Web Technologies in the Development of Computational Thinking of Students with Mental Disabilities

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Abstract—Computational thinking is an important and necessary part of a modern person's thinking. It has been proven that the development of this way of thinking in students with mental disabilities allows them to navigate quickly in the modern world, identify problems and create complex solutions. Online schooling during the COVID-19 pandemic demonstrated the possibilities of the usage of web technologies in the education of children with mental disabilities. This study aims to evaluate the impact of web technologies on the development of computational thinking of students with mental disorders. The experiment involved 14 students aged 8–12 and 4 tutors. For 8 weeks children were trained in computational thinking and computer science. Assessment of computational thinking was performed with cCT-test by El-Hamamsi et al. before and after the experiment. After conducting computer science lessons using web technologies the respondents showed a higher level of computational thinking (M=15,7, SD=3,69), compared to the results of preliminary testing (M=5,93, SD=2,3). Web technologies can significantly increase the effectiveness of inclusive pedagogy, which establishes the importance of integrating web technologies into the teaching system in inclusive classes of general education schools.

Keywords—web technologies, web 3.0, computational thinking, online education, students with mental disabilities, errorless learning, inclusive pedagogy

1 Introduction

In the age of the development of digital society and STEM grows the importance of the development of people's computational thinking, which is aimed at the systematic solution of reality's problems. J. Wing [48] has determined that computational thinking (CT) is aimed at the solution of problems in the real world as a large and complex programmatic system. CT includes algorithmic thinking and parallel thinking, which involve other types of thought processes such as compositional reasoning, pattern acting, procedural thinking, and recursive thinking.

Currently, the recognition of the need to develop CT among the younger generation is confirmed by the fact that CT is tested in PISA tests through mathematical literacy questions [26].

CT is developed through computer science and programming. S. Papert argued that programming develops the meta-skills necessary to solve problems from other subject areas. Computational thinking includes strategies for solving problems at a general level, bringing fundamental concepts and actions to the foreground [38].

The development of CT is important for people with mental disabilities, as it helps to see the problem in a complex way and create systemic solutions. The studies of C. González-González [18] et al., R. Munoz [36], and M. Zubair [52] et al. are aimed at the development of CT with the use of block-based programming. The complexity of the development of CT in children with mental disabilities is described, however, such development influences the further socialization and even professional development of people with mental disabilities as IT specialists.

The use of web technology in teaching programming improves the quality of learning, and motivation, and promotes the development of project skills and teamwork [21], [29], [32], [42], [46].

This study focuses on how web technologies improve the development of CT in students with mental disabilities. The use of digital matching tasks, choice of an object in errorless learning, explanation of the process of problem-solving, and presentation of the results improve the skills of abstract and algorithmic thinking, modeling, and recursion.

1.1 Computational thinking

In 2006, J. Wing re-introduced the term following S. Papert, defining CT as a process that includes problem solution, system design, and understanding of human behavior, based on concepts fundamental to computer science. [48].

Now some researchers differentiate between CT and Computer science. [1]. CT was originally based on computer sciences, but later it became a necessary part of research to solve STEM problems [6], [20].

CT represents a conceptual framework necessary for defining and solving real problems using algorithmic methods to create portable solutions [39]. CT uses strategies and techniques to solve problems and challenges while working with technologies to solve complex and ambiguous problems.

J. Wing's structure of CT includes abstraction, recursive and procedural thinking, parallelism, modeling, decomposition, and heuristic reasoning [20].

K. Brennan and M. Resnick [5] presented the CT structure as:

- computational concepts that programmers interact with while developing software (iteration, parallelism, events, conventions, operators, and data;
- computational practices (project debugging or adaptation of someone else's work);
- computational perspectives.

Prottsman, K. [39] also identified the following CT components:

- formulation of a problem as a path, which promotes the use of a computer and other tools as a solution;
- logical organization and data analysis;

– representation of data through abstraction by creating simulations or models;
– identification, analysis, and application of possible solutions to achieve the goal of developing an effective combination of steps and resources;
– generalization and carry-over of problem-oriented processes to other widespread problems.

