

New Trends and Issues
Proceedings on Humanities
and Social Sciences

Volume 6, Issue 5 (2019) 066-074



www.prosoc.eu

Selected Paper of 8th Cyprus International Conference on Educational Research (CYICER-2019) 13-15 June 2019, Cyprus
Science University, North Cyprus

Examining the relationships between problem-solving and reading comprehension skills

Katalin Harangus*, Faculty of Technical and Human Sciences, Sapientia Hungarian University of Transylvania,
Targu Mures, Romania

Suggested Citation:

Harangus, K. (2019). Examining the relationships between problem-solving and reading comprehension skills.
New Trends and Issues Proceedings on Humanities and Social Sciences. [Online]. 6(5), pp 066–074.
Available from: www.prosoc.eu

Selection and peer review under responsibility of Prof.Dr. Huseyin Uzunboylu, Near East University, Turkey.
©2019 United World Center of Research Innovation and Publication. All rights reserved.

Abstract

Developing problem-solving thinking became extremely important in a well-functioning school system. It must be an integral part of the educational programme as the development of competence in the training of students with the right skills is possible through the processing of a specific curriculum. The purpose of our present survey was to examine the problem-solving skills of the 1st year students of Sapientia University. In our study, we report on the achievements of humanities and science students in solving complex tasks requiring computational thinking. The result data suggest that there is a close correlation between the level of problem-solving skills and the level of reading comprehension and writing skills. For each task, the number of those who tried to solve the task was high, but much more less could reach from recognising to understand and solve the problem.

Keywords: Problem-solving, computational thinking, reading comprehension.

* ADDRESS FOR CORRESPONDENCE: **Katalin Harangus**, Faculty of Technical and Human Sciences, Sapientia Hungarian University of Transylvania, Targu Mures, Romania. *E-mail address:* katalin@ms.sapientia.ro

1. Introduction

The economic and social changes of the past decades, as well as the global spread and accessibility of information and communication technologies, have resulted in the renewal of labour market expectations. Permanent, routine work has been increasingly replaced by a challenging work environment with dynamically changing problem situations (Autor et al., 2003), thus problem-solving thinking is a preferred capability on the labour market. For the labour market, it is essential to train professionals who can be successful in life-like, complex problem situations. The most appropriate framework to achieve this is provided by the school and then by university education (Toth, 2007).

One of the goals of the higher education institutions has been to develop an educational programme that helps students develop problem-solving skills. Therefore, the research studies of the recent years focused on measuring the level of problem-solving skills and examining the effectiveness of different development methods: theoretical papers (Fischer & Neubert, 2015; Schoppek & Fischer, 2015), papers about measurement issues (Alison et al., 2013; Danner et al., 2011; Greiff, Wüstenberg & Funke, 2012; 2015; Gobert, Kim, Pedro, Kennedy & Betts, 2015; Greiff and Fischer, 2013; Herde, Wustenberg & Greiff, 2016; Stadler, Niepel & Greiff, 2016) and papers about applications (Ederer, Patt & Greiff, 2016; Fischer & Neubert, 2015; Tremblay et al., 2017).

In our research conducted in the 2015/2016 academic year, we measured within problem-solving the level of algorithmic thinking among students (Harangus & Katai, 2017). Based on the results obtained, it can be stated that the students' thinking requiring algorithms is weak. There was a significant difference between students in humanities and students in science. Those students who had studied science subjects such as mathematics, physics and computer science in a greater number of lessons were doing much better. Students in humanities achieved a better result in the case of a task requiring text interpretation, but they distanced themselves from solving a word problem embedded in a mathematical environment.

With our current empirical research, we want to connect to the international practice that has demonstrated with a series of measurements that examination of cross-curricular skills provide information about the development of students that traditional knowledge measurement cannot show. Our research is exploratory and gap filling as the measurement of the level of problem-solving skills was realised for the first time in a nationwide study covering the Hungarian-language school network.

2. Problem-solving skills

Many people have attempted to describe the typical stages and typical activities of the problem-solving process. The ideas of Wallas and Polya are often referred to, who together with others, have given certain stages of the thinking process only by generalising observations. According to Lenard (1982), in such generalisations, the problem is that they are not based on an accurate examination of individual thinking.

