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Assessing competence in teacher education: Development of university students’ problem-solving skills

Katalin Harangus [a 1], Sapientia Hungarian University of Transylvania, Faculty of Technical and Human Sciences, Târgu Mureș, Romania

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Abstract

In our research, we examined the development of complex problem-solving skills among 1st-year teachers training undergraduate students in engineering at Sapientia Hungarian University of Transylvania (N = 73). The research aimed to determine whether knowledge transfer works among students in interpreting life-like, specific problems. A worksheet was used as a measuring tool. In compiling it, we applied the concept that tasks include computer-transferable algorithms (such as cryptography process, parallel computing, and constraints), and their solution does not require any special IT knowledge, only structured and logical thinking. The research reports on the extent to which teacher training students have acquired knowledge and problem-solving strategies related to certain disciplines. The obtained data shed light on the fact that the lack of an interdisciplinary approach hinders the recognition of the connections between the different fields of education.

Keywords: Computational thinking; problem-solving skills; Teaching education.

* ADDRESS FOR CORRESPONDENCE: Katalin Harangus, Sapientia Hungarian University of Transylvania, Faculty of Technical and Human Sciences, Târgu Mureș, Romania

E-mail address: katalin@ms.sapientia.ro

1. Introduction

The acquisition of an appropriate level of basic skills, such as literacy, numeracy, and a certain level of scientific and technical knowledge is essential for young people leaving an educational institution to have easy access to the labor market (Milkias, 2020; Guerra, 2021). Data from international research suggest that 20-25% of young people in formal education (PISA surveys) and working-age adults (as shown by the PIAAC survey 2011-2018) do not have the essential basic skills for active participation in every area of modern social life. In the last three PISA cycles, specific competencies across disciplines were also measured. In 2012, students reported on their complex problem-solving skills, in 2015 on their collaborative problem-solving skills, and in 2018 on their awareness of global issues. All this poses a difficult task for training institutions, as they need to provide adequate training so that especially young people would be able to acquire these competencies.

In an education system that aims to successfully prepare students for the needs of the labor market, the development of digital competence must be key (Sacramento, Ibanezr & Magayon, 2021). It can provide the appropriate framework by developing educational programs which help students develop problem-solving skills. Qualified teachers having the right level of metacognition to establish and strengthen cognitive motivation in their students play an important role in all this.

Incompetence development, the task of teacher training institutes is to develop the problem-solving skills of university students by developing appropriate professional training so that future teachers can encourage students in public education to acquire independent knowledge, thinking, and self-regulated learning (Dadashi, Soltani & Rahimi, 2020; Ramírez-Montoya, 2021). By strengthening cognitive motivation, students must be prepared to operate knowledge transfer and to transfer knowledge effectively, as well as to be able to introduce the approach of competence development teaching in public education. Students' prior knowledge plays a key role in making decisions that meet the challenges of everyday life. In the present research, we examine the complex problem-solving skills of teachers training students through tasks that require computational thinking to determine whether knowledge transfer works, i.e., whether they can apply their acquired knowledge in new situations.

1.1. Literature review

Measuring problem-solving thinking is not new; it has been one of the most studied thinking skills in the last two decades. It aims to provide a comprehensive picture of students' knowledge, level of development of their abilities, and skills. Whereas earlier the factual knowledge was measured, today the basic idea of the measurements is the examination of the students' ability to orient themselves in new, life-like situations.

Molnár (2006) formulates that we talk about complex problem-solving when the problem is a set of dynamically changing and untransparent barriers between the initial and the target state. Complex problem solving includes the interaction between the problem solver and the problem as well as the problem solver's cognitive, emotional, personal, and social skills and knowledge (Frensch, & Funke, 1995).

