Identifying Programming Skills Impacted in Students with Cognitive Disabilities

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***Abstract*—This Full Research Paper aims to identify and compare the skills involved in learning programming and the difficulties that students with cognitive disabilities may face, discussing the impacts generated by these skills for these students. Several studies talk about what skills a person needs to learn to program. However, we do not have enough to consider the needs of students with disabilities, especially cognitive impairments. Did we conduct a study to answer the following research questions: RQ1 - What skills are involved in programming teaching? RQ2 - Can cognitive impairments affect the skills needed to program? We lift the part the skills involved in learning programming and the cognitive skills impediments in the literature. Finally, we made a critical analysis impact on that audience. By cross-referencing this information, we can highlight that the skills needed to program impact students with cognitive impairments such as math, logic, and problem-solving. This impact does not necessarily mean that these students cannot learn to program. We believe adapting materials, exercises and assessments can foster learning for this audience.**

***Index Terms*—teaching programming, cognitive disabilities, programming skills**

I. Introduction

Inclusive education can be considered enriching for teachers, promoting values such as empathy, respect, and equity, and can also have a beneficial effect on other students within the university [24]. Providing inclusive access to Computer Science education is a significant challenge for educators as they need to address the diverse needs of diverse students in the classroom, including students with learning disabilities such as reading, math, neurodevelopmental disorders, and others [1].

Learning programming is considered an exciting competency for individuals to have a promising professional career in Computer Science and other fields. Programming is challenging knowledge, and teaching people to program is not a simple task [5]. Even though it is a career that attracts many people, Computing is still considered excluding for people with disabilities, especially those with cognitive disabilities [11].

The first programming discipline is essential because it is the students' first contact with the fundamentals and programming languages. Typically, they arrive at university without programming classes in their previous school life. It is a discipline that traditionally has significant rates of failure and dropout, which has generated research to investigate ways to keep students in the course. There are many efforts to solve these problems, investigating new curricular adaptations and the search for the insertion of this knowledge at earlier ages, including childhood [20].

Several studies talk about what skills a person needs to learn to program. Understanding how to solve a problem with programming requires different skills from the student, such as thinking logically and understanding some mathematical concepts. Students need to know the skills involved in creating computer programs that solve real-world problems, which are specific and usually acquired in a short time, over [7]. Another critical issue is the difficulty in identifying programming skill demands, as different programmers may use different ways to solve a problem. We may find a programmer who has issues with specific skills, like designing solutions, but is good at debugging programs [21].

Despite existing efforts, we still do not have enough to consider the needs of students with disabilities, especially cognitive disabilities. Cognitive impairment affects the individual's cognition in some way, including neurodevelopmental disorders such as autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD), but not limited to these [12], [18]. Understanding the prerequisites to direct how to deal with these students, especially those with more significant difficulties, is essential. The cognitive aspects of computer programming are an area of research where there is much to be explored [15]. We still need more research to improve programming teaching materials, methodologies, and how students absorb it.

Compared to other disabilities such as visual impairment, few studies investigate cognitive impairments in Computer Education [11]. We conducted this research to explore what might impact the learning of programming students with intellectual disabilities. Several works discuss the skills needed to program, but we did not find studies linking these skills to people with cognitive disabilities with specific limitations and needs. This article presents research on skills for learning to program and aims to analyze the likely impacts of these skills on the learning of students with cognitive disabilities. It seeks to answer the following research questions: RQ1 - What skills are involved in programming teaching? and RQ2 - Can cognitive impairments affect the skills needed to program?

This paper is structured as follows: Section II contains related works. In Section III, we present the methodology, and in Section IV, we have the results answering the research questions. We discuss the results found in Section V. We show threats to validity in Section VI and conclude and point to future work in Section VII.

II. Related Works

Several jobs deal with programming skills in general. It is pertinent to understand if anyone can learn to program as long as they have or somehow acquire specific skills. Given this, it is still not explored how people with disabilities can be impacted when learning programming, which is a vast field of research, as each category of disability may have different characteristics and needs.

