Perceptions about Teaching Programming in the Neurodiverse Students' Context

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***Abstract*—This research full paper presents the perception of programming teachers and students in the context of neurodiverse students. Among the wide range of disabilities, Neurodevelopmental Disorders encompass types of disabilities that are not easily visible, such as Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). A section of the literature does not consider these disorders to be disabilities. Therefore, neurodiverse describes a person whose brain functions differently than typical. Given this, we can look at these students as people who learn differently and who need to have their specific needs met. With the inclusion of students with disabilities in technical and undergraduate courses, they face several challenges, both for these students and teachers. Specifically, several peculiarities can impact this process regarding teaching programming, such as the creation of algorithms based on problems described in extensive texts. Despite efforts to meet the needs of students with disabilities in teaching programming, we still do not have enough studies that address this issue. The main objective of this research is to investigate the current reality of teaching programming to neurodiverse people, what the difficulties are, and how teachers and students are trying to solve them. Thus, given the phenomenon's complexity, we created a case study with two units of analysis: (1) neurodiverse students and (2) their respective programming teachers. The phenomenon studied was programming teaching, and the context was the first programming discipline of two undergraduate courses and a high school technical course. We carried out semi-structured interviews with six students and three teachers. We identified through research that teachers need adequate training to serve atypical students and that educational institutions still need an efficient inclusion process for these students. When we observe the students' vision, we realize that for them to learn to program, there are essential demands, such as the difficulty in understanding the application of programming concepts in practice and the creation of programs without assistance. This study is necessary to show the demand for new approaches to meet the specific needs of neurodiverse students in programming disciplines. To achieve this, inclusive pedagogical strategies and resources must be created and adapted to the characteristics and abilities of these students. Initiatives like this can promote equal opportunities in the classroom, including accessible learning environments, use of explicit language, and individualized support, among others.**

***Index Terms*—teaching programming, students with disabilities, student perceptions**

I. Introduction

We can describe that people with disabilities have some impairment, be it physical, mental, intellectual, or sensory [15]. To consider a permanent disability, the person must have a long-term disability. However, we can also have short-term impediments, such as someone temporarily losing mobility due to an accident. What characterizes disability is that the impediment can cause some difficulty for the person, whether permanent or temporary.

Among the different types of disabilities, we have those that are not easily visible, such as neurodevelopmental disorders [1] or cognitive disabilities. These deficiencies can affect brain development, impacting cognitive, emotional, and social skills. Some common examples of neurodevelopmental disorders include Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), and Intellectual Disability (ID).

Difficulties in social interaction, communication, and repetitive behaviors characterize ASD. ADHD involves symptoms of inattention, hyperactivity, and impulsivity. Individuals with ADHD may have difficulty concentrating, following instructions, and controlling their impulses, which can interfere with their academic and social performance. Individuals with ID may experience difficulties understanding concepts, reasoning, solving problems, and developing social skills [1].

Judy Singer created the term neurodiversity [8], which argues that neurodiverse people would not be people with disabilities to be treated, but rather people whose brains function in an atypical way. This author's view implies that if people have a brain that works differently, they need different strategies to deal with it, such as education.

The problem involving students with cognitive disabilities or neurodiverse people in teaching programming is a complex and challenging issue. Programming requires specific cognitive skills, such as logical reasoning, abstraction capacity, and problem-solving, which can be affected in different ways in these individuals [2]. The lack of adequate adaptations and resources can make it difficult for these students to fully and effectively learn. Traditional teaching approaches may not be flexible enough to meet individual needs, leading to accessibility and inclusion issues. In addition, accessibility initiatives are traditionally geared toward people with sensory or physical disabilities (sight, hearing, or mobility) [9], [18].

The Brazilian Inclusion Law guarantees the rights of people with disabilities [3]. Among these rights, access to education stands out, which is guaranteed, considering these character-

istics, interests, and learning needs.

This study aims to portray the perceptions of neurodiverse students and their teachers in teaching programming. More specifically, we discuss the main learning problems identified in programming classes by neurodiverse students and their teachers and how they are trying to solve them.