In the process of problem-solving, we get from problem raising to solving through a series of steps. Since the early 1900s different models have been developed to describe the process and these models envisioned problem-solving as a linear process. One of the best-known and widely used problem-solving process models in education is the cognitive model of Pólya (2000). He describes problem-solving as a series of cognitive steps in which the path to a solution is not just a one-way process, but also a series of feedback steps. Certainly, there are several theories regarding solution strategies, some of which emphasize the process of designing (Osborne, 1979), while others do not attach particular importance to it (Rossman, 1931; Newell, Shaw, & Simon, 1962).

From the point of view of problem-solving theory, tasks can be analyzed in terms of both problems and solution strategies. Bloom (1956) defines cognitive levels in the function of the level of difficulty in solving tasks: (1) knowledge: remembering, recognizing, recalling; (2) comprehension: interpretation, description in own words, interpretation; (3) application: problem-solving; (4) analysis: analysis, exploration of essential elements, structure, interpretation of motives; (5) synthesis: the creation of an individual and original product; (6) evaluation: making opinions and judgments based on one's values. This order points to increasingly higher and more complex levels.

All levels except evaluation are present in problem-solving tasks, but the role of application is decisive in the process of achieving the goal. Only those who have the appropriate level of thinking operations presented here can become expert, routine problem solvers (Markóczi Revák, 2001). According to Carbonell (1986), problem-solving strategies can be grouped according to the general (discipline-independent) and specific (discipline-dependent) nature of the knowledge applied in them. It is important to note that a problem usually belongs to one of the disciplines, but the strategy needed to solve it may include discipline-independent elements (Pólya, 2000).

In a complex interpretation of problem-solving, two types of thinking, creative and critical thinking, are juxtaposed. Modern learning theories do not highlight the essential features of one or the other but view cognitive activities as rooted in the intertwining of the two. For example, a reinterpretation of the cerebral hemisphere model also emphasizes that the more processes are involved in the right ("creative," "artistic") and left ("logical," "scientific") hemispheres, the more effective learning is (Tóth, 2019).

Treffinger, Feldhusen, & Isaksen (1990) breaks down productive thinking into overlapping levels. At the basic level, the basic prerequisites for thinking are (1) existing factual knowledge; (2) motivation and disposition; (3) and metacognition. Creative and critical thinking are at the middle level, and problem-solving is at the top level.

According to Lipman (1991), critical and creative thinking consist of similar elements but are organized differently. Moreover, he interprets higher-level thinking as the interaction of these two, which do not add up but multiply during actual cognitive activity. In engineering training, where computer science education plays a prominent role, the field of algorithmic thinking illustrates its theory well. Critical thinking is fostered by the use of algorithms, and although they discourage creative solutions, they are important in the problem-solving process. At the same time, it is also clear that whenever the emphasis is not on the application of algorithms but their creation, creative thinking comes to the fore.

Based on all this, it can be stated that problem-solving can be described as a complex cognitive process in which the critical thinking that controls the reorganization of existing knowledge, and creative thinking that promotes the acquisition of new knowledge are present in equal proportions. This balance is emphasized by Tóth (2019), who highlights three cognitive components on both sides: analysis, evaluation, and the search for correlations in the field of critical thinking, and synthesis, elaboration, and recognition of correlations linked to creative thinking.

School education (general and vocational) is the most appropriate framework for developing problem-solving skills or knowledge. The core curricula aim to develop students' algorithmic and problem-solving thinking and creativity, but schools do not focus enough on these competencies in their assessment systems. Yet the school system, which seeks primarily to increase and measure lexical knowledge and mathematical skills, is an evolutionary impasse in the 21st century in terms of educational development.

1.2. Antecedents of the research

In our research conducted in the 2015-2016 academic year (Pletl, 2016) we measured the level of algorithmic thinking within problem-solving (Harangus, & Kátai, 2018) while in our research conducted in 2017-2018 (Pletl, 2018) we measured the level of computational thinking within problem-solving (Harangus, 2019) among teacher training students. The results of both measurements showed that the performance of students is halved if they have to solve a task different than a school task, and the usability of the knowledge acquired during classes is extremely poor. The result obtained showed that:

(1) Due to the shortcomings of high school education, the applicability of school knowledge is weak, the lack of an interdisciplinary approach hinders the recognition of the connections and correlations between different fields of education;
(2) Knowledge transfer does not work in solving practical, lifelike problems;
(3) Networks have not been set up to ensure communication between the various levels of education (high school - higher education) and educational regions, which would allow the transfer of good practice.

