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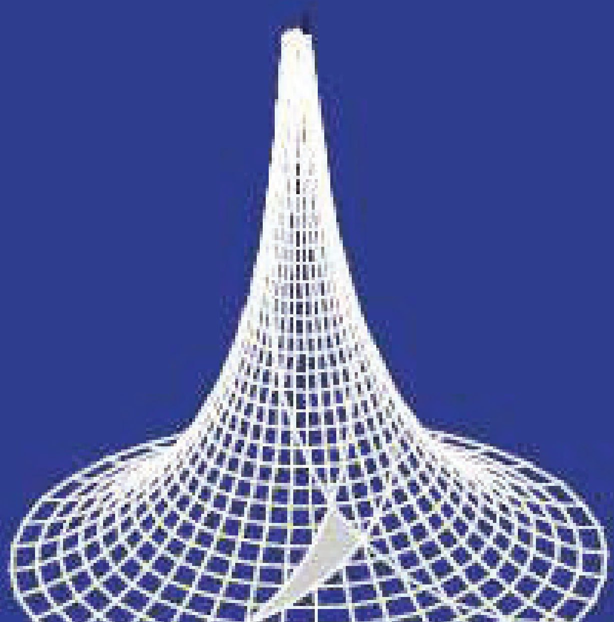
Teaching Mathematics and Computer Science



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Teaching Mathematics and Computer Science

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The use of e-tests in education as a tool for retrieval practice and motivation

Gabriella Papp

Abstract. In many studies we can read about what techniques are used in the educational process to deepen knowledge, and what can motivate students to learn. We aimed to give our students (who will be a teacher) a practical demonstration of learning techniques. We carried it within the framework of a course, at the end of which we also examined how much it motivates students if they write an e-test as a retrospective in order to deepen the material of the lesson. In the paper, we will present the results of the research as well as students' opinions regarding the motivating effect of the tests.

Key words and phrases: retrieval practice, motivation, e-test.

MSC Subject Classification: 97-01, 97D40, 97I10.

Introduction

There are many studies abroad on learning techniques, those that are known and used in the educational process to deepen knowledge. One of these techniques is test-enhanced learning (retrieval practice), which is still new abroad as well, and has only recently been applied in Transcarpathian Hungarian education. In this paper, we explore students' experience using this learning method, how motivating it is for them to write the retrieval tests, and what impact they think the retrieval tests have on the knowledge assessment test.

With the digitalisation of education, various electronic tools are used to facilitate measurement (Korenova, 2013). In pedagogical measurement, the observable behaviour and the created product of the learner are matched to a scale fixed on a measuring instrument according to predefined criteria and criteria in order to quantify the achieved result (Molnár & Vígh, 2013). In this process, several techniques can be used. One of the innovative tools is the e-test, which became topical at the beginning of the pandemic, but can be seen as a positive remnant for the future.

The e-tests

In educational contexts, tests are usually seen as a means of assessment. Students take tests in class to assess what they have learned, their knowledge and their aptitude (Roediger & Karpicke, 2006). Tests can be used at several levels of the educational system. They (1) have a clearly evaluable solution; (2) are mainly used to assess the cognitive knowledge domain, i.e., the learner's knowledge and skills that are precisely delimited and predefined at the beginning of the assessment process; (3) the results obtained can be quantified, expressed in points and standardised after individual and group level evaluation (Molnár & Vígh, 2013).

Molnár and Vígh point out that a distinction is made between diagnostic and summative tests. Diagnostic tests can be used at any stage of the teaching-learning process to ensure that the area of knowledge being tested is covered as fully as possible by the tasks. The purpose of using these tests is to determine what students already know and what they do not yet know, by knowledge element (2013). Tests are most commonly used as summative assessment tools to assess whether students have achieved the learning objectives of the course (Brame & Biel, 2015). In this case, the primary objective is to grade on the basis of the test score achieved, so results are usually not analysed at item and task level, but rather at subtest and test level (Molnár & Vígh, 2013).

According to Korenova, today we can define the term "e-test" dually:

(1) In a narrower meaning, the e-test is an electronically controlled didactic test with an option to enrich it with multimedia elements.

(2) In a wider meaning, the e-test is an electronic interactive material based on a system of questions and searching for answers created not only for measuring, but also for reaching educational goals (hence can serve as tools for innovative teaching methods) (Korenova, 2013).

These tests are only considered as a worksheet as long as they do not have any goodness indicators. The three goodness indicators traditionally distinguished in tests are objectivity, validity and reliability (Csapó, 2004). The purpose of using any measurement instrument is to measure the property under test accurately and reliably, and to evaluate it objectively (Molnár & Vígh, 2013).

One of the most important properties of a test is its reliability (Csapó, 2004). Test reliability is an indicator of the accuracy and reliability of measurement (Demkanin et al., 2015), which estimates measurement errors at the group level. For a test with high reliability, measurement errors are low (Molnár & Vígh, 2013).