A previous systematic review [19] identified some efforts to teach programming to people with cognitive disabilities. She made a collection of articles that addressed programming and people with some cognitive disabilities. He identified that much of the work is focused on contact with programming at an early age, still in childhood, in extracurricular courses. Therefore, there is a large paper space focusing on teaching programming and cognitive impairment in higher education, where we can deal with people seeking programming as a potential career. The results indicated that students with cognitive disabilities could develop the skills necessary to learn programming provided they have adequate support, both in access to teachers prepared to receive them and in adapted materials and collaborative work. In this previous work, the need arose to observe in more detail the relationship between the difficulties inherent to cognitive deficiencies and the teaching of programming. Then, this research inspires us to design the current research seeking answers to this goal.

Medeiros et al. brought interesting results identifying student skills for programming [32]. The review gave an overview of the teaching and learning of programming in higher education, revealing the challenges and problems. One of the research questions was to identify the skills and prior knowledge that the student would need to learn to program. The other issue was related to the challenges of students and teachers. As part of the results, he categorized skills into programming-related (such as problem solving and mathematics) and education-related in general (such as knowledge of English and creativity).This paper seeks the skills needed to program but is not concerned with students who may learn differently from the traditional way.

Stuurman et al. aimed to create a set of recommendations for the inclusive education of autistics related to Software Engineering [22]. For this, it compared the cognitive style of autistic students with Computational Thinking. The work resulted in guidelines for the education of students with autism that are: (1) Explicit Context, (2) Explicit Guidelines, (3) Exercises, and (4) Consequences for Education. Although these recommendations are based only on the student's opinions, there is a conviction that they are valid but that the area needs further exploration. The authors point out some suggestions for future work to support the autistic cognitive style, such as listening to students' opinions, a collaboration between autistic and neurotypical students, and explicit recommendations for everything done. However, this research speculatively created guidelines without empirical evidence of its efficiency.

Israel et al. present a study that researched the academic engagement of students with autism in the elementary teaching of Computer Science [36]. A case study was carried out using collaborative work with three elementary school students with ASD in an extra course. One of the limitations of the work was the number of students and their selection criteria. As a result, they observed that engagement was varied, often low, with little problem-solving. They also saw that the experience could have been more positive if they had had individualized support. In future work, they suggest deepening the students' experiences with deficiencies to improve their performance.

Eiselt et al. presented a work in progress that sought to integrate social skills with computer programming for students with autism [40]. An extracurricular course analyzed the results for nine students between 9 and 16 years. Research suggests that combining social skills with computer education benefits autistics, but more studies are needed to prove it.

Silva et al. sought to show the experience of teaching Computational Thinking through the teaching of Programming to a high school student with ADHD [13]. An extracurricular course was conducted for 34 weeks, which resulted in solid evidence of student learning. It was divided into three phases: (1) Discovery of the Computer; (2) Introduction to Computational Thinking through Programming; and (3) Learning by doing, with problem-solving, collaborative work, and challenges. The researchers used the following steps to validate the method: (1) Student Profile Analysis, (2) Student Assessment and (3) Student Performance Analysis with the results of the Assessment. To consider that the student was successful in learning programming, the authors expected him to reach at least 80% of correct answers in the evaluation. The student obtained 84% of correct answers, suggesting the experiment's effectiveness. For future work, recommend carrying out courses with more students to prove the method's success. The experience presented is engaging but carried out in an extracurricular class. In addition, we have no evidence of positive results for students of Computing courses with ADHD.

With these related works, we did not answer our research question as they work on programming skills without taking into account students with disabilities [32] or use extracurricular courses to evaluate their theories [13], [22], [36], [40], which leaves us with gaps to explore, such as knowing what skills are needed for programming that can be impacted by cognitive impairments, to which we are dedicated in this research. We want to research ways to encourage students of Computer Science courses to learn to program so that they can progress in their courses and, who knows, get a profession.