T. Palts and M. Pedaste [37] have outlined the skills which define the steps of CT's development: a) problem identification (formulation, abstraction, decomposition); b) problem solution (data collection and analysis, algorithmic design, parallelization, iteration, automatization); solution analysis (generalization, testing, evaluation).

CT training is carried out in the process of teaching block programming, in particular, Scratch [50], in project-oriented, problem-oriented learning, collaborative learning, and game-based learning [22].

Educational robotics is an effective tool for the development of CT skills through students' knowledge expansion on subjects of natural sciences, technology, engineering, and mathematics. Artifacts of robotics programming positively affect the learning of CT students [9].

1.2 The development of computational thinking in children with mental disabilities

Students with mental disabilities are the most underestimated category of students for teaching them computer science and the development of CT. Studies exist that are generally aimed at people with hearing and vision impairments. There are not enough studies focused on developing CT in children with mental disabilities.

Mental disabilities include such nosologies as autistic spectrum, Alzheimer's disease, traumatic brain injuries, memory disorders, developmental or learning disabilities, Down's syndrome, and cognitive disabilities.

Several authors chose the development of programming skills for further employment of people with mental disabilities as a goal in teaching computer science, other authors focused on the development of game design skills. In addition to these main goals, secondary goals such as the development of CT, communication skills, group work skills, and leadership skills were achieved.

When teaching programming most researchers use visual and block languages such as Scratch to improve the accessibility of the programming environment through the color perception of different algorithm blocks. In the study of R. Munoz [36] Scratch was used as a game platform. In other cases, it was used as a base programming language.

It is noteworthy that K. Eiselt [12] after studying the basic constructs moves on to text-based programming in the Greenfoot environment, which indicates the effectiveness of visual programming as a tool for the development of algorithmic thinking. A similar transition to a different programming environment is seen in a study by V. Koushik [27]: after learning Scratch students with mental disabilities move on to learning the internet of things. A. Begel [3] used the MakeCode Arcade to develop game design skills, which is also a visual-block programming environment.

In teaching robotics researchers used KIBO and Lego Mindstorm robots as the most practical for teaching people with mental disabilities. C.S. González-González [18] used a wooden robot to develop basic programming and CT skills in preschool children with Down's syndrome. In a study by S. Bui [7] cooperative building of Lego Mindstorm robots was used to develop the play activity in children on the autistic spectrum. In both cases, they were helped by teachers and speech therapists. The presence of such studies indicates the success of teaching computer science and CT to students with mental disabilities.

1.3 Assessing the development of computational thinking

There exist various tools for assessing the development of CT which include tests, tasks, and projects [44]. K. Brennan and M. Resnick suggested a popular approach to assessing CT skills through analysis of project portfolios, interviews based on artifacts, and analysis of design scenarios [5]. Other researchers use Bebras tasks as a general measure of children's CT skill levels. These tasks include a wide range of problems, intended for use in the Bebras International Challenge in computer science and CT, which consists of an annual worldwide challenge aimed at increasing the involvement of students aged 5 to 19 in computer science and increasing their knowledge of computer science concepts and facilitating the development of CT skills through solving real and exciting problems [9].

A study by V. Dagiene demonstrates that short Bebras tasks improve the skills of problem-solving and understanding of computer science concepts: the ability to divide complex problems into simple components, algorithmic thinking, pattern recognition, pattern generalization, and abstraction [10]. A test by M. Román-González [41] contains 28 questions with four answer options, each element relates to one or more of the following seven computational concepts, ordered by increasing complexity: main directions and sequences; loops – repetitions of times; loops – repeat up to; if – a simple conditional sentence; if / else – a complex conditional sentence; while conditionally; simple functions. In the study [8] elements of CT were contextualized in two types – coding in robotics and reasoning about everyday events with closed and open questions.