Reliability can be estimated using different methods (Molnár & Vígh, 2013). Cronbach created the formula for calculating the universal index in 1951:

$$\alpha = \frac{n}{(n-1)}\left(1 - \frac{\sum_i V_i}{V_t}\right), \qquad (1)$$

where n is the number of items, V_t is the variance of the total scores, and V_i is the variance of item scores (Panayides, 2013).

The reliability coefficient is generally between 0.65 and 0.95,

- above 0.90: the test is considered excellent;
- 0.85–0.95: decisions can be made on the basis of the test;
- 0.65–0.85: the test can be used as one of the preconditions for decisions;
- below 0.65: unreliable test, unsuitable for classification, entrance examination, etc. (Demkanin et al., 2015).

Validity refers to the validity of the test (Csapó, 2004), one of the basic prerequisites for which is the development of a detailed test specification (Demkanin et al., 2015). Validity is an important goodness-of-fit indicator for tests, and in order to ensure it, it is essential to define the test's measurement purpose, requirements and content in the test design process. Based on this information, test tasks and evaluation procedures can be developed (Molnár & Vígh, 2013). Test objectivity, like objectivity in general, means that the test is objective, objective and not subjective (Csapó, 2004). The objectivity of the test is achieved through the correct selection of items, the clear wording of questions and answer choices, the adequate coverage of items, and the elimination of any doubt about the correct answers to items (Demkanin et al., 2015). It ensures that the test result is independent of the respondent (Csapó, 2004). Objectivity of the assessment is ensured by precise and equal scoring rules and by scoring (marking) identical answers in the same way (Demkanin et al., 2015), so that its results are independent of who does the correcting, coding, i.e., scoring of the results (Csapó, 2004). Objectivity of the testing process is achieved by providing equal testing conditions for all students tested (Demkanin et al., 2015).

A taxonomy is a specific framework in which categories are arranged along a continuum (Anderson & Krathwohl, 2001). Each taxonomy is in fact just a hierarchically arranged classification (Demkanin et al., 2015). Anderson & Krathwohl (2001) point out that in their taxonomy they classify purposes. In 2001, a group of cognitive psychologists, curriculum and instructional theorists, and testing and assessment specialists published a revision of Bloom's taxonomy entitled "A Taxonomy for Teaching, Learning, and Assessment" (Armstrong, 2010). Table 1 shows the revised two-dimensional table of taxonomy.

			The cognitive process dimension					
			1	2	3	4	5	6
			Remember	Understand	Apply	Analyze	Evaluate	Create
The knowledge dimension	A	Factual knowledge						
	B	Conceptual knowledge						
	C	Procedural knowledge						
	D	Metacognitive knowledge						

Table 1. Summary table of the revised Bloom's taxonomy (Anderson & Krathwohl, 2001; Demkanin et al., 2015)

The elements in the table are further elaborated by Anderson & Krathwohl (2001), Armstrong (2010), Demkanin et al. (2015) and Shabatura (2022):

(1) *Remember* (recall): recognition and recall of relevant knowledge from long-term memory (Shabatura, 2022).

(2) *Understand*: constructing meaning from verbal, written, and graphic messages (Anderson & Krathwohl, 2001) through interpretation, exemplification, classification, summarization, inference, comparison, and explanation (Shabatura, 2022).

(3) *Apply*: following instructions or applying a procedure to familiar or unfamiliar task types (Demkanin et al., 2015).

(4) *Analyze*: to break the material down into its constituent parts and determine how the parts relate to each other and to an overall structure or purpose (Anderson & Krathwohl, 2001), to the whole or to the main function of

the material (Demkanin et al., 2015) by differentiation, classification and attribution (Shabatura, 2022).

(5) *Evaluate*: making judgements based on criteria and standards through checking and critiquing (Shabatura, 2022).

(6) *Create*: to create new, interesting, internally coherent units by combining parts (Demkanin et al., 2015), to form a coherent or functional whole; to reorganize elements into a new pattern or structure through generation, design or production (Shabatura, 2022).

In the revised taxonomy, knowledge is the basis of these six cognitive processes, but the kinds of literature mentioned above highlight the characteristics of the dimensions of knowledge used in cognition:

(A) *Factual knowledge*: the basic elements that students need to know to learn about or solve problems in a discipline (Anderson & Krathwohl, 2001).

(B) *Conceptual knowledge*: the relationships between basic elements within a larger structure that allow them to work together (Anderson & Krathwohl, 2001; Demkanin et al., 2015).

(C) *Procedural knowledge*: knowledge of concrete procedures, methods, algorithms, techniques, and application of skills to solve a question/task/problem (Demkanin et al., 2015).

(D) *Metacognitive knowledge*: knowledge of cognition in general as well as awareness and knowledge of one's own cognition (Anderson & Krathwohl, 2001).

