shown in Figures 4 and 5, it can be stated that the majority of students devoted enough time for solution of analyzed test tasks and did not rush to answer. It especially holds for computer science tasks.

CONCLUSION

The present paper examined the relation between students' performance in solving computer science and physics tasks of the STEM assessment test and time consumption on task solution. It was confirmed for all tasks that one of the preconditions of achieving a good result is the proper utilization of the time, however, spending too much time on the solution does not necessarily bring better performance. Correct answers took significantly more time than incorrect answers only in three computer science tasks (CS1, CS2 and CS4), while in the remaining computer science task (CS3) and in one physics task (PH3), solution times for correct answers proved to be significantly shorter. In other three physics tasks there were no significant differences between correct answer and incorrect answer solution times.

By taking into consideration the decreases in the number of responses to each task depending on the number of answers provided over shorter time (40–50 seconds), it can be concluded that, in general, students took the survey seriously and did not just answer without reading the questions and task descriptions carefully. Higher time consumption in computer science tasks could be explained by the relative complexity of these tasks – task CS1 requires calculation or prediction based on the given data, in task CS2 students have to specify a proper sequence of the river crossing steps, in task CS3 they have to execute a sequence of instructions, and finally, in task CS4 they have to analyze an acquaintance network.

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REFERENCES

Adey, P. & Csapó, B. (2012). A természettudományos gondolkodás fejlesztése és értékelése *[Development and assessment of scientific thinking]*. In B. Csapó, & G. Szabó (Eds.), *Tartalmi keretek a természettudomány diagnosztikus értékeléséhez [Content frameworks for diagnostic assessment of natural science]* (pp. 17–58). Budapest: Nemzeti Tankönyvkiadó. ISBN 978-963-19-7236-8.

Czakóová, K. (2020). Developing algorithmic thinking by educational computer games. In I. Roceanu (Ed.), *eLearning sustainment for never-ending learning Volume I* (pp. 26–33). Bucharest: Editura Universitară. ISSN 2066-026X.

Dunbar, K. & Fugelsang, J. (2005). Scientific Thinking and Reasoning. In K. J. Holyoak & R. G. Morrison (Eds.), *The Cambridge Handbook of Thinking and Reasoning* (pp. 705–725). Cambridge: Cambridge University Press. ISBN 978-0-521-53101-6.

Futchek, G. (2006). Algorithmic Thinking: The Key for Understanding Computer Science. In R. T. Mittermeir (Ed.), *Informatics Education – The Bridge between Using and Understanding Computers* (pp. 159–168). Berlin-Heidelberg: Springer. ISBN 978-3-540-48218-5.

Futchek, G. & Moschitz, J. (2011). Learning algorithmic thinking with tangible objects eases transition to computer programming. In I. Kalaš & R. T. Mittermeir (Eds.), *Informatics in Schools. Contributing to 21st Century Education* (pp. 155–164). Berlin-Heidelberg: Springer. ISBN 978-3-642-24721-7.

Gubo, S. & Végh, L. (2022). Assessment of Algorithmic Thinking of Slovak and Hungarian Secondary School Students. In L. Gómez Chova, A. López Martínez, J. Lees (Eds.), *15th International Conference of Education, Research and Innovation (ICERI2022)* (pp. 3484–3493). Valencia: IATED Academy. ISBN 978-84-09-45476-1.

Hsu, Ch. Ch. & Wang, T. I. (2018). Applying game mechanics and student-generated questions to an online puzzle-based game learning system to promote algorithmic thinking skills. *Computers & Education*, *121*, 73–88. https://doi.org/10.1016/j.compedu.2018.02.002.

Juhász, Gy. & Tóth, P. (Eds.). (2021). *A természettudományos és matematikai tárgyak tanításának és tanulásának helyzete Magyarországon és Szlovákiában [The situation of teaching and learning science and mathematics subjects in Hungary and Slovakia]*. Komárno: J. Selye University. ISBN 978-80-8122-405-8.

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs: Prentice-Hall. ISBN 978-0-13-295261-3.

Korkmaz, Ö., Çakir, R., & Özden, M. Y. (2017). A validity and reliability study of the computational thinking scales (CTS). *Computers in Human Behavior*, *72*, 558–569. https://doi.org/10.1016/j.chb.2017.01.005.

Kuhn, D. (2002). What is Scientific Thinking, and How Does It Develop? In U. Goswami (Ed.), Blackwell Handbook of Childhood Cognitive Development (pp. 371–393). Oxford: Blackwell Publishing. ISBN 978-0-631-21840-8.

Lasry, N., Watkins, J., Mazur, E., & Ibrahim, A. (2013). Response times to conceptual questions. *American Journal of Physics*, *81*(9), 703–706. https://doi.org/10.1119/1.4812583.

Morze, N., Smyrnova-Trybulska, E., & Gladun, M. (2018) Selected aspects of IBL in STEM-education. In E. Smyrnova-Trybulska (Ed.), *E-learning Vol. 10 – E-learning and Smart Learning Environment for the Preparation of New Generation Specialists* (pp. 361–379). Katowice-Cieszyn: University of Silesia in Katowice. ISBN 978-83-66055-05-6.

Raven, J. (2000). The Raven's Progressive Matrices: Change and Stability over Culture and Time. *Cognitive Psychology*, *41*(1), 1–48. https://doi.org/10.1006/cogp.1999.0735.

Román-González, M., Pérez-González, J. C., Moreno-León, J., & Robles, G. (2018). Can computational talent be detected? Predictive validity of the Computational Thinking Test. *International Journal of Child-Computer Interaction*, *18*, 47–58. https://doi.org/10.1016/j.ijcci.2018.06.004.

Svitek, S. (2022). Analysis of Mathematical Competences of Secondary School Students in Slovakia and Hungary. In L. Gómez Chova, A. López Martínez, I. Candel Torres (Eds.), *16th International Technology, Education and Development Conference (INTED2022)* (pp. 1677–1683). Valencia: IATED Academy. ISBN 978-84-09-37758-9.

Szarka, K. & Juhász, Gy. (2019). Rozvoj matematického myslenia v chemickom vzdelávaní *[Development of mathematical thinking in chemical education]. Biológia, ekológia, chémia: časopis pre školy*, *23*(3), 9–16.

Szarka, K., Tóth, P., & Csiba, P. (Eds.). (2021). *Módszertani javaslatok a STEM tárgyak oktatásához [Methodological suggestions for teaching STEM subjects]*. Komárno: J. Selye University. ISBN 978-80-8122-407-2.

Tóth, P., Horváth, K., & Kéri, K. (2021). Development Level of Engineering Students' Inductive Thinking. *Acta Polytechnica Hungarica*, *18*(5), 107–129. https://doi.org/10.12700/aph.18.5.2021.5.8.

Wing, J. M. (2006). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society of London A*, *336*, 3717–3725. https://doi.org/10.1098/rsta.2008.0118.