1.3 Purpose of study

The research aimed to determine whether knowledge transfer works among students in interpreting life-like, specific problems

2. Materials and Methods

This study presents a segment of the research launched in the 2017-2018 academic year and planned for two years "*A study of problem-solving skills regarding different subject areas (reading comprehension, content creation, mathematical and computational thinking)*".

2.1. Participants

The Sapientia Hungarian University of Transylvania examines among first year engineer-teacher training students (N = 73) the extent to which they can integrate their knowledge in a new way in solving tasks that require computational thinking. With our empirical study, we would like to relate with the international practice that has demonstrated through a series of measurements, that the examination of cross-curricular skills provides information about student development, development determinants, and the educational system that traditional knowledge level measurement cannot show.

2.2. Data collection instrument

We used a worksheet as a measure of the survey. The tasks that the students had to solve were selected from the BEBRAS (2016) website. The tasks raise interesting issues. They are rather fun thinking puzzles than tests. Contestants can get to know the practical side of IT thinking, its subtopics, and its usability beyond the theoretical concepts. One of the goals of the Bebras International Challenge on Informatics and Computational Thinking for students is to promote Informatics (Computer Science, or Computing) and computational thinking and for teachers to integrate the Bebras challenge in their teaching activities. The selected tasks assumed structured and logical thinking; no IT knowledge was required to answer them. Students were asked to solve problems that focused on the following areas of computational thinking: cryptography process, parallel computing, and constraints.

2.2.1. Presentation of sample tasks

A common element of the tasks was that they assumed an algorithmic approach and that they used the students' ability to abstract, which is an especially important skill for computational thinking. Being a textual task, students had to be able to abstract from irrelevant elements and focus on data relevant to the task. It can also be interpreted that they had to be able to gather relevant information from the texts of the task.

The followings are sample tasks from the worksheet:

1. Task for cryptography process (HÓDítsd meg a biteket, 2015): "Alex and Bea send each other encrypted messages. To do this, each word is coded separately in three steps: they reverse the word (the order of the letters); each letter is shifted two places to the left (circularly, so the first letter is placed before the last one, etc.); each vowel is replaced by the following vowel (the last vowel changes from Ű to the first, A). The word BEAVER will be in this way (REVAEB >> VAEBRE >> VÁÉBRÉ). Bea receives the following message from Alex: VREZO. Which word was coded and sent by Alex?" A) ÁRVÍZ; B) RÁZVA; C) HÓDOL; D) VÉRZŐ.

2. Task for parallel computing (Bebras, 2013, pp 35): „So the beaver loves to cook. His favorite meal is Chakhokhbili. When cooking in the garden he uses a single gas burner. He performs the following actions after each other:

Cook an onion:	10 minutes;
Cook a bell pepper:	10 minutes;
Combine the cooked onion and cooked bell pepper, add tomato and cook this together:	20 minutes;
Cook a chicken:	30 minutes;
Combine everything from steps 3 and 4, add some spices and cook it all.:	20 minutes.

In total Sergo needs 90 minutes to prepare his Chakhokhbili on a single gas burner." At least how much time does Sergo need to cook chakhokhbili if he has six gas burners in his garden? A) 40 minutes; B) 50 minutes; C) 60 minutes; D) 70 minutes.

3. Task for constraints (Bebras, 2016, pp 34): "The beavers and dogs had a competition. In total nine animals taking part. The nine participants had the following scores: 1, 2, 2, 3, 4, 5, 5, 6, 7. No dog scored more than any beaver. One dog tied with a beaver. Two other dogs tied with each other. How many dogs took part in the competition?" A) 3; B) 4; C) 5; D) 6.