A Swiss research team headed by L. El-Hamamsy in 2022 proposed their competent and validated CT assessment test [13]. The test is an MCQ of 25 questions of increasing difficulty that addresses the following CT concepts as defined by Brennan and Resnick (2012): block 1 – sequences (questions 1–4), block 2 – simple loops (questions 5–8), block 3 – nested loops (questions 9–15), block 4 – conditional statements (questions 16–19), block 5 – while statements (questions 20–23), block 6 – a combination of concepts (questions 24–25).

The considered tools for assessing CT are diverse, their choice depends on the goal and speed of assessing the development of CT.

1.4 Web technologies in special education

Web technologies play an important role in inclusive education as auxiliary technologies, digital education resources, education platforms, and information systems.

During the COVID-19 pandemic, a large number of Web 3.0 technology resources have appeared for creating educational content. They are used as an alternative to desktop apps. Research analysis showed the most popular resources used in general and secondary schools [11], [23], [28], [34], [45], [49].

The Table 1 shows the most popular services that are used in the education process. The use of web technologies including Web 3.0 in special pedagogics is aimed at the organization of quality education without errors. Errorless learning is a method of a learning organization that uses tasks and instructions to ensure that people do not make mistakes in the learning process. In other words, this type of learning allows a child to complete any task correctly, which helps keep them interested in lessons and other types of activity [19].

Errorless learning is used to teach children with learning disabilities using feedback instructions to shape or fade a stimulus. Errorless learning is a learning strategy that is widely used with people with mental and developmental disabilities. [14]. The use of errorless learning in teaching people with dementia showed good results. Structured re-education improved the performance of daily tasks [47].

Errorless learning procedures are also commonly used in teaching tactful attitudes to people diagnosed with autism spectrum disorder (ASD) [30]. Errorless learning refers to discrimination teaching methods that eliminate or minimize responses to incorrect choices, allowing the teacher to program learned skills in children with pervasive developmental disorders in a school setting. [35]. The use of digital resources for errorless teaching of students with special educational needs can significantly improve the learning process, and assimilate concepts that were not available in traditional education [40], [43]. The implementation of errorless learning in a mobile application for people with Alzheimer's disease is described in a study [19], learning scenarios such as learning components, and memory training exercises with immediate positive feedback for the active participation of the subjects are programmed in a computer application.

The main conclusions on the development of digital resources for the education of people with mental disabilities:

a) the software should be understandable and easy to use;
b) contain visual images of real objects;
c) contain objects with which students are familiar and which are in their environment;
d) the task is divided into components;
e) repetition and practice to improve skills through memorization;
f) learning from simple to complex;
g) providing immediate positive feedback to reinforce learning;
h) providing a safe training environment with prompts.

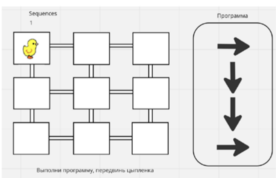
Considering these principles, we have developed errorless learning tasks for teaching CT skills using Wordwall (wordwall.net) and Miro (miro.com). Why did we choose to use these services? Miro allows students to drag elements on the playing field, draw objects, and make commentaries on the actions, while the teacher can enable the working area protection to prevent accidental changes in the tasks.

In the Wordwall service, you can create interactive tasks for dragging elements, matching, and moving the hero in the game. Table 2 shows the tasks that we have developed for teaching CT to children with mental disabilities on the topics of sequence learning, simple and nested loops, conditional operators, recursion, and a combined algorithm.