To achieve this objective, we established three research questions to answer:

- RQ1 What are the difficulties of neurodiverse students concerning the programming class?
- RQ2 What is the perception of programming teachers regarding their work with neurodiverse students?
- RQ3 How are programming teachers acting towards neurodiverse students?

Due to the phenomenon's complexity under investigation, a case study was used in this research to understand this scenario. The scenario is complex because neurodevelopmental disorders are considered non-visible disabilities. Therefore, we only use students who have a medical report confirming their neurodiversity, which makes our sample small. We collected data through interviews at two public educational institutions, with neurodiverse students from technical and undergraduate courses in Computing and their respective teachers from the first programming discipline.

As a contribution to this study, we highlight the presentation of an urgent demand for new approaches to serving neurodiverse students in programming disciplines. Even though it is a small sample, we get a realistic view of the experience of neurodiverse students in programming classes. In addition to the students' vision, we can also see the concern of teachers, who want to help these students but often need help knowing where to start because they usually don't have adequate training.

We organize this paper as follows: Section II presents the Background, Section III presents related work, Section IV describes the methodology, and Section V presents the results. We discuss the results in Section VI, and in Section VII, we present threats to the validity of this research. Finally, Section VIII presents the conclusion and future works, and Section VIII presents Acknowledgements.

II. Background

Some concepts found in the literature are essential for this research. We must understand teaching programming and the characteristics and particularities of some of the primary cognitive disabilities that come into the context of neurodiversity.

A. Programming Teaching

Programming is an essential part of Computer Science (CS) and a knowledge to learn with dedication. Programming disciplines are often considered complex. Moreover, teachers constantly search for strategies and approaches to improve student performance. In general, the difficulties are related to understanding concepts that are not clear in theory but made clear through practice [25].

Understanding the concept of algorithms is necessary to learn how to program. An algorithm is a sequence of well-defined steps that can receive values as input and generate an output [12]. We can create different solutions to solve a particular problem, but some may be simpler or faster than others.

Some methods or approaches to teaching programming concern how teachers deliver knowledge to the students. One way to teach traditional programming is Thompson's approach [26]. This approach presents the following steps to solve a programming exercise: (1) understand the problem, (2) plan the solution, (3) implement the program, and (4) review. These steps can be easy and natural for students to solve their programming problems. However, the entire process can be challenging for some beginning students, increasing the need for guidance and assistance.

B. Cognitive Disabilities and Neurodiversity

Cognitive Disabilities is an umbrella term in the literature to discuss mental disabilities. The most common cognitive impairments include Neurodevelopmental Disorders such as Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), and Specific Learning Disorders such as Dyslexia [27]. Koushik and Kane [23] declare that little research still focuses on teaching informatics to people with diverse cognitive abilities. There are also few reports of strategies for this audience, which shows us a considerable gap to explore.

An exciting approach came from Australian Judy Singer, who coined neurodiversity. Drawing a parallel with biodiversity, she showed that all human beings have their brain characteristics. Therefore, being neurotypical, autistic, or having any other neurodevelopmental disorder is just having different brain characteristics, as well as ethnicity or gender [8].

1) Autism: Autism Spectrum Disorder (ASD) is part of the set of neurodevelopmental disorders and can affect individuals mainly in communication and repetitive behaviors [1]. It is a disorder with three different levels of severity. The most severe level is level 3, and the mildest level 1. According to each level, the autistic person can have more or less resistance, mainly in social interactions. Another essential characteristic is the need to maintain a well-defined routine, making sudden changes painful for the autistic person.

Autism can manifest itself in different ways and will not permanently impair the intelligence of individuals, including research indicating that approximately half of autistics have average or above average intelligence [28]. Over the years, we have had more and more diagnoses of autism, which implies that there is an increase in autistic people entering the school environment, including higher education [29].

2) Attention Deficit Hyperactivity Disorder: ADHD is another neurodevelopmental disorder characterized by dysregulation in the form of inattention, disorganization, hyperactivity, and impulsivity. A person with ADHD may have only inattention, hyperactivity, or both as the central dysfunction. This disorder usually appears in childhood and continues into

adulthood, which can cause impairments in social, academic, and professional functioning. ADHD can manifest in three ways: (1) hyperactivity alone, (2) just attention deficit, and (3) hyperactivity and inattention combined [1].