3. Results

Encryption of information, as well as decryption of encrypted data and the retrieval of information, has evolved into a whole discipline, cryptology. The encryption method is an algorithm that converts the information to be encrypted into another information. The method Alex and Bea use include steps that can also be found in cryptological procedures. The first two steps, in which the word is reversed, and each letter is shifted two places to the left, is a relocation, a rearrangement of the signs of the message. The third step, in which all vowels are replaced by the following vowel, is a substitution where the signs are replaced by other signs. The codeword can be retrieved from the VREZO word sent by Alex by performing the steps given in the task backward:

(1) We replace each vowel with the one in front of it (VRÁZÍ; According to the rules of the Latin alphabet used in Hungarian);
(2) We shift the letters two places to the right (ZÍVRÁ);
(3) We reverse the word (ÁRVÍZ).

The correct answer: ÁRVÍZ means 100 points. It was also possible to get sub-points during the task. Because at least the consonants in the B and D answers were correct, they meant 25 points. The consonants of the word HÓDOL (answer C) were not included in the message and since the consonants did not change, this word could be excluded from the solutions immediately. Since, as a first step, all vowels had to be replaced by the next vowel, and since the other operations did not involve a change of letters, it was easy to see that the word ÁRVÍZ would be the right solution. Students recognized this (98%), many who decoded the message in one step justified it with the following: "…because only one of the words given contains the letter Í.", "…because Á is before E and Í is before O, this combination was only in ÁRVÍZ.", or "…because I looked at the vowels and only one could be the correct word."

Some students marked the words RÁZVA and VÉRZŐ as correct answers. Presumably, these words were chosen because the word VREZO contains the consonants V, R, Z which were not requested to be replaced by the decoding algorithm, and these words included these consonants. When asked how many steps they used to decrypt the message, more than half answered 1 or 2 steps, meaning that they did not recognize the direction of the algorithm and they marked the answer without following the steps of the recryption to the end.

One of the cornerstones of modern programming is parallel programming, which has spread with the advent of multi-core processors. Several university lectures are discussing this topic. In the task, the concept of multiple cores appears in the fact that there is a 6-burner stove in the garden, which allows certain kitchen operations to be carried out in parallel.

The correct answer to the problem: 50 minutes. With two burners Sergo needs at least 60 minutes, but with three burners he needs at least 50 minutes. Cooking is not possible faster than this, as steps 4 and 5 must be performed one after the other. For these, Sergo needs at least 50 minutes (Figure 1).

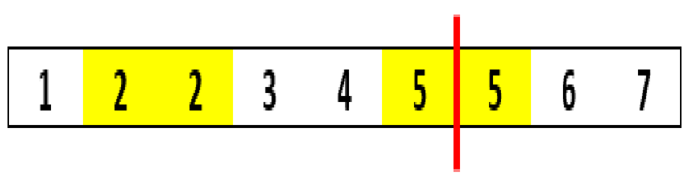

Figure 1. Illustrative diagrams for solving the task

By solving the task, the following scores could be obtained: 100 points (50 minutes), 50 points (60 minutes), and 30 points (30 minutes). Those who marked 30 minutes as the correct answer parallelized all the activities, and thus saw the solution in simply selecting the most time-consuming operation. Because the specificity of the task was parallelization, we gave 30 points for this approach. The logic behind the 60 minutes as an answer may have been that students did not parallelize the cooking of the onion and peppers, but they did the cooking of the chicken. By parallelizing certain activities, students who scored 50 points had a clearer (even if not perfect) view of the task than those who parallelized everything or nothing (0 points for "90-minute responses").

The proportion of those who solved the task correctly (84%) suggests that students had recognized the possibility that Chakhokhbili can be cooked in less time using multiple burners. They saw the potential of working in parallel and were able to build the steps of the algorithms running in parallel by dividing the task into several parts. Conditions are often referred to as constraints in computer science. Constraints can play a role in translating a computer program, in database systems, or, as here, in finding the best solution to a problem.