Table 1. Analysis of web services for errorless learning and CT development

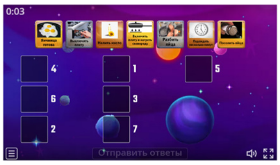
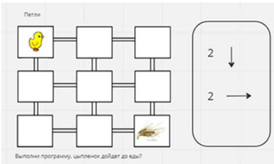
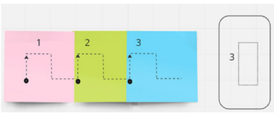
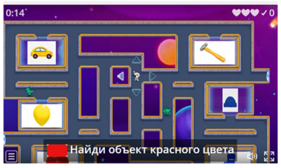
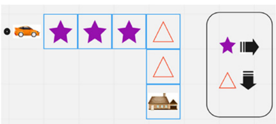
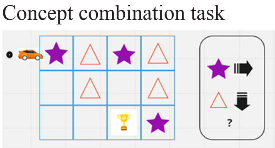
Direction	Types of Tasks	Visualization
Video content	Educreations, Annotate, Jing, Loom	Services can be used to create video content: videos and screencasts.
Educational content	iSpring, Genial.ly, BlendSpace	Services can be used to create teachers' interactive worksheets. They are very practical for the organization of flipped classroom strategy. With the use of these services, you can create all types of learning materials. It is possible to exchange feedback with students.
Quizzes, quests	Socrative, Kahoot, Quizziz, Quizlet, GoSoapBox, Learnis	Services can be used to create quest games, quizzes, flashcards (terminological dictionaries), and interactive videos.
Tests, surveys	Plickers, BrandQuiz, Wick Editor, Formative, GoogleForms	Convenient applications for quick assessment of students' knowledge in the classroom.
Interactive presentations and worksheets	Mentimeter, UDOBA, H5P, Visme	Constructors of open interactive digital educational resources. Tools for creating various digital didactic material for the purpose of data visualization.
Game exercises, interactive tasks	Educaplay, Interacty, Raptivity, LearningApps, Flippity	Services allow the teacher to organize digital support for formative assessment in a playful way.
Virtual classrooms	Spiral, GoogleClassRoom	Free virtual classrooms for organizing various types of learning activities in synchronous and asynchronous modes.
Interactive board	AMW board, WhiteboardFox, Annotate	Virtual whiteboard for online lessons, a distance learning tool that can be used in almost any subject.
Virtual wall, maps	Padlet, ThingLink	Virtual whiteboard for online lessons, a distance learning tool that can be used in almost any subject.

Table 2. Examples of tasks on the Web platform

Task Example	Description	Goals
Sequence task: introduction to the interface  	The task is performed in the Miro.com service together with a tutor, who can be located nearby or remotely. The exercise is aimed at tracing the program, which is represented by arrows on the right.	1. get the student familiar with the program's interface, teach them to read the program; 2. form an incentive to execute the program in the environment by dragging the performer.

(Continued)

Table 2. Examples of tasks on the Web platform *(Continued)*

Sequence task: writing your program 	The task is performed in the Wordwall service. Sequence game. The student reads the action and moves it to the cell.	1. actualize the knowledge about algorithms; 2. formation of the concept of a linear algorithm (sequence).
Simple loops task 	The task is performed in the Miro.com service together with the tutor. The student moves the performer while looking at the program.	1. reinforcing the concept of a loop; 2. distinguishing simple loops within the algorithm.
Nested loops task 	The task is performed in the Miro.com service. The student needs to see the repeating blocks and write a program by using the arrows on the right.	1. introduction to complex loops; 2. distinguishing nested loops within the algorithm.
The task for mastering conditional statement 	The task is a labyrinth in the Wordwall service that is made in the form of a game. The student must find the object, given in the task.	During the task, students learn to distinguish objects and act based on the situation.
While statement learning task 	By moving the performer in the Miro environment, the student executes the program without error. The tutor focuses on the new concept of the algorithm and asks in which sector the car is.	Introduction to the concept of a while loop.
Concept combination task 	The student must not only read and execute the program but also determine what action is missing.	Formation of skills to write complex programs to solve a problem.

Taking into account the technology of errorless learning, procedures for stimulus attenuation, stimulus formation, response prevention, delayed prompt, imposition with stimulus attenuation, and imposition with stimulus formation were used in the tasks [19], [30].