Wallas (1926) gave the following stages: (1) preparation: the solver collects relevant information; (2) incubation: the activity continues without the conscious effort; (3) illumination: after a successful incubation, the solution comes as a sudden 'insight' ('Aha' experience); (4) Verification: verification of the solution. The four-step decision-making process for problem-solving based on Polya (1969)—(1) recognising and understanding the problem: selecting the problem from context, understanding the problem, recalling the right knowledge, creating a table, drawing, figure; (2) formulating the problem and making a plan: defining relevant and irrelevant variables, revealing, organising, reflecting on and critical evaluating information about the text, displaying the problem in the form of a table, drawing or figure to help finding a solution; (3) selecting the strategy and implementing the plan: switching between different forms of presentation, using appropriate procedural knowledge, the use of previous knowledge used in similar situations, creating or combining new versions of the given information with inductive and/or deductive thinking, using technical tools to solve the problem; (4) examining the

solution: checking the solution from different perspectives to see if the problem could be solved differently, whether the result or the method could be used to solve another problem.

The American researchers began to examine problem-solving in different areas (physics, writing, reading, counting, chess, computer skills, etc.). They claim that the more expertise we have in an area, the greater the probability is that we can deal with a problem in that particular area. In Europe, researchers work with computerised laboratory tasks with a structure similar to real-life problems, which are relatively complex and semantically rich problems, just in the real life. Area-specific tasks are always new for the participants, they cover several areas, and are therefore suitable for monitoring how individuals solve different problems in completely unknown situations. Problem-solving does not have a universally accepted definition in either America or Europe. Due to the diversity, many definitions have emerged and are emerging, but no one disputes that developing thinking is a fundamental task of education.

In recent years, more and more emphasis was placed on the importance of developing computational thinking within problem-solving. Wing's article published in 2006 gave a particularly strong impetus to this trend (Wing, 2006). There is a growing body of professionals who agree that the basics of computational thinking should be part of common knowledge. Besides the three basic skills—writing, reading and counting—computational thinking should be the fourth skill. In Wing's approach, computational thinking is a way of thinking that 'involves solving problems, designing systems and understanding human behaviour, by drawing on the concepts fundamental to computer science'.

Computational thinking involves problem-solving, planning systems and understanding of human behaviour. To solve a seemingly difficult problem means turning it into a simpler task (reducing, embedding, transforming and simulating). Organisations committed to CSTA (<http://csta.acm.org/>) and ISTE (<http://www.iste.org/>) education and IT education have linked nine key concepts to computational thinking: data collection, data analysis, data representation, sub-task breakdown, abstraction, algorithm, automation, parallelisation and simulation. It is evident that cognitive operations related to these concepts could be developed and practised in the course of any subject.

3. Presentation of survey

Our research 'A study of problem-solving skills regarding different subject areas (reading comprehension, content creation, mathematical and computational thinking)' focused on examining the problem-solving skills of Hungarian high school and university students in Romania as well as on exploring relationships between performance and background variables (cognitive, affective, learning environment and family background) (Pletl, 2018a). The research was based on a multidisciplinary approach, examining topics such as challenges related to mother tongue education (Pletl, 2018b), the helping effect of the family on pupils' school performance (Horvath, 2018); development of problem-solving skills in IT education (Katai, 2018); the role of problem-based teaching in teacher training (Harangus, 2018a); the process of identifying with the career and acquiring a professional role (Szentés, 2018); educational strategies in processing foreign language texts (Kovacs, 2018); examining the affective and cognitive learning factors of high school students (Horvath & Szentés, 2018).

The survey took place in the first semester of the 2017–2018 academic year. The survey was carried out personally by the members of the research team, on the one hand, to inform the students about the nature of the measurement and on the other hand to be able to check the timeframe set for the solution. The collected questionnaires and task sheets were coded according to the study programmes. The assessment of the problem-solving tasks was carried out by students in teacher training who worked in pairs. The assessment groups were prepared for evaluation according to the type of tasks: students in engineering corrected the tasks checking the level of mathematics and computer skills, while the students in translation corrected the tasks checking the reading comprehension and writing skills. The papers were graded according to a guide and a key. The

verification of correction was carried out by the members of the research team (depending on their fields of expertise).

In this paper, we present the results of the research, which aimed to measure the students' problem-solving skills. The sample was composed by 1st year students in science ($N = 66$) and 1st year students in humanities ($N = 75$) of Sapientia Hungarian University of Transylvania. The stratifications of the sample were ensured by the selection according to study programmes: we listed students of computer engineering, automation, information science, mechatronics, computer-aided operation planning in the science group and students in translation, in communication and public relations and in public health in the humanities group.