Traditional qualitative and quantitative tests can be used to measure the participant's knowledge. These are created and evaluated in the field of testing theory (Korenova, 2013). Quantitative tests are typically used to assess the process of familiarisation, while qualitative tests are used to help with differentiating measurement.

E-tests are classified according to their use as follows:

- to determine students' knowledge;
- to improve students' motivation, to challenge them to solve tasks;
- to use it as an interactive worksheet (it is no longer a traditional test, the electronic test is just a tool); to use it in controlled discovery (after incorrect answers, it directs the student to the assigned tasks) (Korenova, 2013).

The use of digital technologies in teaching, distance learning and e-tests is addressed by several authors such as Gunčaga et al. (2018), Korenova (2015), Kónya and Kovács (2019).

Retrieval learning

Retrieval learning means trying to recall information without having it in front of you (Gonzalez, 2017). This technique is different from the questioning and retrieval techniques often used at the beginning of lessons to check and measure what you have learned. The idea is to recall information that has been stored in short-term memory, thus activating retention. Research reports on the extent to which knowledge levels increase for students who have used this technique.

In recent years, cognitive psychologists have compared pre-recall learning with other learning methods – strategies such as review lectures, study guides and re-reading texts. They found that nothing captures long-term learning as strongly as retrieval learning (Gonzalez, 2017). One of the keys to maintaining access to knowledge in memory is to use this information from time to time – that is, to retrieve it. Unlike other memory systems, such as the memory of a tape recorder or computer, where retrieval of stored information does not change the state of the information in memory, human memory is significantly altered by retrieval (Bjork, 1988).

The traditional approach to improving learning and retrieval, both in laboratory studies and by extending it to the classroom, means changing learning strategies. A century of research has been devoted to studying the testing effect – the fact that active recall leads to better deepening than passive re-reading (Roediger et al., 2011). One of the most consistent findings in cognitive psychology is that testing increases deepening better than learning alone. This effect can be enhanced when students receive feedback on failed tests and is observed for both short- and long-term retention (Brame & Biel, 2015).

There is evidence that testing not only improves learners' memory for the information being tested, but also for related information (Brame & Biel, 2015). The central assumption of the idea of retrieval practice is that retrieval does not simply strengthen the representation of an object in memory, but also strengthens some aspect of the retrieval process itself. Considerations supporting this assumption include the following (as cited in Bjork, 1988):

> (a) If an initial retrieval simply strengthened an item's representation in memory, one might expect that an initial test of recall might facilitate a later test of recognition as much as it does a later test of recall. Typically, however, the effects of an initial recall test on a later recognition test are far less than on a later recall. (b) If, on the other hand, one makes a later recognition test more difficult in ways that might be

> viewed as making that recognition test more recall-like, then the positive effects of an initial recall test are much larger (Gelfand, Bjork, & Kovacs, 1983). (c) Similarly, as Whitten and Leonard (1980) have shown, as one makes an initial test of recognition more difficult, and recall-like, by increasing the alternatives on an initial forced-choice test, performance on that test decreases but later recall increases. (Bjork, 1988)

Testing seems to reinforce further learning, allowing students to gain more from post-test study periods (Brame & Biel, 2015). There exists a uniquely optimal way to sequence learning through pretesting. The almost immediate first test should be followed by further tests in succession in case of longer delays. Such an expanding schedule represents a kind of optimal shaping procedure. Each successive prefetching promotes successful retrieval after the next (longer) interval, and as the interval gets longer, each retrieval becomes increasingly powerful as a learning event (Bjork, 1988).

As Roediger and Karpicke (2006) put it:

> To state an obvious point, if students know they will be tested regularly (say, once a week, or even every class period), they will study more and will space their studying throughout the semester rather than concentrating it just before exams (Roediger & Karpicke, 2006).

E-testing is very attractive for students because the digital world is very close to them (Korenova, 2013).

The motivation

Ceglédi points out the essence of motivation with a quote from György Pólya:

> A mathematics teacher must be a good salesman, he must be able to sell his product (the knowledge) to the buyer (the student) (Ceglédi, 2011).

The word 'motivation' is of Latin origin, meaning: the incentives or triggers of action. And the word 'motive' means motivators, moral motives (Orosz, 1994). According to previous research, motivation can be defined as the driving power that has become active; can be said to be a response from action, that is the goal (Fuqoha et al., 2018). Orosz argued that motivation is an intrinsic tension in the process of active activity, operating in a specific hierarchy, which plays an essential role in all human activity (Orosz, 1994). Motivation was included as a subcategory of "beliefs about self" (Schukajlow et al., 2023). Or, as Fuqoha et al. (2018) interpret: "The need to do something to something very important activities for the children, because it contains joy. Activities in itself is a pleasure. If it is connected to the learning activities, then learning will be successful if it is accompanied by a sense of delight, wonder, and interest in the study."