Students with ADHD are more likely to have learning difficulties than neurotypicals and deficits in reading and math. This common comorbidity can reach up to 45% of those with this disorder [30].

3) Learning Disorders: Individuals with learning disorders present various difficulties throughout school life, such as dyslexia, which has characteristics of impaired word recognition and spelling. You may also have problems with reading and mathematical reasoning [1].

While learning disabilities can come from specific learning disorders such as dyslexia or other disorders such as ADHD [31], the specific learning disorder can affect people without another disorder. In some cases, they may even have high levels of intelligence but have academic difficulties due to psychological deficits.

III. Related Works

Academic research has explored different approaches to teaching programming to various audiences. A recent study [2] aimed to investigate the impact of cognitive disabilities on the skills needed to learn programming. To this end, the primary skills involved in programming were identified, cataloged, and compared with the characteristics of some of the primary cognitive disabilities. The study revealed that programming requires various mathematical and logical skills. Furthermore, different types of cognitive impairment can affect the skills needed to program differently. Not all skills are necessarily affected by all kinds of impairment. These findings highlight the importance of inclusive and adaptive approaches to teaching programming to meet the needs of neurodiverse students or students with cognitive disabilities.

The difference between the research in [2] and this is that in the work proposed, we visualize the intersection between the skills involved in programming and the characteristics of cognitive disabilities. This analysis does not consider perceptions of neurodiverse people and their teachers, seeking to make its analysis based on literature.

Koushik and Kane's paper [23] presents observations about a program for teaching computing concepts to young adults with cognitive disabilities. They conducted interviews, observations, and classes for two instructors and ten students. They used Universal Design concepts to learn but stated that the practices were done by trial and error. The work presented in [23] differs from this in that it analyzes the perceptions of students with cognitive disabilities and their instructors. Still, it collects data from a course created to teach programming to this audience, so the course would already have an accessibility proposal. In our research, we sought the perceptions of students and teachers in secondary and undergraduate courses, which were not designed with any prior accessibility recommendations in mind.

Silva et al. [4] offered an interesting perspective on teaching computational thinking through learning algorithms and programming for individuals with ADHD. A case study was conducted in the format of a 34-week course, focusing on strategies for teaching programming to a student with ADHD. The authors established as a success criterion that the student achieved a minimum accuracy rate of 80% in the assessment as an indicator of successful learning in programming. At the end of the course, the student completed an accuracy rate of 84%, suggesting the experiment's effectiveness. Although the experience presented is relevant, it is essential to highlight that it was carried out as an extracurricular course for just one student. In addition to this, we still see an absence of positive evidence for students with ADHD in regular Computer Science courses.

The difference between the paper presented in [4] and this research is that an extracurricular course was also monitored, which already had in mind recommendations for accessibility for a student with ADHD. Our research starts from perceptions of courses not designed to be accessible.

The study by Israel et al. [6] analyzed the engagement of students with autism in a course that covered Computer Science concepts. This case study involved the collaborative participation of three elementary school students with Autism Spectrum Disorder (ASD) in an extracurricular course. As a result, we observed that student engagement could have been more varied, often low, with little problem-solving. The researchers also found that the experience could have been more positive if there had been individualized support for each student. They observed that students had difficulty persisting and received little help, in addition to the teacher's lack of help planning.

In [6], it is another case of an extracurricular course for k12 students, which is valid for observing student engagement but may not reflect the same experience of students on a regular course in Computing.

A paper [22] presents an educational game for teaching programming to children with ADHD. The objective was to teach programming to children in a playful way. Initially, they planned to create a game using the Scratch platform but could not, so they created it using the Unity 3D platform. The game has not been tested with the target audience, and we do not know if it works effectively with children with ADHD.

Haynes-Magyar performed an exploratory study [17] with five neurodiverse students. Students studied eight chapters of a digital Python programming book and solved problems. From this, the students reported through interviews what their accessibility recommendations would be for Parsons' problems. This study has limitations, such as not being able to generalize its results since we have a small and specific sample. Furthermore, the research is focused only on students' opinions and does not address teachers' opinions and strategies.