As a tool for the experiment, we set up a test and used a task sheet to measure the skills. The tasks of the survey did not measure the fulfilment of the criteria of the curriculum, but primarily the extent to which students were able to utilise their task-solving skills in the case of problems that had to be analysed by real life-like situations. The tasks outlined a novel problem for the students, but their solutions did not require mathematical or IT skills. Our purpose in the compilation of the task sheet was that the task should measure computational thinking within problem-solving and be independent of the students' expertise.

The tasks were word problems, the problem had to be understood through the information extracted from the text and the solution could be achieved by performing successive thinking operations. There were logical problems requiring algorithmic thinking that did not require mathematical knowledge but only creative thinking (Harangus, 2018b).

4. Results

The tasks examined how students can use the acquired knowledge in the extracurricular context in practical situations and how they can transfer their previous experiences when solving a task. When interpreting the results, we took into consideration that the task sheet in question was not a test of knowledge in a traditional sense, but it was an unusual problem-solving task sheet for students.

First, we examined the overall performance of the whole test. The task sheet measured the level of computational thinking of students with a total of 20 items. The total score available for the full test was 100 points. Approximately 89.8% of the students tried to solve the tasks, there were only a few who didn't even try (10.2%), but no student achieved the maximum score. Their average performance was around 56.52 points. The results are presented in more details in Table 1, where we present the average and standard deviation of the results achieved for each task by science and humanities group breakdown. The average of science students in computational thinking is higher than that of humanities students.

Table 1. Average and standard deviation of individual items by study programmes

Items	Overall performance		Performance of science students		Performance of humanities students	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
1	6.63	0.46	9.12	0.55	4.44	0.69
2	6.12	0.48	8.82	0.51	3.74	0.65
3	6.15	0.53	5.44	0.52	6.77	0.68
4	2.05	0.41	3.16	0.42	1.07	0.58
5	1.77	0.42	2.87	0.43	0.80	0.61
6	1.71	0.47	2.72	0.41	0.82	0.59
7	1.66	0.50	2.57	0.42	0.86	0.56
8	1.66	0.51	2.72	0.47	0.73	0.58
9	1.54	0.49	2.43	0.51	0.76	0.42
10	1.54	0.49	2.43	0.54	0.76	0.45

11	1.52	0.48	2.35	0.61	0.79	0.41
12	1.54	0.43	2.43	0.62	0.76	0.38
13	0.70	0.48	0.88	0.46	0.54	0.39
14	3.36	0.55	4.52	0.48	2.34	0.67
15	5.91	0.48	7.49	0.48	4.52	0.35
16	3.18	0.52	5.21	0.49	1.39	0.32
17	2.27	0.51	2.61	0.48	1.97	0.36
18	8.18	0.44	12.2	0.46	4.64	0.35
19	3.64	0.61	5.41	0.47	2.08	0.38
20	0.00	-	0.00	-	0.00	-
Test average	56.52	-	75.20	-	40.08	-

If the tasks are sorted by difficulty, the item difficulty indicator, apart from the 20th task, is roughly evenly distributed between 1 and 9, that is, the task sheet is well-differentiated across the whole population (Figure 1). The item difficulty indicator (i) is the higher the lighter the item is and vice versa. Therefore, in this case, the most difficult task for the given sample is the last task, the 20th, and the easiest is the 18th.

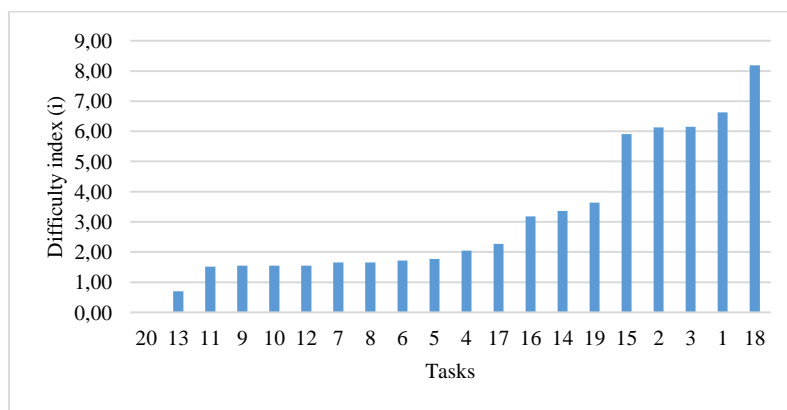


Figure 1. The tasks in order of difficulty

Based on the results of the students, the last task, which measured the level of computational thinking with 6 items, proved to be the most difficult. The task was as follows:

The freight train B is approaching the station, but the express train A will soon catch it up and train B has to allow it forward. At the station, a siding is branched off from the main track, where wagons can be pushed out of the main track for a while. In how many ways can the problem be solved depending on the length of the siding? Give solutions depending on the length of the siding relative to the train length.