In a broad understanding, motivation comprises reasons for human behavior and represents psychological forces that shape the goal direction, intensity, and persistence of human behaviour (Schukajlow et al., 2023).

Psychological areas of motivation:

- *Affective* (emotional) *domain*: there are two extreme poles of this domain. One is the positive emotional relationship with teachers, peers, and parents. It is characterised by a desire to meet expectations. The other pole is the negative emotional relationship with the same person. This is characterised by cold rejection, turning away, defiance, "just not because" behaviour.
- *Cognitive* (intellectual, thinking) *domain*: this domain may be characterised by a tendency to cognize, to learn, to strive to learn, to actively participate in the acquisition of knowledge. This can be effective if the teacher finds the student's interests.
- *Effective* (moral) *domain*: the positive pole in this domain is when the learner sees the social benefits of his/her work and takes responsibility for his/her work. The negative pole is the learner's poor self-control, acceptance (and explanation) of inefficiency, and avoidance of challenges (Ceglédi, 2011; Orosz, 1994).

The subject and characteristics of motivation are discussed in more detail by several authors such as Kim (1998), Román and Kucsinka (2019), Polinski and Kuchinka (2023), Schukajlow et al. (2023), Skemp (2005).

Methods

After learning about the retrieval learning technique, we wanted to try it ourselves. Since our students will become teachers at the end of their Bachelor's programme, we wanted to make the choice of learning techniques valuable for them by trying them out with them. By gaining experience in a learning technique, it is easier to decide what you want to use in the future.

Our research also looked at the motivational impact of the retrieval tests we created. We were looking for answers to the question: *What is the motivational impact of a test in a given subject?*

The retrieval learning technique was applied in the 4th-grade group of Mathematics of the Ferenc Rákóczi II Transcarpathian Hungarian College of Higher Education in the spring semester of the academic year 2021–2022, with the aim of covering the whole course of Selected Chapters of Mathematical Analysis. The course, consisting of 15 contact hours, was structured in such a way that we could then evaluate and analyse the mini-tests not only as a diagnostic test as part of the retrieval learning but also as a motivational tool for learning. The study involved 10 participants, however, we were able to use the results of 7 students due to the lack of an input or output test.

The tests were composed of items selected from a test bank that we had created ourselves, and which was being improved and expanded as a result of previous results. The test bank is structured by topic, with attention to the wording and editing of distractors (incorrect answers) and correct answers. From the knowledge dimension of the taxonomy to conceptual, procedural and metacognitive knowledge, we focused on the processes of analysing, understanding and applying from the cognitive processes dimension.

In order to treat it as a real test, we also pay attention to the goodness indicators. Objectivity is ensured by creating and setting up items in the online interface, so the correction is independent of the editors. To ensure validity, it was necessary to apply the knowledge and cognitive process dimensions of Bloom's taxonomy while editing the items. The tests include both closed and open tasks, and for a more accurate measurement, they include one-choice and multiple-choice items with one or more correct answers, true-false, pairing and short-answer items. Reliability was tested after completion using Cronbach's alpha.

The *input* and *output* tests that are part of the research were created in the OnlineTestPad interface. These tests are identical, so students were given the same test as an assessment of prior knowledge as a summative knowledge assessment tool at the end of the course. The test, consisting of 20 items, was edited in the OnlineTestPad interface, because the platform offers the possibility to edit mathematical formulas based on LaTeX in an easy and detailed way, while the commands can be selected from the LaTeX work window menu.

The *mini-tests* were created using Google Forms. The interface, which does not handle mathematical formulas, was chosen in order to be able to assign the task in an environment that is familiar and more familiar to the students. We did not plan the elicitation at the end of each lesson, but at the end of each topic, so students wrote 6 tests in total. In the spirit of retrieval learning, we tried to elicit the most important theoretical knowledge and type tasks with short e-tests

Bloom's taxonomy	Piece		Items	Piece
B1	5		One choice	6
B2	2		Multiple choice	1
B3	2		True – false	4
C1	4		Matching	5
C2	2		Input digit	2
C3	4		Input text	2
D3	1			
Sum	**20**		**Sum**	**20**

Table 2. Distribution of questions by Bloom taxonomy and item type

of 5-6 items using open and closed questions. The items are compiled according to the B1, B2, C2 and C3 levels of Bloom's two-dimensional taxonomy. As agreed with the students in advance, the points collected from these were used to pass the course.