A paper [24] deals with the mental health of 53 students in the field of Computing, who shared their positive and negative experiences. In this way, the work proposed presents these

points by showing that some students believe that mental symptoms such as stress and panic attacks can affect their academic performance. They also believe that mental health conditions, because they are invisible, make it difficult for teachers and instructors to assist. For these reasons, students believe that it is necessary for teachers and instructors to actively observe their classes to try to identify students with mental health issues, as it is difficult for students to deal with the issue spontaneously.

The paper [24] differs from this research for several reasons. As for the participants, data was collected from students who identified themselves as having some mental health condition, which implies that they did not ask for proof of medical reports. It also did not collect data from these students' respective teachers and was not limited to specific content like us, who focused on the programming course. Furthermore, he collected information to find out how the course affected students' mental health, which is not the focus of our work.

IV. Methodology

This research has an exploratory and descriptive nature [7]. We aim to understand the current state of teaching programming to neurodiverse students. Participants in this research belong to one of two profiles: (1) neurodiverse students taking their first programming subject or (2) their respective teachers. This choice was made due to the complexity of the phenomenon researched, as we only considered students with a confirmed diagnosis of neurodevelopmental disorder, even though we know that some students may present characteristics of certain neurodiversity. Here, we have a single-case exploratory case study [10], [19], [20].

For this study, we considered the teaching of programming as a phenomenon. As a context, we have the first programming class in two undergraduate courses and a high school technical course. The units of analysis of this case study are (1) neurodiverse students and (2) their respective teachers within this context.

This research follows the ethical principles established by the Brazilian National Health Council (CNS) by Resolution No. 510/2016, which supports research with human beings and is approved by the Research Ethics Council (CEP) of the Federal University of Campina Grande (UFCG) under number 46773221.9.0000.5182.

A. Participants Profile

For this study, we need to investigate the impressions of six neurodiverse students and their respective teachers in the context of the first programming course. The research participants were, therefore, students with some diagnosis of neurodiversity enrolled in a course in the Computing area at a higher level or a technical course at a secondary level. In addition to these, we also selected their respective teachers in the first programming course.

Student participants were selected through contact with two educational institutions, seeking to locate students who had diagnoses issued by specialized professionals. In this context, the institutions had these diagnoses, which were received upon admission of students to the respective selection processes. We know that some students may present characteristics of neurodiversity but do not have a report or do not want to be classified as such. As we do not have professional qualifications to diagnose them, we chose to select only those who already have a report and, of their own free will, agreed to participate in the research.

As our research field is very restricted, we established that all students who fit the profile and were enrolled in a first programming course would be selected. Six students and three teachers were located: five undergraduates and one high school technical course student. To preserve students' privacy, we identify them using an acronym, where undergraduate students are identified by the letter G followed by a control number, and the acronym T1 identifies technical course students.

Regarding diagnoses, it is possible to observe a diversity among them, although they all fall into the category of cognitive disability or neurodiversity as shown in Table I.

TABLE I
Students Profile

Pseudonym	**Diagnose**
G1	Asperger's Syndrome (ASD)
G2	Asperger's Syndrome (ASD)
G3	Asperger's Syndrome (ASD) and ADHD
G4	ADHD
G5	ADHD and Mood Disorder
T1	Noonan Syndrome, ADHD, and mild ID

It is important to mention that what was previously known as Asperger's Syndrome is now classified within Autism Spectrum Disorder, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [1]. Furthermore, Mood Disorder is included in Attention Deficit Hyperactivity Disorder (ADHD). On the other hand, Noonan Syndrome is a physical condition, but the student in question also with ADHD and Intellectual Disability (ID), which qualified him to participate in the study.

After identifying students eligible for the study, we contacted each student's teacher in the first programming subject. As we can see in Table II, we have teachers with training in Computing and extensive experience in teaching.

TABLE II
Teachers Profile

Pseudonym	**Graduation**	**Highest Academic Degree**	**Teaching Experience**
TG1	Computer Science	Master Degree	11 Years
TG2	Computer Science	PhD	17 Years
TT1	Informatics	Postgraduate Specialization	16 Years

B. Data collect

Data collection took place through semi-structured interviews; in this way, we sought to obtain information from the

participant's perspective [16]. We created a script for each unit of analysis, dividing the questions into parts, one for neurodiverse students and the other for their teachers. To this end, the question sought to guide interviewees in presenting as much relevant information as possible to this research. The interviews were carried out individually at different times, outside the classroom, to make participants feel comfortable throughout the process.