Students had to find out in how many ways can an express train (A) overtake a freight train (B) ahead in case of a siding that can be accessed from the main track. Depending on the length of the siding, three cases can be distinguished to solve the problem:

1. the full freight train B can fit on the siding;
2. the full express train A can fit on the siding;
3. (only a part of the trains can fit on the siding).

In order to solve the problem, we had to recognise the algorithm whose successive steps led to the solution. Each correctly distinguished answer was scored. Similarly to the previous tasks, the proportion of students who tried to solve the problem was high (85.3%). Table 1 shows the proportion of students who distinguished the three cases and gave solutions to them.

Table 2. The proportion of students who distinguished and solved the individual cases

On the siding:	The full freight train B can fit	The full express train A can fit	Only a part of the trains can fit
Distinguished case (%)	59.1	31.8	22.7
Solutions (%)	40.9	18.2	0

The solution to the case (1) was to shunt the freight train onto the siding while the express train A went on, then the freight train B shunted back the main track and went on. The proportion of those who recognised and understood the problem was above average (59.1%), but the proportion of those who gave the correct solution was much less (40.9%).

The solution to the case (2) required a similar train of thought but it was possible to get to the result only in several steps: the freight train B passes over the junction and stops while express train A shunts onto the siding. After this, freight train B shunts back to the junction, express train A shunts from the siding and passes on. Because the solution required the recognition of a more complex problem situation, students found it difficult to develop a strategy that could lead to the right solution. Less than a third (31.8%) could recognise and distinguish the second case as a solution. The solution given depending on the length of the siding relative to the train length was barely more than half (18.3%) able to formulate and describe.

Case (3) required more case studies, the ability to recognise, analyse and interpret several consecutive steps. The following process has led to the solution: the freight train B crosses the junction while the express train A shunts onto the siding where the overhanging part is uncoupled. The part uncoupled from the express train A is attached to the freight train B and it pushes back to the junction. The express train A shunts from the siding and passes on. The freight train B crosses the junction again, shunts the part taken from the express train A to the siding and uncouples it. The freight train B then returns to the junction, the express train A shunts back to the siding to attach the uncoupled part and passes on. Most of the students couldn't distinguish the third case, only 22.7% of them were able to find a proper solution to the complex problem situation. However, they couldn't formulate and write the solution.

Although the proportion of those attempting to solve the problem is high in both study programmes, there is a significant difference between the two groups in the extent they could interpret the task and provide solutions to possible cases. Table 3 shows the proportion of students in science and students in humanities group breakdown.

Table 3. The proportion of students in science and in humanities who distinguished and solved the individual cases

On the siding:	The full freight train B can fit		The full express train A can fit		Only a part of the trains can fit	
	Science	Humanities	Science	Humanities	Science	Humanities
Distinguished case (%)	74.9	43.3	45.1	18.5	26.5	3.8
Solutions (%)	45.1	36.7	22.1	14.3	0	0

Case (1) could be correctly distinguished by three-quarters (74.9%) of the students in science, compared with only 43.3% of the students in humanities who were able to solve the problem how to take over train A, train B if on the siding can fit the whole train B. If we examine how they can formulate their own solutions, the difference between the groups disappears. The students in humanities were able to put their solutions in text form while the students in science weren't able to do it. Most of them (22.3%) didn't even try to interpret the solution in text form, or the texts they formulated were inaccurate: 'If the express train A fits, it will pull off the siding', 'The siding is as long as train B', 'If train B fits into the length of the siding, we put it on it'.

Case (2), where students had to lead a more complex problem situation compared to the case (1), could be interpreted by fewer students in both groups. Less than half of the science students (45.1%) and only 18.5% of the humanities students distinguished 'the whole express train A can fit on the siding' case. There were few, who tried to put in the text the solution. Those students who attempted to put into text the solutions wrote the following inaccurate formulations: 'Train B steps aside because A has priority', 'Train A can fit on the siding, train B stays on the main track'.