1.5 Purpose of the study and research questions

The present study is carried out in order to assess the development of CT in students with mental disabilities after using Web 3.0 online technologies. The CT of students was assessed according to the competent cCT-test according to the method of L. El-Hamamsy [13].

Our study addresses two research questions:

RQ1: How does CT develop in children with mental disabilities when using web technologies?

RQ2: What problems did the students face when completing web tasks for the development of CT?

2 Research methodology

2.1 Design

This study was approved by the University Ethics Committee. The study was conducted in a general education school with students of inclusive classes as subjects, who were monitored for two months.

Before the experiment, the students had traditional lessons in computer science. A pre-test of 25 questions on the level of development of CT was conducted, then the same students were given classes on the development of CT using online tools (slides, a system of exercises for errorless learning). After classes with online services, students took the same post-test on the development of CT to compare the development of CM before and after the pedagogical intervention. Thus, this is a quasi-experimental study.

The cCT-test [13] consisted of 25 questions of increasing difficulty, covering the following CT concepts: sequences (4 questions), simple loops (4 questions), nested loops (7 questions), conditional statements (4 questions), while statements (4 questions), a combination of concepts (2 questions). This test by El-Hamamsy et al., has been psychometrically tested and is a valid and reliable tool for testing CT.

The experiment involved 18 people, including 4 teachers. The teachers have additional qualifications in behavioral analysis and special education. The training involved 14 children with mental disabilities aged 9–12, all children are students with special educational needs.

2.2 Respondent data

Respondent data is presented in Table 3. Respondent data is coded. Prior to the start of the experiment, we obtained parental consent for children to participate in the study.

Since this study is the first for Kazakhstan, a large number of parents expressed their desire to participate in the experiment, however, the study group selected children who have mental disabilities of the average level and are ready to study in preparatory courses to develop academic skills. This condition became important for the experiment, because without the skills of perseverance, and the implementation of elementary verbal instructions from the teacher, children would not be able to study computer science and complete projects. All children study at school according to an adaptive program in inclusive classes.

Preparing students for participation in the experiment. Prior to the start of the experiment, the children were prepared so that they could concentrate on the material. For more than six months, the children were trained individually with episodic trials of group work. Individual and general classes were organized with the inclusion of children with mental disabilities in the group of normotypical children in the BrainPark educational center (brainpark.kz).

In the first lessons, skills needed in order to start computer science learning were defined. Among them were:

- motor skills (ability to operate the remote, press the buttons, track motor actions);
- behavioral reactions (reactions to success and failure, attention and frontal instructions while working behind the desk);
- speaking skills (more than 150 words from everyday speech);
- interest in working with computers (using gadgets as supporting tools in other activities).

Table 3. Characteristics of study participants

Index	Sex	Age	Diagnosis	Status
P1	male	10	Sensorimotor alalia with ASD	5th grade
P2	female	11	Moderate mental disability	5th grade
P3	female	8	Cognitive learning problems	2nd grade
P4	male	7	Cognitive disorders	1st grade
P5	male	10	Cognitive disorders	4th grade
P6	male	10	Cognitive disorders	4th grade
P7	male	10	Cognitive disorders	4th grade
P8	male	10	Impaired mental function	4th grade
P9	male	10	Cognitive disorders	4th grade
P10	male	10	Cognitive disorders	4th grade
P11	male	11	Cognitive disorders	5th grade
P12	male	11	Cognitive disorders	5th grade
P13	male	11	Cognitive disorders	6th grade
P14	male	11	Cognitive disorders	6th grade
T1	female	24	–	tutor
T2	female	33	–	tutor
T3	female	40	–	tutor
T4	female	42	–	tutor

2.3 Pedagogical influence procedures

Classes were held for 25–30 minutes individually with the students. The tutor opened the exercises on the online platform using a laptop and sequentially showed the tasks, explaining the material or including digital material to reproduce the algorithm. The same performers were chosen as in the test with a slight variation in stimulus attenuation.