The teachers' interview script was divided into three parts, as shown in Table III. Part 1 sought to collect the participants' profiles with their training data and whether any training supported classes involving students with disabilities. In part 2, we seek to detail the teacher's experience with students with disabilities in the first programming course. In part 3, we finish the interview by collecting data about the discipline.

The interview guide with students was organized into six parts, as shown in Table IV. Part 1 collects name and age data, which only serves as a control. The participant's name will not be disclosed, preserving their privacy. In part 2, we open space for the student to talk about their main doubts without reminding them of the content so that they can try to explain on their own. Part 3 specifies the main contents covered in the first programming course. The opportunity allowed the students to recall the content and report their doubts and understanding about each of them. Part 4 seeks to understand students' difficulties when doing programming exercises. Part 5 aimed to understand the difficulties in assessments. Finally, in part 6, we allowed the students to express anything important to conclude the interview.

TABLE III
TEACHER INTERVIEW GUIDE

Part 1 Participant's Profile
Graduation; How many years of classroom experience; Experience involving students with disabilities in the classroom; Training for Inclusive Education;
Part 2 Experience with Students with Disabilities
Students with disabilities from the programming course in previous semesters; Types of Disabilities; Details about students with disabilities this semester; The adaptations made in classes for students with disabilities; The adaptations made in the materials and activities for students with disabilities; Interested in learning how to assist these students in programming lessons.
Part 3 Conducting Discipline
Detail how the discipline is currently conducted

V. RESULTS

We performed a content analysis of the data collected during the interviews [11], [13], [14]. Our objective was to observe how the teaching and learning process occurs in the context of neurodivergent students in the first programming subject.

We interviewed six students who reported some neurodevelopmental disorder and their three respective teachers from the first programming subject. As one of the teachers had more than one student who fit into the study, we observed that the number of teachers was smaller than the number of students.

TABLE IV
STUDENT INTERVIEW GUIDE

Part 1 Participant Profile
Name; Age.
Part 2 Questions about Programming
Detail programming doubts
Part 3 Contents
Input and output; Variables; Definition of Algorithm; Conditional Structures; Repetition Structures; Vectors; Functions.
Part 4 Exercises
Statement; Input; Exit
Part 5 Assessment
Part 6 General Information

The data analysis was manual because the sample was small. We carefully read the interview responses and compiled the results according to the research questions below.

A. RQ1 What are the difficulties of neurodiverse students concerning the programming class?

The first question to the students (Interview Guide - Part 2) was to seek information about the questions they had in programming, but without mentioning any specific content. We aimed to extract difficulties neutrally because they would inform the interviewer if the student had a particular doubt. In Table V, we see how students responded about their difficulties in programming without any reminders about the programming topics.

TABLE V
PROGRAMMING DOUBTS

Difficulties	**G1**	**G2**	**G3**	**G4**	**G5**	**T1**
Exercises	X					
Materials	X					
Algorithms Application		X				
Looping				X		
No Doubt			X		X	
Doubt about almost everything						X

Observing the answers about difficulties in general, students gave varied answers, but we see that of the total number of students interviewed, two believe that they do not have difficulties in programming. Only one student believes that he has difficulty in all the topics mentioned.

After the student spontaneously expressed their doubts about programming, we asked them about their difficulties concerning programming topics. Based on each topic mentioned, the student said whether and what their question would be. In Table VI, we see how students answered their questions in the programming topics. It is marked with "X" if the student has questions about the topic asked.

We can observe that, of the students who responded that they had doubts, none indicated that they had concerns about the initial topics, input-output, and variables. Regarding functions' content, some students have not yet studied this topic.