III. Methodology

This section presents the research questions and the methodology for answering each one.

A. Research Questions

The main objective of this work is to identify the primary skills involved in the programming learning process that could impact students with cognitive disabilities. Thus, we derive the following research questions:

- (RQ1) What are the skills involved in teaching programming?
  The RQ1 aims to identify the skills needed to learn to program, carrying out a bibliographic search related to the skills involved in programming learning.
- (RQ2) Can cognitive impairments affect the skills needed to program?
  In RQ2, we analyze the impact on students with cognitive disabilities based on the skills needed to program. We looked for the potential cognitive impediments that would impact these skills.

B. A Systematic Review Protocol

We adopted a systematic review protocol based on Kitchenham and Charters [25] to answer RQ1. We present the steps as follows:

1) Conducted Search: To initially identify the skills needed to program, we focused our bibliographic research on the IEEE Xplore and ACM digital libraries, performing a literature review necessary for our analysis.

The search string chosen to obtain skills related to teaching programming was:

("programming" AND "teaching" AND "skills")

We searched for the terms chosen in the articles' titles, abstracts, and keywords. At the end of the search, we obtained several works, as shown in Table I.

TABLE I
SUMMARY OF THE STUDIES RETURNED IN EACH DIGITAL LIBRARY

Digital Library	Search Results
ACM	374
IEEE	500
Total	**874**

When searching the databases with this search key, we obtained 874 papers. We choose the inclusion and exclusion criteria. The inclusion criteria are:

- (IC1) - Papers in English;
- (IC2) - Papers published between 2018 and 2022 (until January);
- (IC3) - Papers that contain the terms in the search string at least in the title, abstract, or keywords;
- (IC4) - Papers dealing with skills involved in teaching programming.

The exclusion criteria are:

- (EC1) - Repeated papers;
- (EC2) - Papers that do not adhere to the theme;
- (EC3) - Studies that do not address skills in the context of programming.

2) Screening of papers: We present the screening process results in Table II, applying exclusion and inclusion criteria. Later we read the titles, abstracts, and keywords because the database can return articles unrelated to what we were looking for, even applying the chosen search key. Some of the articles returned in the search were discarded because they did not meet the criteria.

TABLE II
SCREENING OF PAPERS

Steps	Papers
Step 1: Identify and organize the papers found in the search bases by the inclusion criteria IC1 and IC2;	874 papers
Step 2: Refine by inclusion criteria IC3;	325 papers
Step 3: Review of titles removing papers that fit the exclusion criteria;	69 papers
Step 4: Review of abstracts, removing papers that fit the exclusion criteria;	25 papers
Step 5: Review of the complete papers that fit the exclusion criteria;	8 papers

We check the number of articles returned in the search for the first step by refining the result. We applied the IC1 and IC2 inclusion criteria, thus removing papers not in English or had not been published from 2018 to 2022 (until January).

In the second step, we selected only the articles with the keyword search terms in the title, abstract, or keywords. We eliminated several articles that passed the automated search but were not related to what we were researching, and we had 325 papers as a result. In the third stage, we analyzed the titles of the articles, refining them once more and removing what was not related, obtaining 69 papers. We read the abstracts in the fourth stage, and then we had the number of articles even further reduced, with a total of 25 papers for analysis. Finally, the last step of the screening process was the complete reading of the articles resulting from the previous steps, of which only eight were considered relevant for the research and on which we focused our work.

C. Theoretical Analysis

To answer RQ2, we used a literature search based on papers obtained in the previous review [19] and an official document from health agencies [18] that crossed with our findings from RQ1. In this search, we found some of the main characteristics of each disability and reports of how people who have one of these can react to situations that involve teaching programming. Based on this investigation, we proposed a cross between this information and the skills needed for the program we saw in RQ1, seeking to find evidence of how to help these students better.