The correct solution to the problem: 6. At best, each dog had the same number of points as a beaver. Therefore, we can find the score limit between the dogs and the beavers. Where a dog has the same score as a beaver, it must be 2 or 5 – as only these points are listed twice. If the limit were 2 points, a beaver would also have 2 points. But in this way, two dogs with the same points would have 5-5 points, which is more than a beaver with 2 points. Since none of the dogs had more points than any beaver, this is not possible. So, the score limit is 5: Dogs 1, 2, 3, 4, 5 | 5, 6, 7 Beavers. Thus, six dogs (and three beavers) took part in the contest.

When searching for the number of dogs, the possible solutions are limited in turn by the different conditions in the history of the competition:

(1) At least one beaver took place in the contest (and had the same score as a dog);
(2) Dogs and beavers are not mixed up on the score list, a line can be drawn between them;
(3) There were two tie scores: between two dogs and one beaver and one dog.

For the correct answer (D, 6 dogs participated in the competition) students got 100 points and those who chose A (3 dogs) as a solution received 50 points. We considered that by choosing point A the student thought well, but inadvertently gave the number of the beavers (3 = 9 – 6) and not of the dogs. About 78% of the students followed the algorithm of the task well; they were able to narrow down the number of choices so that they could reach the solution.

4. Discussion

In real sciences, problem-solving is a process in which the solver has to move from an initial state (problem raising) to the target state (solution) so that in the meantime the road leading there is unknown. Experience shows that in school education solutions based on the pattern and algorithm of a previously solved problem that requires less prior knowledge are used, as this corresponds to the prior knowledge of the students due to their age.

The results of our previous empirical skills testing have shown that knowledge transfer does not work well enough or at all. The results of our large-sample measurement examining the problem-solving skills of schoolchildren (Harangus, & Kátai, 2018; Harangus, 2019) showed that students' performance is halved if they have to solve different types of tasks than a school task, and the usability of the knowledge acquired during classes is extremely poor.

5. Conclusion

Building on the results of our preliminary measurements, we examined in the present research whether first-year teacher training students have the key elements of successful problem solving recognizing the relationship between the problem situation and what has been learned before; the development of the ability to create independent hypotheses; the ability to incorporate knowledge into previously learned material; problem sensitivity. Overall, it can be said that the students have the knowledge elements needed to solve the task, the analytical, synthesizing skill that is essential in a problem situation. However, the data also suggest that a significant proportion of them (25%) were unable to establish a link between existing knowledge and problem situations and did not recognize the algorithm for the solution.

The basic task of teacher training is to prepare teachers to train students for the new expectations in education that require the acquisition of applicable knowledge. It can be formulated as an objective for teacher training institutes that by validating the interdisciplinary approach in their training, which highlights the importance of connections between different fields of education, to develop the key competencies which would reduce the deficiencies in secondary education. Issues related to the effectiveness of education (skills development, problem solving, knowledge transfer) should be given a more prominent role in the preparation of teacher candidates.

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References

Bebras Australia Computational Thinking Challenge, Tasks and solutions 2016, p. 35: http://bebras.org/

Bloom, B. S. (1956). Taxonomy of educational objectives: cognitive domain. New York: McKay.

Carbonell, J. G. (1985). Derivational analogy: A theory of reconstructive problem solving and expertise acquisition. CARNEGIE-MELLON UNIV PITTSBURGH PA DEPT OF COMPUTER SCIENCE. https://apps.dtic.mil/sti/citations/ADA156817

Dadashi, M., Soltani, A., & Rahimi, A. (2020). Bilingualism and reading proficiency: Experiences of Armenian, Persian and Azeri students. International Journal of New Trends in Social Sciences, 4(2), 61–76. https://doi.org/10.18844/ijntss.v4i2.4768

Frensch, P. A., & Funke, J. (1995). Definitions, traditions, and a general framework for understanding complex problem solving. Universitätsbibliothek der Universität Heidelberg. https://www.academia.edu/download/47922111/Frensch_Funke_1995_Complex_Problem_Solving.pdf#page=24