TABLE VI
PROGRAMMING DOUBTS BY TOPICS

Topics	G1	G2	G3	G4	G5	T1
Input/Output						X
Variables						X
Algorithm Definition					X	X
Condition	X			X		X
Loops	X			X	X	X
Vectors	X			X	X	X
Functions	X					

TABLE VII
TEACHER'S STRATEGIES

Strategy	TG1	TG2	TT1
Increase in course workload	X		
Increased time to carry out activities or assessments	X	X	X
Monitor Use	X	X	X
Constant intervention	X		
Repetition of the explanation		X	X
Use of Images			X

Then, the students responded about their difficulties in the exercises and assessments (Interview Guide Parts 5 and 6). Five of the six students interviewed reported that their most significant difficulty was understanding the questions statements. This difficulty is also reported concerning evaluations. One of the students also highlighted that many exercises involve mathematical calculations as a difficulty.

B. RQ2 What is the perception of programming teachers regarding their work with neurodiverse students?

We interview three programming teachers to answer this question. In the interview, we asked each teacher about their experience with students with disabilities. All teachers interviewed were teachers of at least one of the neurodiverse students we also interviewed. All interviewees responded that they had students with disabilities in previous semesters, received students with different types of needs, and did not have any specific training to help these students.

The TG1 teacher noticed the difficulty of his neurodiverse student, especially in attention and memorization, looking for strategies to help him. The TG2 teacher, who has four neurodiverse students, realized that each student has different levels of interaction and attention to the subject. In the same way that there are neurodiverse students who perform well and interact well, there are also neurodiverse students who do not interact and do not seek to answer questions, harming their performance in the subject. Teacher TT1 noticed that his neurodiverse student has a lot of difficulties, low interaction, and a lack of attention.

Finally, all teachers interviewed believe that they need adequate training to deal with neurodiversity, which falls under non-visible deficiencies, and that educational institutions still need to improve support for teachers in this context.

C. RQ3 How are programming teachers acting towards neurodiverse students?

Based on the teachers' perception of neurodiverse students, related in RQ2, another important question arises, which is how these teachers try to support neurodiverse students, even without having adequate training. Given this, we have essential information that helps us reflect on how more than traditional practices may be needed to teach these students, as shown in Table VII.

Professor TG1 reported an attempt to increase the students' workload, making them use two semesters instead of one to complete all the programming content.

All teachers indicated they sought to increase the deadline for completing exercises and activities for neurodiverse students. They also reported that they have a monitor to help the student.

Only the TG1 teacher sought constant intervention for the student as a strategy, which could be from himself or the monitor. Two of the three teachers used the trick to explain the same thing more than once, seeking understanding from neurodiverse students. Only teacher TT1 reported that he sought to adapt his class material, using more images and less text as much as possible.

VI. DISCUSSION

By evaluating the interview data, we gained insights from each of our units of analysis; guided by the research questions, we discuss these questions below.

A. Perceptions of the Difficulties of neurodiverse students in Programming classes

The students interviewed pointed out difficulties in programming classes, generating reflection on what could be done to make these students successful in the course. We can point out some key questions below:

- **Materials and Exercises** - The students point out difficulties in the class materials and exercises, generating reflection on how these could be adapted to a neurodiverse audience. What would be the points to improve?
- **Understanding the application of Programming -** It was mentioned by the students that there is difficulty in understanding the application of Algorithms in the real world. This difficulty signals the need for greater contextualization between Programming concepts and the practical needs of the market, for example.
- **Interpretation of problems -** Students claimed difficulty in interpreting what the problems ask. This occurs both in exercises and in assessments. It is a fact that, in some types of cognitive disability, we have some characteristics that can impact, for example, logical reasoning and abstraction [2], which would require a reformulation in the way questions are written.
- **Creating Algorithms without help -** Another critical problem identified in the responses was the difficulty in knowing how to start an algorithm without help, which may suggest the need for devices to remind them of the structure and main elements of an algorithm within the scope of the problem they want to solve at that moment.

- **Remembering what to do in exercises and assessments -** Difficulty was reported in knowing which programming elements should be used for each problem situation.

The issues identified during data collection provide strong evidence that it is necessary to re-evaluate the approach to teaching programming in the classroom. Various strategies can be considered to improve the student learning experience, such as revising the texts of exercise statements and materials to minimize their negative impact. These measures aim to provide a more inclusive and accessible learning environment, ensuring all students can engage and learn to code effectively.