IV. RESULTS

This section presents the search results between October 2021 and January 2022. Here we offer the general results supporting the answer to each research question.

As this work focuses on the intersection of programming skills with cognitive disabilities, we seek to identify how the specificities of students who fit this diagnosis impact in this case through a bibliographic search.

To achieve our research objective, we started a literature review to find out what is necessary for anyone to learn to program so that we can later analyze the impact on students with cognitive disabilities using our findings from the previous review [19] . We selected papers that listed likely skills for learning programming and compiled the results to answer the first research question in the next section.

First, we present the general results, such as studies distribution by year, country, and publication vehicle (journal or conference).

We distribute articles by year, as shown in Figure 1. We can see that there is interest in the topic, but even searching papers from 2018 to 2022 (until January), we found papers only in 2018, 2019, and 2020 using our criteria.

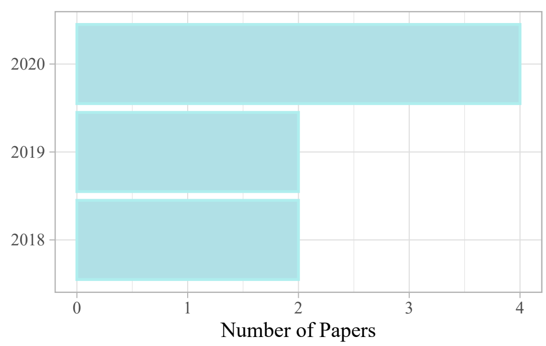

Fig. 1. Frequency of publication of papers distributed per year

Observing Figure 2, we can see the papers from different countries, with only Mexico responsible for more than one paper.

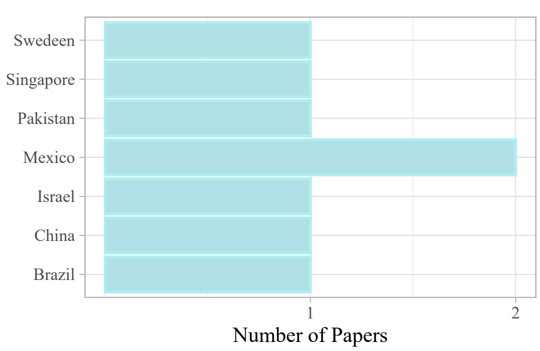

Fig. 2. Frequency of publication of papers distributed per country

As for the publication vehicle, most of them (five papers) are conference papers, and the rest (three articles) are journal papers, as shown in Figure 3.

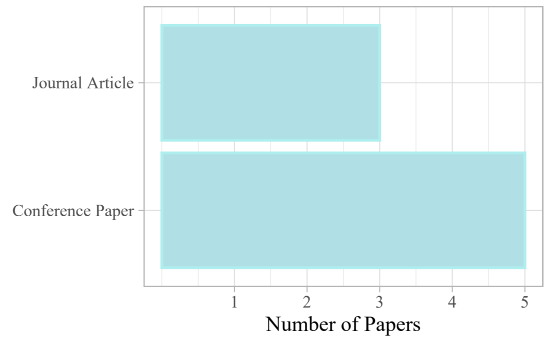

Fig. 3. Frequency of publication of papers distributed per vehicle

A. RQ1: What skills are involved in teaching programming?

To answer RQ1, we searched the literature for what skills would be necessary for those who want to learn to program. From the search focused on the IEEE and ACM, we selected eight papers that dealt with the subject [28]–[35]. By synthesizing the selected ones, we could enumerate a set of skills we will use as a basis for this research. These skills are what we will discuss in detail as follow.

To learn to program, the student needs some skills that they can acquire throughout his life; they are:

1) Problem Solving: Problem-solving is part of the concept of Computational Thinking (CT) [27], where programming is also inserted. Part of the learning process is planning the resolution of a given problem, breaking it down into smaller steps, and making its solution more effective.

One of the biggest challenges for Computer Science students is learning programming concepts, including problem-solving skills. Many students have difficulties understanding the problem and converting it into a program [28].