Results and discussion

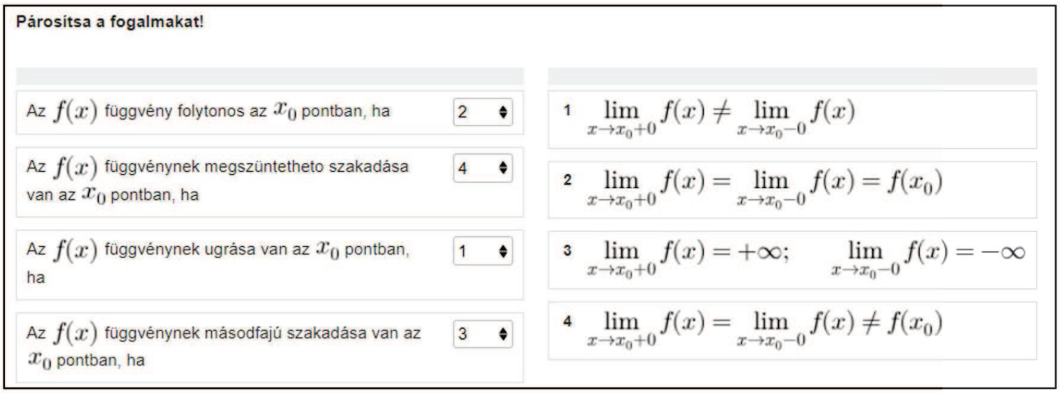
For the purpose of scoring the results, the items we prepared so that each correct solution was worth 1 point. For the pairing items, students could also earn partial points for each correct pair. The statistical coverage of both the input and output tests was 9 points, although their means differ significantly. Cronbach's alpha was used to determine the reliability, based on the variances of the output test, which showed a low reliability of 0.49, which could be due to the small number of participants.

Following the input tests, we concluded that although the pairing type was typically constructed to measure conceptual knowledge, they proved to be difficult. As an example, see Figure 1, we present one of the pairing type items (with correct answers) that proved to be difficult:

The task: *Match the concepts.*

Answers:

- The function $f(x)$ is continuous at the point x_0 if...
- The function $f(x)$ is not continuous (hole) at the point x_0 if...
- The function $f(x)$ is not continuous (jump) at the point x_0 if...



Párosítsa a fogalmakat!

Az $f(x)$ függvény folytonos az x_0 pontban, ha	2	1	$\lim_{x\to x_0+0} f(x) \neq \lim_{x\to x_0-0} f(x)$
Az $f(x)$ függvénynek megszüntetheto szakadása van az x_0 pontban, ha	4	2	$\lim_{x\to x_0+0} f(x) = \lim_{x\to x_0-0} f(x) = f(x_0)$
Az $f(x)$ függvénynek ugrása van az x_0 pontban, ha	1	3	$\lim_{x\to x_0+0} f(x) = +\infty; \quad \lim_{x\to x_0-0} f(x) = -\infty$
Az $f(x)$ függvénynek másodfajú szakadása van az x_0 pontban, ha	3	4	$\lim_{x\to x_0+0} f(x) = \lim_{x\to x_0-0} f(x) \neq f(x_0)$

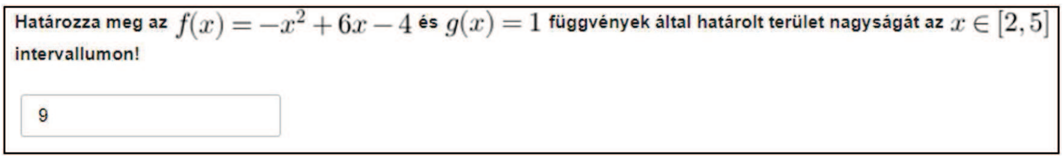
Figure 1. A pairing type item in input and output test

- The function $f(x)$ is not continuous (vertical asymptote) at the point x_0 if...

Unsurprisingly, in the pretest measuring prior knowledge, the majority could only correctly pair monotonicity, which may have been because the shape property of the function is typically mixed by students as early as their high school years. Correcting a poorly formed set of concepts at this age depends (to a large extent) on self-education and awareness of the wrong set of concepts. In the output test, there appears to be greater confidence among the completers, with 7 out of 9 students scoring the maximum points after pairing, only 2 students confusing convex and concave concepts showing the shape property.

To measure procedural knowledge, Bloom's taxonomy C2 and C3 items were mostly practical tasks. These proved easier to solve after completing both the input and output e-tests. Figure 2 shows an example of this type.

Task: *Determine the area bounded by the functions $f(x)$ and $g(x)$ on the given interval.*



Határozza meg az $f(x) = -x^2 + 6x - 4$ és $g(x) = 1$ függvények által határolt terület nagyságát az $x \in [2,5]$ intervallumon!

9

Figure 2. A practical task of item in input and output test

At the start of the research, students were marked S1 to S10 to ensure anonymity. These marks were used to assign test results to them and the same marks were used during the documentation of the interviews.

Figure 3 compares the input and output tests, showing the level of progress made by each student in relation from the input to the output test.