B. Perceptions of Programming Teachers regarding neurodiverse students

Teachers' perception regarding neurodiverse students indicates some issues that need to be explored, as can be seen below:

- **Lack of Adequate Training -** Teachers recognize that neurodiverse students need adequate assistance in programming classes and everyone is interested in adequately serving students with disabilities in their classes. There is a problem but there is no adequate training for these teachers. Looking for ways to help students with their specific needs takes extra time and work, making it difficult to find solutions without proper guidance.
- **Insufficient communication -** Both educational institutions have support centers for people with disabilities. These centers aim to welcome and seek adequate support for all students with specific needs within the teaching environment. In practice, this support is more effective for those with sensory or physical disabilities (hiring Brazilian Sign Language interpreters to support deaf students, for example). In the case of neurodivergent students, this support is limited to signaling that the student has a specific need, that they need support, but it is not clear what support they are owed.

Regarding the lack of communication on the part of the educational institution, it is observed that specialized sectors generally inform teachers when there are students with disabilities and, as far as possible, provide guidance that may be useful. However, support is still insufficient for students with disabilities that are not "visible", leaving teachers concerned about their students' progress and without adequate guidance on how to act. There is a clear need to improve support and provide more comprehensive guidance so that teachers can more effectively meet the needs of these students.

Faced with the demand for insufficient training, each teacher sought alternative solutions based on their perceptions. This generated our third research question, which addresses how teachers sought to address the inclusion of neurodiverse students in their programming classes.

C. Perceptions of Programming Teachers Acting towards neurodiverse students

With inadequate training, teachers reported looking for strategies to help neurodiverse students.

- **Increase in Time -** There was a consensus among the teachers that these students needed more time to carry out the activities than the other students in the class. One of the teachers even used the strategy of having the student study content that would only last one semester in two. The extra time can be interesting, especially for students who have levels of inattention and take longer to concentrate.
- **Explanation** A strategy adopted by two teachers was to explain the subject more than once, seeking to vary the ways of speaking to minimize the students' difficulties. This way, students with different levels of difficulty can benefit.
- **Adaptation of Materials and Activities** Only one teacher reported that he tries to adapt his classes. His strategy is to increase the number of images. Using images is insufficient for adequate adaptation, but it is a start.

As we can see, teachers' actions toward neurodiverse students still lack better strategies to effectively help these students in programming classes. Teachers lack adequate support to show them what can be done. We know that adaptations require time and knowledge, but we must understand that they are essential for effectively including these students in programming classes.

VII. Threats to Validity

Any research presents threats to validity. In this case, we identified the number of participants as a limitation, which we justify because the number of eligible subjects is small in the population. Therefore, we cannot guarantee that the findings would generalize to other participants with different types of cognitive impairment at different levels.

Another limitation would be human factors. These can affect the interview screening and content analysis process, as the same researcher defined, carried out, and analyzed the research.

VIII. Conclusion and Future Works

This research aimed to portray the perceptions of neurodiverse students and their teachers when teaching programming. The main difficulties reported by teachers were the need for more adequate training and communication. From the students' point of view, our study highlighted the main difficulties in understanding the application of programming, interpreting problems, creating algorithms without assistance, and remembering what to do in exercises and assessments.

We saw that there is still a lot to be discussed and explored and that teachers are interested in how to proceed but need guidance. With adequate support, we believe that teachers can positively reach this group of students, who will benefit their learning through conditions suited to their needs. Educational institutions must invest in specialized support for teachers, which can make a big difference in welcoming students with specific needs. Furthermore, it can be decisive in whether these students remain in the course.

Given the difficulties reported by students and teachers, we saw an apparent demand to consider new approaches to teaching programming to neurodiverse people. It is essential to develop inclusive pedagogical strategies and resources adapted to the characteristics and abilities of these students, providing them with equal opportunities. This may involve creating accessible learning environments, using clear language and instructions, and providing individualized support and differentiated learning structures. Overcoming this problem requires a collective commitment to ensure that all students have equal access to programming learning opportunities, regardless of their cognitive abilities.

Inclusion initiatives benefit students who have permanent limitations. Still, they can also help any student with a temporary restriction or even difficulties arising from poor educational training, as programming is not traditionally learned throughout school life.