Guerra, J. (2021). Portuguese as a foreign language textbooks: Framing the discourses on the teaching and learning of writing. Global Journal of Foreign Language Teaching, 11(2), 94–100. https://doi.org/10.18844/gjflt.v11i2.5588

Gyöngyvér, M. (2006). Knowledge transfer and complex problem-solving. Technical Publishing. https://www.antikvarium.hu/konyv/molnar-gyongyver-tudastranszfer-es-komplex-problemamegoldas-648503-0

Harangus, K. (2019). Examining the relationships between problem-solving and reading comprehension skills. New Trends and Issues Proceedings on Humanities and Social Sciences. 6(5), 066–074. https://un-pub.eu/ojs/index.php/pntsbs/article/view/4375

Harangus, K., & Kátai, Z. (2018). Algorithmic Thinking vs. Text Comprehension. Procedia Manufacturing, Volume 22, 1031-1037. https://doi.org/10.1016/j.promfg.2018.03.146

HÓDítsd meg a biteket, (2015). Tasks and solutions. p. 30: http://e-hod.elte.hu/archiv/feladatok/e-hod_2015.pdf

Lipman, M. (1991). Thinking in education. Cambridge: Cambridge University Press.

Markóczi Revák, I. (2001). The development of problem-solving and its relationship other influential factors. In L. Balogh, L. Tóth (Eds.), Gifted development at schools: research and practice (pp. 152-158). The University of Debrecen, Department of Education

Milkias, E. (2020). Action research's instructional impacts: Article review. Contemporary Educational Researches Journal, 10(1), 1–6. https://doi.org/10.18844/cerj.v10i1.4608

Newell, A., Shaw, J. C., & Simon, H. A. (1962). The processes of creative thinking. In H. E. Gruber, G. Terrell, & M. Wertheimer (Eds.), Contemporary approaches to creative thinking: A symposium held at the University of Colorado (pp. 63–119). New York: Atherton Press. https://doi.org/10.1037/13117-003

Osborne, A. (1979). Applied imagination. New York: Scribner.

Pletl, R. (2016). The context, purpose, objective, and methods of the study. In R. Pletl (Ed.), Mother Tongue Education. Qualities and opportunities in Hungarian-language vocational training [Mother tongue education. Features and opportunities in Hungarian-language vocational education]. (pp. 27-36). Cluj-Napoca: Abel For Rent.

Pletl, R. (2018). Examining problem-solving ability in different areas of performance. Mother tongue teaching. New Challenges — Changing the Concept of Knowledge, 21-32.

Pólya, Gy. (2000). A gondolkodás iskolája [How to solve it]. Budapest: Akkord Kiadó.

Ramírez-Montoya, M. S., Loaiza-Aguirre, M. I., Zúñiga-Ojeda, A., & Portuguez-Castro, M. (2021). Characterization of the Teaching Profile within the Framework of Education 4.0. Future Internet, 13(4), 91. https://www.mdpi.com/1999-5903/13/4/91

Rossman, J. (1931). The psychology of the inventor. Washington: Inventor's Publishing Co.

Sacramento, M., Ibanezr, G., & Magayon, V. C. (2021). Technology adaptation of teachers and students under the learning continuity plan: A case of one school in the Philippines. International Journal of Learning and Teaching, 13(4), 204–223. https://doi.org/10.18844/ijlt.v13i4.5594

Tóth, P. (2019). Problémaalapú tanulás [Problem-based learning]. Komárom: Selye János University. https://www.researchgate.net/profile/Peter-Toth-12/publication/345876532_Problemaalapu_tanulas/links/5fb03296a6fdcc9ae051616c/Problemaalapu-tanulas.pdf

Treffinger, D. J., Feldhusen, J. F., & Isaksen, S. G. (1990). Organization and structure of productive thinking. Creative learning today, 4(2), 6-8. http://www.creativelearning.com/~clearning/images/freePDFs/CPS-2007GTI.pdf