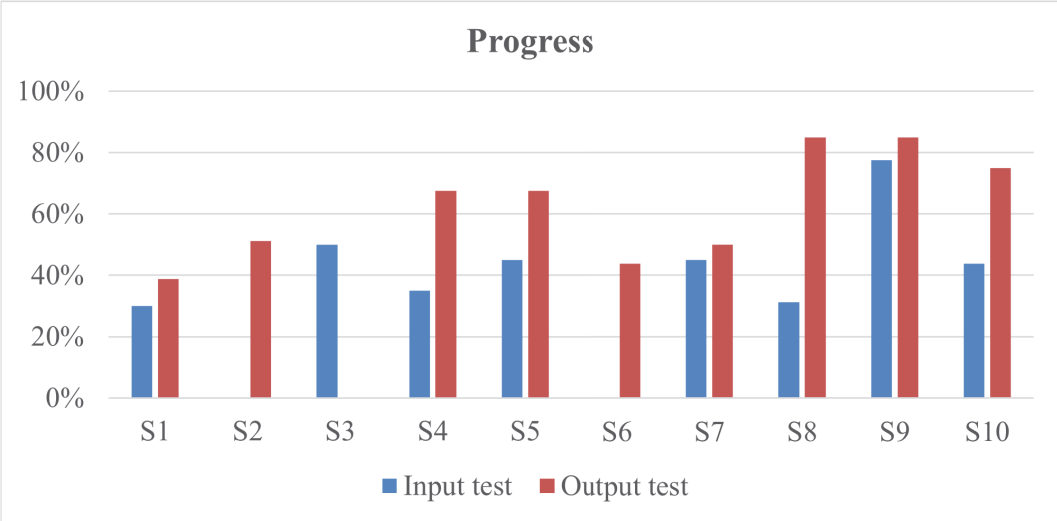


Figure 3. Students' progress between testing

While in the input test only one student (S9) exceeded half of the test items correctly, in the output test following the mini-tests, five students exceeded this by showing improvement, and two more achieved the correct answer to half of the test items.

S1, S7 and S9 students also show the most minimal improvement after the mini tests. Figure 2 strikingly shows that out of these students, S1 and S7 show little lasting knowledge in the input test, which after their minimal progress does not exceed answering at least half of the items in the e-test correctly. Nevertheless, for all students there is a demonstrable improvement between prior knowledge and the performance expectation of the subject. We highlight the result related to S8, which shows the progress we expect in our research.

For some students, we also examined the results as a function of the retrieval tests: in Figure 4, the results of the retrieval mini-tests are marked from T1 to T6. The first thing to notice is that the students have almost the same level of residual knowledge based on the input e-test.

For both selected students, the retrieval tests were close to good or excellent on all items. Here again, we conclude that they have almost the same level of knowledge or good short-term memory, with some minor differences in recall. With regard to the mini-tests, our expectation as teachers was that greater progress, comparable to the S8 student's results, would be shown in the final retrospective, as they were structured based on Bloom's taxonomy and some type

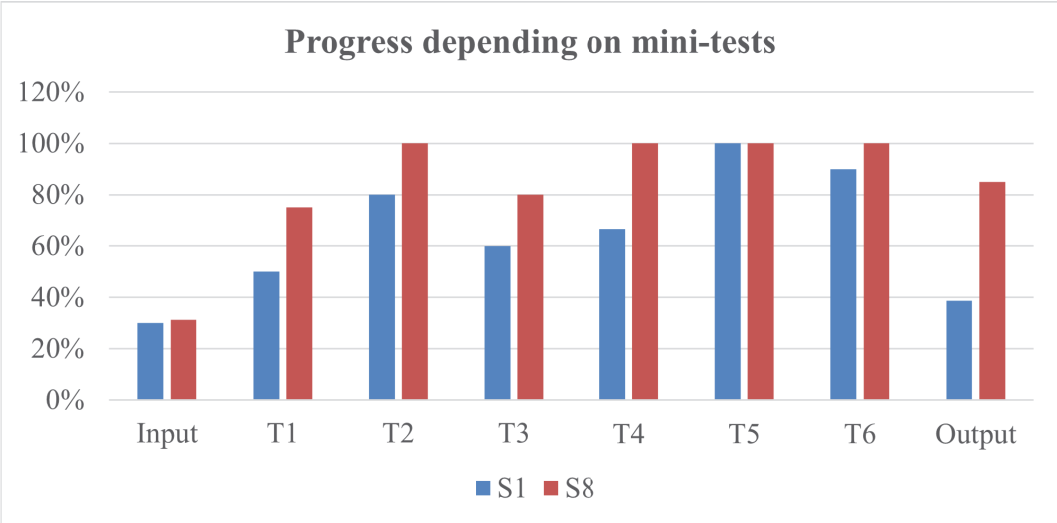


Figure 4. Examining the progress of individual students

tasks in the same way as the corresponding items in the input and output e-tests. Overall, both students showed improvement compared to their own baseline, but not to the extent we expected from the retrieval learning technique.