Distinguishing case (3) caused problems for the students, they were unable to develop a strategy for a complex problem situation that could lead to the solution. To the fact that only a part of the trains can fit on the siding, only a quarter (26.5%) of the science students could find a solution. The students in humanities couldn't distinguish this case. Only a few of the students attempted to put the solution into text, but it was also wrong: 'Train B is off the track, express train A forward, freight train B station', 'The siding is small and only a part of the train can fit', 'They decide among themselves which one to pull down on the siding'. There were some students who misinterpreted the task, they couldn't recognise and interpret the information needed to solve the problem, instead of the solution they wrote: 'None of them fit perfectly', 'It doesn't give priority'.

5. Conclusion

One of the key factors of the efficiency and effectiveness of higher education and education systems is the ability to solve problems. The development of competence helps students to utilise their knowledge in different disciplines in their everyday working life. This requires that students possess the knowledge necessary for the solution, and to be open to solving new kinds of problems different from common types of tasks.

Our examination did not measure the fulfilment of the criteria of curricular requirements, but primarily the ability of students to use their problem-solving skills for problems where they needed to analyse real, lifelike problems and situations. The results of the study suggest that the success of problem-solving and the effectiveness of using knowledge in new situations are significantly influenced by the appearance and context of the problem. The solution rate of the unpractised tasks was low.

The results of the science students versus humanities students are awareness-rising. For humanities students, it was more difficult to distinguish the cases (43.3%, 18.5% and 3.8%), but if a solution was found on how to let train A overtake train B, they could also put their solutions into text (36.7%, 14.3% and 0%). In contrast, science students performed better in distinguishing potential cases (74.9%, 45.1% and 26.5%), but they couldn't put the solutions into text (45.1%, 22.1% and 0%).

Although the task required computational thinking, students were still struggling with designing and constructing algorithms for solutions. Only a portion of the students were able to distinguish the three cases (59.1%, 31.8% and 22.7%), but they couldn't make a proper description of the solution or they couldn't formulate at all the solutions (40.9%, 18.2% and 0%). All this suggests that the level of development of problem-solving skills is not only related to the level of reading comprehension but also to the level of text production skills.

The results obtained can be used to increase the efficiency of education. Data showing the level of problem-solving skills could serve as a basis for the management of higher education institutions to develop further education policy since the preparation of students for new expectations in the labour market should be one of the objectives of higher education institutions. It should develop cognitive abilities that would help students apply knowledge in new situations and transfer it from one context to another.

Acknowledgements

The research was carried out with the financial support of the KPI—Institute of Research Programmes, Cluj-Napoca.