Considering that a computer program is also a solution, we observe that the programmer needs to know how to solve problems. Problem-solving is a core skill in computer programming. Students need to learn how to solve a problem, understanding that there is no one-size-fits-all solution, and its a need to create another solution for each issue [29]. Assuming that there is no single solution to a problem, we can say that students with different learning profiles can reach other solutions for the same problem.

Another critical issue is that in addition to having the ability to solve problems, it would be interesting for the programmer to have the ability to solve problems collaboratively since, in employment, they will often face the creation of solutions with a team of workers [34].

2) Mathematical Skills: We can say that programming and mathematics go together. Observing traditional programming exercises, we see several of these using mathematical formulas as a starting point. The student then needs to interpret the problem and identify what would be the mathematical logic that would fit there to arrive at its solution.

The logical reasoning part of mathematics is about understanding the cause-and-effect relationship of things. Following a precondition, a logical conclusion is inferred from it. It also comprises sequencing steps to solve a given problem, sometimes using mathematical procedures and formulas [28].

3) Abstraction: Abstraction is a concept that can help the student create a structure to solve a given problem. Usually, in this phase, at the end of the solution, he will refine the steps into your algorithm [23]. Abstract thinking consists of thinking about a problem on several levels simultaneously, seeking to detail each level [28].

4) Critical Thinking: Critical thinking consists of conceptualizing something, analyzing and synthesizing it to obtain a conclusion or answer to a problem [28].

Critical thinking is often difficult for people. Understanding what it means and inferring a conclusion is considered a significant challenge when having information about something.

5) Reading Comprehension: Text comprehension is about finding the main idea of the text, its implications, and the possibility of relating it to the knowledge the reader already has, which can help in its understanding [28].

The first step of programming would be to understand the problem to solve a problem. To understand a problem, the programmer must have mastery of reading and effectively understand what he is reading.

Most approaches to teaching programming revolve around problem-solving skills, which can leave out other essential skills such as language skills [14].

6) Knowledge in English: When we talk about computer programming, we can see that the mastery of the English language can be a facilitator, as programming languages use this language in their syntax [32], so understanding English helps to decipher what each command does for the meaning of the term.

7) Attention to Details: It seems evident that paying attention to learning something is necessary, but this skill is not so simple. In a dynamic world full of stimuli, paying attention to something with so many others becomes difficult.

From a programming point of view, paying attention requires considerable concentration from the observer to analyze, for example, a problem or a source code. For programming, it is essential to think when creating, testing, or correcting a solution, thinking about both the happy flow and the failures that can be estimated [28].

8) Creativity: Creativity is a general skill where the individual can think to have ideas, which can be beneficial when creating an algorithm since there is no single solution to solve a problem. Computer programming helps to develop skills like creativity [7]. Being creative can help the programmer.

9) Time Management: Managing time well is considered an essential skill for programming [32]. When developing a project, we need to know how to divide the time for the execution of the resolution steps properly.

B. RQ2 - Can cognitive impairments impact the skills needed to program?

We use the term cognitive impairment to cover various impairments that somehow limit the individual's mental functions [16]. To answer RQ2, we first worked with some of the characteristics associated with cognitive impairments extracted from the literature and health agencies [18] and related to programming learning. We sought to observe the set of characteristics of each disability, which crossed with the list of skills we have.

Several types of disability can affect individuals' cognition. In this work, we focus on some of the most known; they are:

- Autism - Autism Spectrum Disorder is characterized by deficits in communication, social interaction, and repetitive behavior patterns.
- ADHD - Attention Deficit Hyperactivity Disorder is characterized by inattention, impulsivity, or both that persist over time.
- Dyslexia - In Dyslexia, we have a pattern of learning difficulties, mainly in word recognition and understanding.
- Intellectual Disability - People with intellectual disabilities usually have deficits in mental functions such as reasoning, problem-solving, and abstract thinking, among others.