Following the research, we conducted short interviews with students to find out their views on the use of the retrieval learning technique and its motivational impact. The interviews were conducted one by one with the students in informal conversations outside of lessons so that in addition to the planned questions, changes were made depending on the answers given.

The first questions asked each student about his/her knowledge of the concept of retrieval learning and the techniques he/she knew or had used. Not too surprisingly, none of the students in this group had any previous knowledge of this learning technique. Several of them said that during their previous studies, they had been used to oral questioning and paper-based "ten-minutes" (open tests) at the beginning of the lesson, but they had not typically written a pre-test mini-essay on the material of a given lesson or the topic studied on a given day.

Let us now look at some of the important questions that arose during the interview and the answers given:

In your opinion, is it better to use the learning technique you were used to or the one you have just learned?

Students' answers:

- "Although I'm more used to the old accountability, as previously we answered for the teacher or wrote ten-minute papers in class, I really liked this one.

Now, maybe I pay more attention to the important things in class in the hope that they will come up as questions (S4)."

- "The tests were great, at least I didn't have to write so much (S1)."
- "I prefer the earlier methods because I can prepare more, and now, although the mini tests were good, I felt I started the test unprepared and could easily confuse things and mess up the solution. But it didn't turn out that way, and I was always happy about that, because they turned out well in the end (S5)."

How do you feel, did the success of the motivation tests affect you, did they help you prepare for the final exam?

Students' answers:

- "In the first lesson, I was very surprised by the test result. I thought I was remembering better, but in the end, the result was not very good. Then, the mini-tests were not too difficult, even if I didn't get all of them completely right, but I only had to remember what I had studied in 1-2 hours. Of course, I prepared for the final test, but in the meantime I remembered which questions were in the mini-tests and tried to look them up (S8)."
- "The mini-tests were good, but they had no completely right results either. Maybe I paid a little more attention to them, but they didn't do well enough to make the test good (S10)."
- "I could definitely describe the positive effect as the tests made me try and concentrate more in class. I'm not saying that I memorized everything or knew everything later, it shows in the tests, but it was good to always remember what we had recently learned. I would have liked to do well in the subject, and the last test doesn't reflect that, but at least it was better than what we wrote in the first class (S4)."

Were you motivated by the tests and their results?

Students' answers:

- "I was not really motivated by the tests. I didn't prepare for them any more than I otherwise would have (S1)."
- "The first test motivated me the most because it was a test with a very bad result. For the others, I was more focused on meeting my own expectations in my studies (S8)."

Would you use this technique in your future work?

Students' answers:

- "I think it is harder in secondary school because there is less time for everything. But it looks good, I might try it (S4)."
- "You have to prepare a lot if you want to use e-tests, and maybe in a school there is no internet, or the students are forbidden to use the phones and don't bring them. And if it's not an e-test, it takes more time to correct all the papers, although it's the same with the traditional ten-minute ones. I don't know if I'd go for it, but I might (S5)."

Conclusion

In conclusion, e-tests are indeed useful. Retrieval learning is a new technique in this group, and apparently it is also new in the Hungarian schools (where these students studied). Based on the figures in the study, it seems that it has not yet had a big enough impact on deepening the knowledge of the students in the group. This may be due to the difficulty of the subject, the low reliability of the output e-test as measured by Cronbach's alpha or the demotivation of the learners. It was not possible to measure the long-term impact of retrieval learning, as the research ended before the final exams of the Bachelor's programme, so the group could not be reached later.

During the interviews, we tried to find out the students' views on the motivational impact of the new learning technique. In our opinion, we can report a positive impact, as the questions presented in the study were answered with positive comments from the majority of the students in terms of retrieval learning, active attention and concentration in class, and of the impact on their performance for the final test.

All this leads us to conclude that more changes are needed to achieve the objectives of the research. The interview questions need to be modified to examine the motivational impact of the mini-tests. The number of respondents needs to be increased to test the accuracy of reliability. Furthermore, it would be worthwhile to investigate the long-term effect of the retrieval test in deepening knowledge, and for this purpose, the development of the tests should be prepared for a subject that is studied in the lower grades of basic education.

References

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives.* Longman.

Armstrong, P. (2010). *Bloom's taxonomy.* Vanderbilt University Center for Teaching. `https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/`

Bjork, R. A. (1988). Retrieval practice and the maintenance of knowledge. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory II.* (pp. 396–401). Wiley. `https://bjorklab.psych.ucla.edu/wp-content/uploads/sites/13/2016/07/Bjork1988ReRetrieval.pdf`

Brame, C. J., & Biel, R. (2015). Test-enhanced learning: The potential for testing to promote greater learning in undergraduate science courses. *CBE Life Sciences Education*, *14*(2), 1–12. `https://doi.org/10.1187/cbe.14-11-0208`

Ceglédi, I. (2011). *A matematika tanításának pedagógiai – pszichológiai vonatkozásai.* EKF. `https://dtk.tankonyvtar.hu/bitstream/handle/123456789/8131/0038_matematika_Ceglediı.pdf?sequence=2\&isAllowed=y`