Tasks' base criteria:

- the task is divided into basic elements depending on the complexity of the concepts being formed;
- every step is demonstrated by the tutors and accompanied by oral instructions;
- the student is offered to complete a task and tutors direct them by giving oral instructions and providing feedback;
- the tutor demonstrates the next step only when the student performs the first step correctly;
- in case of hesitation or possible error the step is repeated until the task is completed successfully;
- starting from the sixth lesson help is no longer provided to the students.

The purpose of the errorless learning program is to work around errors and reinforce accurate communication, given that students with mental disabilities have difficulty self-correcting errors. In the beginning, the students were given two demonstration questions and answers so that the respondents could see a sample task. The tutor determined the complexity of the tasks by considering the level of mental activity. Tips were given to the child until he or she learned to do the task on his own. The tutor, while working with the child, moved on a scale from the strongest prompt to the weakest. In this case, the hint was given immediately after the instruction, so that the subject did not have the opportunity to make a mistake. Thus, the use of errorless learning avoided premature frustration during learning. It should be noted that all students attended computer science classes, where they programmed using Scratch. This means students have already been trained in CT. Students were tested before classes on CT using web technologies. In the span of 8 weeks, they studied individually in the inclusion support room with a teacher, the exercises were performed online. Feedback was given immediately. After a period of training with online tools, post-testing was conducted to determine if the training was useful and if the level of CT had changed.

3 Results

RQ1: How does CT develop in children with mental disabilities when using web technologies?

Prior to the pedagogical influence, students with mental disabilities were tested for the level of CT. After that, for 8 weeks, they were taught classes (sessions) of CT using web technologies. The students were tested again with the same test.

To analyze the data, we used the technique of testing statistical hypotheses. Since the measurements were made with the same group of children at different time intervals, we used the Student's t-test to calculate the empirical value of the t-test in the situation of testing the hypothesis of differences between two dependent samples. The overall result of the level of CT in children with mental disorders is shown in Table 4.

Table 4. General results of the development of computational thinking

Test	N	Mean	SD	SE	t	Critical t-Value
pretest	14	5,93	2,30	0,62	9,93	2,16
posttest	14	15,7	3,69	0,99		

Notes: N-number, SD: Standard deviation, SE: Standard error. The dataset is available on Zenodo at https://doi.org/10.5281/zenodo.7614088.

Our null hypothesis H_0 is that the development of CT in children with mental disorders occurred not due to purposeful pedagogical influence, but due to random factors. The alternative hypothesis H_1 is that the pedagogical impact of using web technologies affects the development of the CT of students with mental disabilities.

After the final test students showed higher CT scores (M=15,7, SD=3,69), compared to the results of preliminary testing (M=5,93, SD=2,3).

As we can see from the table, the t-test (9.93) has a statistically significant difference with the critical value of t (2.16). This means that the H_0 hypothesis is rejected, and the opposite hypothesis that the introduced pedagogical influence using online technologies had an impact on the development of the SM of students with mental disabilities is accepted. Figure 1 shows the percentage ratio of the CT development.

Before the classes with online technologies, the quality of the formation of the participants' ability to compose programs with a linear sequence was 35.5%, after the training it reached 64.5%. As for the use of simple loops, the percentage of skill formation was 30.3% before the experiment and it reached 69.7% after the training. Prior to the experiment students showed 28.8% of skill development in creating programs using nested loops. After classes using online technologies, students showed 71.3% of skill formation. The indicator of the skill of programming with conditional constructions also increased from 17.9% to 82.1%. The skills of using cycles improved (11.4% of the skill formation before the experiment and 88.6% of the skill formation after the experiment) and compiling combined programs (with a combination of basic algorithmic structures) – from 28.6% of pre-test tasks to 71.40% completing post-test tasks. In general, there is a positive difference in the development of CT before and after the experiment. If we analyze the development of each CT criterion, we can notice heterogeneous development dynamics (Table 5).