Cognitive impairments can have levels of severity: mild, moderate, severe, and profound. Levels may vary from person to person, and we may have cases of individuals with more than one disability simultaneously, for example, Autism and Intellectual Disability [18].

We used a theoretical search based on the literature to cross skills and characteristics of disabilities, and, as a result, we found the relationships explained in Table III.

Crossing skills and different types of cognitive disabilities, we have in Table III an outline of which skills impact each disability to have a starting point for future interventions.

TABLE III
SKILLS VERSUS COGNITIVE DISABILITIES

Skill	**Disability**
Problem Solving	Intellectual, Dyslexia
Mathematical Skills	Intellectual,
Abstraction	Intellectual, ADHD
Critical Thinking	Autism
Reading Comprehension	Intellectual, Dyslexia, ADHD
Knowledge in English	Cognitive Disabilities
Attention to Details	ADHD
Creativity	ADHD
Time Management	Intellectual, Autism

1) Problem Solving: Studies show that there is still little research linking students with Intellectual Disabilities and programming skills. These students have more difficulty in adaptive functions directly related to skills such as problem-solving, acquired more slowly than a neurotypical student [37].

2) Mathematical Skills: Analyzing the skills found in RQ1, we can see that students with Intellectual Disabilities will have difficulties in skills mainly linked to concepts of logic and mathematics [37].

3) Abstraction: Students with Intellectual Disabilities have an easier time understanding concrete concepts rather than abstract concepts [37].

4) Critical Thinking: Critical thinking can be complex, for example, for those who have Autism and challenging behaviors, so programming activities that incorporate this skill should be designed to favor this skill [39]. In ADHD, critical thinking can also be impaired [18].

5) Reading Comprehension: Autistic individuals may have delays in language and understanding, a lack of speech, and impairments in social communication. People with moderate Intellectual Disabilities may make slow progress in reading and writing. [18].

6) Knowledge in English: The programming languages are English-based, so anyone unfamiliar with the idiom may have difficulties. People with cognitive disabilities who are not native speakers of English [17] may need additional support. Several factors can affect performance for programmers [15], especially beginners. Language is one of those factors which can influence the programmer having a significant impact on performance and programming learning.

7) Attention to Details: Attention is an essential skill for programming. We need to be attentive to details when we are creating code. In addition to creating the solution, we must also be careful to obey the language's syntax. Those with ADHD may have difficulty with attention, hyperactivity, or both [2].

8) Creativity: Skills that involve greater concentration, such as creativity, would be more impacted in students with ADHD [2].

9) Time Management: People with an Intellectual Disability may have trouble understanding time. Autistic people have difficulty switching activities and organizing and planning their time [18]. This condition can cause damage to meeting deadlines, for example.

Studies suggest that learning skills in computer programming can lead to skills in sequencing, investigation, or problem solving for students with intellectual disabilities [37]. On the other hand, studies have shown that students with dyslexia can solve problems quickly, and programming is an area that can enhance their strengths and overcome their weaknesses [2], [38]. When interviewed, some professional developers with dyslexia stated their condition would not pose significant obstacles in their careers [4]. People with Autism and ADHD can develop hyperfocus, a trait where the person devotes a great deal of concentration to something that interests them. This characteristic can facilitate if the student is interested in learning programming. The teacher can look for ways to bring this interest through the use of situations that hold his attention, such as the use of games if he likes to play [13]. We can not look at cognitive deficiencies only about their difficulties but their potential, verifying the characteristics of each deficiency that could help in programming learning.

V. Discussion

This study made it possible to realize that the skills involved in teaching programming can impact students with some cognitive disabilities. As this condition can vary in level and affect individuals differently, we can infer that each student may need specific support. In this way, the teacher's watchful eye will be essential to understand which skills each student is having difficulties using the appropriate recommendations and observe their potential to help them in their studies. The teacher alone may not be successful, so how could he know how to identify these difficulties and skills? What approach could he use: tools, games, specific tests? It's an important question.