References

- Alison, L., van den Heuvel, C., Waring, S., Power, N., Long, A., O'Hara, T. & Crego J. (2013). Immersive simulated learning environments for researching critical incidents: a knowledge synthesis of the literature and experiences of studying high-risk strategic decision making. *Journal of Cognitive Engineering and Decision Making*, 7, 255–272. doi:10.1177/1555343412468113
- Autor, D. H., Levy, F. & Murnane, R. J. (2003). The skill content of recent technological change: an empirical exploration. *Quarterly Journal of Economics*, 118(4), 1279–1333.
- Danner, D., Hagemann, D., Holt, D. V., Hager, M., Schankin, A., Wustenberg, S. & Funke, J. (2011). Measuring performance in dynamic decision making. Reliability and validity of the Tailorshop simulation. *Journal of Individual Differences*, 32, 225–233. doi:10.1027/1614-0001/a000055
- Ederer, P., Patt, A. & Greiff, S. (2016). Complex problem-solving skills and innovativeness – evidence from occupational testing and regional data. *European Journal of Education*, 51, 244–256. doi:10.1111/ejed.12176
- Fischer, A. & Neubert, J. C. (2015). The multiple faces of complex problems: a model of problem solving competency and its implications for training and assessment. *Journal of Dynamic Decision Making*, 1(6), 1–14. doi:10.11588/jddm.2015.1.23945
- Gobert, J. D., Kim, Y. J., Pedro, M. A. S., Kennedy, M. & Betts, C. G. (2015). Using educational data mining to assess students' skills at designing and conducting experiments within a complex systems microworld. *Thinking Skills and Creativity*, 18, 81–90. doi:10.1016/j.tsc.2015.04.008
- Greiff, S. & Fischer, A. (2013). Measuring complex problem solving: an educational application of psychological theories. *Journal of Education Research*, 5, 38–58.
- Greiff, S., Fischer, A., Stadler, M. & Wustenberg, S. (2015). Assessing complex problem-solving skills with multiple complex systems. *Thinking & Reasoning*, 21, 356–382. doi:10.1080/13546783.2014.989263
- Greiff, S., Wustenberg, S. & Funke, J. (2012). Dynamic problem solving: a new assessment perspective. *Applied Psychological Measurement*, 36, 189–213. doi:10.1177/0146621612439620
- Harangus, K. (2018a). A problémamegoldó kepeség vizsgálat a középiskolások és a tanárképzés hallgatók körében. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihívások—a tudás fogalmának változása* (pp. 58–70). Kolozsvár: Abel Kiado.
- Harangus, K. (2018b). Examining computational thinking through logic tasks. *The Turkish Online Journal of Educational Technology*, 3 (2018), 172–178, ISSN: 2146-7242.
- Harangus, K. & Katai, Z. (2018). Algorithmic thinking vs. text comprehension. *Procedia Technology*, 22, 1031–1037. doi:10.1016/j.promfg.2018.03.146
- Herde, C. N., Wustenberg, S. & Greiff, S. (2016). Assessment of complex problem solving: what we know and what we don't know. *Applied Measurement in Education*, 29, 265–277. doi:10.1080/08957347.2016.1209208
- Horvath, Zs. I. (2018). A kisebbsegi közösek iskolai: a család segítő hatása a tanulók iskolai teljesítményének alakulására. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihívások—a tudás fogalmának változása* (pp. 34–46). Kolozsvár: Abel Kiado.
- Horváth, Zs. I. & Szentés, E. (2018). Középiskolások tanulók affektív és kognitív tanulási tényezőinek vizsgálata. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihívások—a tudás fogalmának változása* (pp. 58–70). Kolozsvár: Abel Kiado.
- Katai, Z. (2018). A problémamegoldó kepeség fejlesztése az informatikaoktatásban. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihívások—a tudás fogalmának változása* (pp. 58–70). Kolozsvár: Abel Kiado.
- Kovacs, G. (2018). Szövegértés, olvasási stratégiák és fordítás. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihívások—a tudás fogalmának változása* (pp. 58–70). Kolozsvár: Abel Kiado.
- Lenard, F. (1982). *A gondolkodás hetköznapijai*. Budapest, Hungary: Akadémiai Kiado.
- Pletl, R. (2018a). A problémamegoldó kepeség vizsgálata különbozó műveltségi területeken. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihívások—a tudás fogalmának változása* (pp. 22–33). Kolozsvár: Abel Kiado.

Harangus, K. (2019). Examining the relationships between problem-solving and reading comprehension skills. *New Trends and Issues Proceedings on Humanities and Social Sciences*. [Online]. 6(5), pp 066-074. Available from: www.prosoc.eu

Pletl, R. (2018b). Az anyanyelvoktatást ero kihivasok. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihivasok—a tudás fogalmanak változása* (pp. 8–22). Kolozsvár: Abel Kiado.

Polya, Gy. (1969). *A gondolkodás iskolája*. Budapest, Hungary: Gondolat Kiado.

Schoppek, W. & Fischer, A. (2015). Complex problem solving—single ability or complex phenomenon? *Frontiers in Psychology*, 6(1669). doi:10.3389/fpsyg.2015.01669

Stadler, M., Niepel, C. & Greiff, S. (2016). Easily too difficult: estimating item difficulty in computer simulated microworlds. *Computers in Human Behavior*, 65, 100–106. doi:10.1016/j.chb.2016.08.025

Szentes, E. (2018). A palyaval valo azonosulas folyamata es a szakmai szerep elsajatitasa. In P. Rita (Ed.), *Anyanyelvoktatás. Új kihivasok—a tudás fogalmanak változása* (pp. 58–70). Kolozsvár: Abel Kiado.

Toth, P. (2007). Gondolkodásfejlesztés informatika oran. *Iskolakultúra*, 17(6–7), 47–65.

Tremblay, S., Gagnon, J.-F., Lafond, D., Hodgetts, H. M., Doiron, M. & Jeuniaux, P. P. J. M. H. (2017). A cognitive prosthesis for complex decision-making. *Applied Ergonomics*, 58, 349–360. doi: 10.1016/j.apergo.2016.07.009

Wallas, G. (1926). *The art of thought*. London, UK: Jonathan Cape.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33–35.