According to the first five criteria, there is a statistically significant (non-random) difference between the found t-test and the critical t-value (t-test above), However, according to the sixth criterion "Combinations", there is a statistically insignificant difference between the t-test and the critical t-value. This is due to the fact that it is more difficult for children with mental disabilities to use complex algorithms with a combination of concepts.

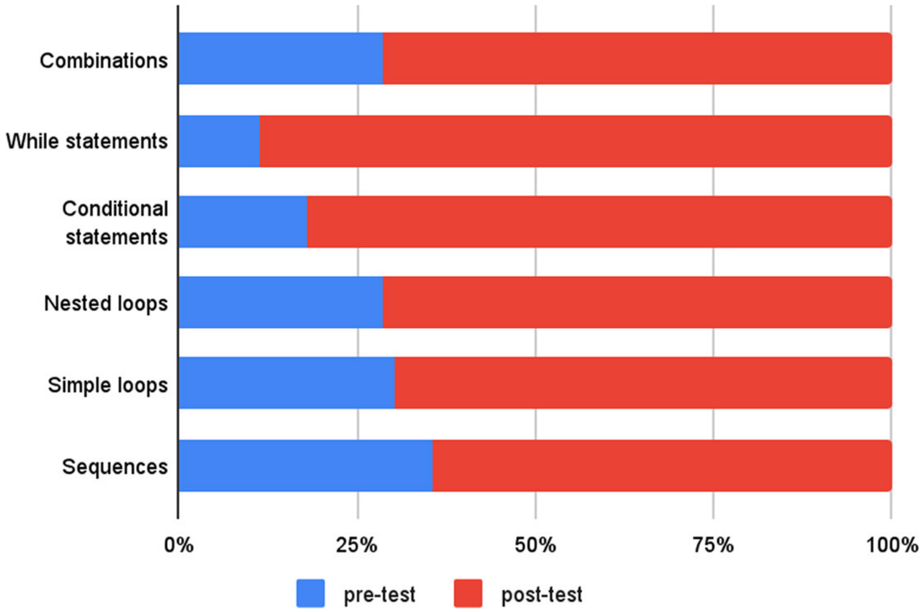


Fig. 1. Growth chart of CT level in children with mental disabilities

RQ2: What problems did the students face when completing web tasks for the development of CT?

To find out the problems that students encountered when completing tasks with online technologies, we interviewed tutors, since many students do not have the opportunity to express their learning experience in words. An in-depth interview was conducted with four tutors.

Teachers T3 and T4 noted that at the first completion of the task, students faced orientation problems in the new interface, but after 1 minute of working with the task, they could already freely use the resource. In Miro, there were available variable tasks for signal attenuation (for example, task 3 in Table 2). Students easily switched to this task however, difficulties arose when moving to a more difficult level when performing complex loops. This is where feedback needs to be given. If feedback is not received by the respondent, they immediately get distracted and frustrated. The problem with the use of online technology by children with mental disabilities is the constant distraction from the task. Teacher T1 noted: "My students were constantly distracted if they saw bright colors or an extra detail in the task." The solution to the problem was the timely emphasis by the tutor on the purpose of the task. Changing activities is also a problem in teaching children with mental disabilities. It lies in the fact that when using bright colorful applications, the child is distracted by other details and begins to connect other programs and applications. In this case, the timely help of the teacher is necessary.

Teachers T2 and T4 indicated an implicit problem associated with the fact that students get used to prompts and they demonstrate "learned helplessness" or start expecting help from the teacher.

All tutors noted that the use of errorless learning in online assignments increased the number of successful situations, which made the trainees more confident by the end of the class.