We need to analyze what it will take to provide this support for future research. Therefore, the teacher's perspective may be an essential issue. Technologies are constantly evolving, but the school resists traditionally approaching the curriculum, leading to students' lack of interest [10]. Improving didactics for programming courses has always been a challenge for teachers [9]. Teachers often do not provide adequate support due to a lack of knowledge about practical [3] approaches. Teachers must give a constant and personalized support to each student, allowing them to acquire and improve their specific programming skills [8].

Another issue would be the teaching perspective. Programming teaching can revolve around different teaching theories, such as constructivism [9]. These widely used theories can facilitate or hinder adequate support for students with cognitive disabilities. It is necessary to deepen the studies with what we already have as an alternative and propose other possibilities of knowing what works for this audience.

The challenges are not limited to these. We can also add the evaluative question, which is very important and needs to be fair within the limitations and potential of the student.

The Universal Design for Learning [3] was presented as a strategy for teaching people with disabilities. It is based on three basic principles: (1) Multiple means of engagement, (2) Multiple means of representation, and (3) Multiple means of action and expression. Its essence of offering the student multiple ways to learn seems to be a promising approach. Still, it was not created explicitly to meet the specifics of teaching programming, nor for a specific type of disability. We need more research on it, especially for people with cognitive disabilities.

The W3C [26] currently has a working group dedicated to creating guidelines for web content for people with disabilities. These guidelines are supplemental to the existing and consolidated Web Accessibility recommendations [42]. We have a lot of content and materials about programming on the web, especially after the COVID pandemic, which increased the need to explore new teaching opportunities, especially at a distance [41]. These notes are interesting because some can be applied to content creation, for example, for programming classes.

For the following steps, the question remains, if people with cognitive disabilities have difficulties in concepts such as abstraction, logic, and mathematics, how can they learn programming that is content that requires these same concepts? The key to the answer is the constant search for relevant information that brings a sensitive look to the cause of these students. Difficulties exist, and students may take longer to learn, but evidence suggests they can learn. We can not only look at the challenges presented but also explore students' potential, seeking the best in them to favor their learning. Constant support is the key to the success of people with cognitive disabilities in achieving their goals [17].

VI. Threats to Validity

Like any research, this one has threats to its validity. We conducted a bibliographic study through a systematic review of the skills literature and subsequent analysis. There were limitations due to the terms and characteristics of each search base. As the screening and analysis work is manual, human factors can affect the extraction and analysis of data and the interpretation of articles. Still, we tried to minimize them with more than one check.

VII. Conclusion and Future Works

Computer Education is still a new field of research [6], but there are already considerable efforts in the literature to discuss what skills are needed for programming. This work focused on a new look at these skills, a more inclusive look, seeking new perspectives to help people with cognitive disabilities who can learn, but in a different way and with the proper support of teachers and institutions.

We observed through RQ1 that a wide range of skills is necessary for those who want to learn to program. These skills are mainly linked to Mathematics and Logic. With RQ2, we found that the various types of cognitive impairment can impact the skills needed to program, and every kind of disability would not necessarily impact all skills.

It is a great challenge to offer equal opportunities to students with and without disabilities, and we need to plan adaptation strategies for content, practice, and exercises. It does not look like an easy but necessary task. We must research the likely problems about the difficulties presented by the students for each content. Try to foresee many challenges with traditional teaching and propose changes, testing your results with the target audience. We are confident that students with cognitive disabilities will have equal opportunities to access knowledge that involves programming with appropriate adaptations.

For future work, we suggest the creation of proposals for curricular adaptations, materials, contents, exercises, and assessments. For this, they must consider the skills impacted by each disability as a starting point. We can take these proposals to practical application in the classroom and follow the evolution of students in the first programming discipline, providing training and support to teachers.

When considering inclusion, we will favor students who need permanent support, and all students in the class will benefit.

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