Csapó, B. (2004). Tudásszintmérő tesztek. In I. Falus (Ed.), *Bevezetés a pedagógiai kutatás módszereibe* (pp. 277–316). Műszaki Könyvkiadó. `https://core.ac.uk/download/pdf/84775002.pdf`

Demkanin, P., Hajdúk, M., Hanuljakova, H., Kubiš, T., Lapitka, M., & Malčík, M. (2015). *Metodika tvorby testových úloh a testov.* Národný ústav certifikovaných meraní vzdelávania. `https://www.researchgate.net/publication/349279914_Metodika_tvorby_testovych_uloh_a_testov`

Fuqoha, A. A. N., Budiyono, B., & Indriati, D. (2018). Motivation in mathematics learning. *Pancaran Pendidikan*, *7*(1). `https://doi.org/10.25037/pancaran.v7i1.151`

Gonzalez, J. (2017). Retrieval practice: The most powerful learning strategy you're not using. *Cult of Pedagogy.* `https://www.cultofpedagogy.com/retrieval-practice/`

Gunčaga, J., Koreňova, L., & Kostrub, D. (2018). The educational research focused on the development of mobile technologies in education. In M. Artois (Ed.), *Teaching with technology: Perspectives, challenges and future directions* (pp. 57–115). NOVA Science Publishers.

Kim, R. (1998). A belső motivációt befolyásoló tényezők és megjelenésük a Montessori-pedagógiában. *Új Pedagógiai Szemle*, *48*(3), 44–54. https://ofi.oh.gov.hu/belso-motivaciot-befolyasolo-tenyezok-es-megjelenesuk-montessori-pedagogiaban

Kónya, E., & Kovács, Z. (2019). Do calculators support inductive thinking? *The Electronic Journal of Mathematics and Technology*, *13*(2), 181–189.

Korenova, L. (2013). Usage possibilities of e-tests in a digital mathematical environment. *Usta ad Albim BOHEMICA*, *13*(3), 77–83.

Korenova, L. (2015). What to use for mathematics in high school: PC, tablet or graphing calculator? *International Journal for Technology in Mathematics Education*, *22*(2), 59–64. https://doi.org/10.1564/tme_v22.2.03

Molnár, E. K., & Vígh, T. (2013). *A tantervelmélet és a pedagógiai értékelés alapjai.* "Mentor(h)áló 2.0 Program" TÁMOP-4.1.2.B.2-13/1-2013-0008 projekt. http://www.jgypk.hu/mentorhalo/tananyag/Tantervelmlet_s_a_pedaggiai_rtkels_alapjai/index.html

OnlineTestPad. https://onlinetestpad.com/

Orosz, Gy. (1994). Motiváció a matematikaórákon. In *Az Eszterházy Károly Tanárképző Főiskola tudományos közleményei (Új sorozat 22. köt.).* Tanulmányok a matematikai tudományok köréből = Acta Academiae Paedagogicae Agriensis. Sectio Matematicae (pp. 155–162). http://publikacio.uni-eszterhazy.hu/id/eprint/4200

Panayides, P. (2013). Coefficient alpha: Interpret with caution. *Europe's Journal of Psychology*, *9*(4), 687–696. https://doi.org/10.5964/ejop.v9i4.653

Polinski, O. S., & Kuchinka, K. J. (2023). The development of mathematics anxiety in secondary school students in the context of gamification. *Current issues in modern science*, *10*(16), 696–705 (in *Ukrainian*). https://doi.org/10.52058/2786-6300-2023-10(16)-696-705

Roediger, H. L., Agarwal, P. K., McDaniel, M. A., & McDermott, K. B. (2011). Test-enhanced learning in the classroom: Long-term improvements from quizzing. *Journal of Experimental Psychology. Applied*, *17*(4), 382–395. DOI: 10.1037/a0026252.

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, *17*(3), 249–255. https://doi.org/10.1111/j.1467-9280.2006.01693.x

Román, E., & Kucsinka, K. (2019). Nem csak versenyre. In *Limes: a II. Rákóczi Ferenc Kárpátaljai Magyar Főiskola tudományos évkönyve*, VI (pp. 47–52). II. Rákóczi Ferenc Kárpátaljai Magyar Főiskola -"RIK-U" Kft.

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2023). Emotions and motivation in mathematics education: Where we are today and where we need to go. *ZDM Mathematics Education*, *55*(2), 249–267. https://doi.org/10.1007/s11858-022-01463-2

Shabatura, J. (2022, 26 July). Using Bloom's taxonomy to write effective learning objectives. *tips.uark.edu*. https://tips.uark.edu/using-blooms-taxonomy/

Skemp, R. R. (2005). *A matematikatanulás pszichológiája*. Edge 2000 Kft.

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