Table 5. Pre- and post-testing data by criteria

Test	Test	Mean	SD	SE	t-Student
1. Sequence	pretest	1,93	0,73	0,20	9,04
	posttest	3,50	0,17	0,65	
2. Simple loops	pretest	1,43	0,51	0,14	9,57
	posttest	3,29	0,19	0,72	
3. Complex loops	pretest	1,64	0,93	0,25	9,90
	posttest	4,07	0,25	0,92	
4. Conditional operators	pretest	0,5	0,52	0,14	9,20
	posttest	2,29	0,19	0,73	
5. While operators	pretest	0,29	0,47	0,12	9,0
	posttest	2,21	0,21	0,80	
6. Concept matching	pretest	0,14	0,36	0,10	1,61
	posttest	0,36	0,13	0,50	

Notes: N-number, SD: Standard deviation, SE: Standard error.

4 Discussion

In the first research question, we considered how the CT of schoolchildren with mental disabilities develops when using tasks on online services. We used the technology of errorless learning in the Miro and WordWall online environments when performing tasks for mastering the sequence, using loops, cycles, and conditions. Classes and tasks were designed in a special way so that students could not make mistakes and would receive support in order to form an educational result.

The results showed that students achieve significant development in CT after completing online tasks for eight weeks, despite the fact that they were trained in computer science in a traditional way. This study contributes to the development of inclusive pedagogy, namely the use of innovative technologies for teaching STEM courses and programming to people with disabilities. In the study by A. Begel [3], students with autism spectrum were taught programming online. When teaching people with mental disabilities, a mentoring system and constant support of the student devised by V. Koushik were used [27]. The tasks in web services are used to adapt a student with mental disabilities to learning CT and passing the test, these strategies for teaching informatics are used when adapting the training program [25], [27], and in the preliminary preparation of students for the learning process, in the form of speech and cognitive therapy [31], [3], [18].

Our results are confirmed by studies of the development of CT in the process of learning computer science in people with autism spectrum [4], [7], [36], [51], and in children with Down syndrome [18].

The effectiveness of the use of online technologies in the development of computational thinking and teaching computer science is shown in studies from the online technologies section, which corresponds to the results of the experiment.

The answer to the second research question is related to the identification of the problems that students with mental disabilities encountered when performing online tasks for the development of CT. The tutors called the main problems disorientation in the interface, distraction from the task, and unreasonable expectation of help from the tutor. Our results confirm previous studies [16], [17], [19], [47] that describe similar problems in the use of ICTs by people with disabilities.

In several studies [2], [48]–[51], the design of an online service or application affects the speed of task completion and motivation. The important aspect here is timely feedback [30], [33], [35], and the use of reinforcements [15], [24].

5 Limitations

The study has some limitations. Firstly, the training of children with mental disorders was short (8 weeks) and was conducted by different tutors with different levels of pedagogical competence, which affects the nature of classes with the student and the results of the development of CT. Secondly, a small sample does not allow us to draw convincing conclusions, although most empirical research in the field of studying people with mental disorders also included small samples in their work.

Thirdly, we found technical delays in task loading that could distort the experience of our experiment participants. On the other hand, the brilliance and multimedia aspect of the interface affected the concentration of participants' attention.

Despite the limitations, the results of this study highlight the relationship between the use of online technologies, errorless learning, and the development of CT.

6 Conclusion

This study allows us to take a fresh look at the possibilities of online technologies in inclusive pedagogy. The use of web resources and mobile applications enriches the practice of teaching people with mental disabilities. Errorless learning allows for choosing pedagogical strategies to control the behavior and cognitive process of students. It can also be used in teaching STEM courses.

The results of the study conducted on the students of the general education school in Pavlodar clearly demonstrated that online technologies using errorless learning procedures had a positive impact on the development of CT in children with mental disabilities. After the pedagogical intervention, the level of CT in children increased significantly. In this regard, it is important to focus the attention of STEM teachers on the use of online technologies and their integration into the teaching system in inclusive classes of general education schools for students with mental disabilities.

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