Considering this context as a suggestion for future work, we propose the development of educational artifacts that can assist teachers in planning and conducting their classes in the context of neurodiversity. These educational resources can support educators by providing specific strategies, materials, and approaches to promote an inclusive and effective learning environment for these students. This initiative aims to strengthen teachers' ability to meet the individual needs of each student, promoting quality education for all.

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REFERENCES

[1] American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. Arlington, VA: American Psychiatric Association, 2013

[2] E. C. Juvino de Araújo, W. L. Andrade and A. L. Souto Oliveira, "Identifying Programming Skills Impacted in Students with Cognitive Disabilities," 2022 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden, 2022, pp. 1-8, doi: 10.1109/FIE56618.2022.9962703.

[3] Brazilian Law on the Inclusion of Persons with Disabilities (Statute of Persons with Disabilities) Law 13.146/2015. URL: http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2015/lei/l13146.htm

[4] F. F. da Silva, L. Beatrys Ruiz Aylon, and D. E. Flôr, "Teaching Computational Thinking to a Student with Attention Deficit Through Programming," in 2020 IEEE Frontiers in Education Conference (FIE), 2020, pp. 1–9. doi: 10.1109/FIE44824.2020.9273915.

[5] M. Israel, G. Jeong, M. Ray, and T. Lash, "Teaching Elementary Computer Science through Universal Design for Learning", in Proc. of SIGCSE 20, 2020, pp. 1220–1226. doi: 10.1145/3328778.3366823.

[6] Maya Israel, Moon Y. Chung, Quentin M. Wherfel & Saddeddine Shehab (2020): A descriptive analysis of academic engagement and collaboration of students with autism during elementary computer science, Computer Science Education, DOI: 10.1080/08993408.2020.1779521

[7] A. C. Gil, Como Elaborar Projetos de Pesquisa. Atlas, 2022.

[8] J. Singer, Neurodiversity: The birth of an idea. 2017.

[9] "Making content usable for people with cognitive and learning disabilities", Www.w3.org. [Online]. Available: https://www.w3.org/TR/coga-usable/.

[10] R. K. Yin, Case study research: Design and methods, 5o ed. Thousand Oaks, CA, USA: SAGE Publications, 2014.

[11] Bardin L. Análise de conteúdo. Lisboa: Edições 70; 2015.

[12] Cormen, T.H. and Leiserson, C.E. and Rivest, R.L. and Stein, C. Introduction to Algorithms, fourth edition. MIT Press, 2022.

[13] Johnny Saldaña. 2021. The coding manual for qualitative researchers. (2021), 1–440.

[14] Lindgren, B. M., Lundman, B., & Graneheim, U. H. (2020). Abstraction and interpretation during the qualitative content analysis process. International journal of nursing studies, 108, 103632. https://doi.org/10.1016/j.ijnurstu.2020.103632

[15] "Disability - PAHO/WHO — Pan American Health Organization". [Online] Available: https://www.paho.org/en/topics/disability.

[16] Leitão, Carla. "A entrevista como instrumento de pesquisa científica em Informática na Educação: planejamento, execução e análise. In: PIMENTEL, Mariano; SANTOS, Edméa." (Org.) Metodologia de pesquisa científica em Informática na Educação: abordagem qualitativa. Porto Alegre: SBC, 2021. (Série Metodologia de Pesquisa em Informática na Educação, v. 3) [Online] Available: ¡https://metodologia.ceie-br.org/livro-3/¿

[17] Carl Haynes-Magyar. Neurodiverse Programmers and the Accessibility of Parsons Problems: An Exploratory Multiple-Case Study. In Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1 (SIGCSE 2024). Association for Computing Machinery, New York, NY, USA, 491–497. https://doi.org/10.1145/3626252.3630898

[18] E. C. J. De Araújo and W. L. Andrade, "A Systematic Literature Review on Teaching Programming to People with Cognitive Disabilities," 2021 IEEE Frontiers in Education Conference (FIE), Lincoln, NE, USA, 2021, pp. 1-8, doi: 10.1109/FIE49875.2021.9637361.

[19] Castro Filho, Jose Aires; Freire, Raquel Santiago; Maia, Dennys Leite. Estudo de Caso como método de pesquisa em Informática na Educação. In: PIMENTEL, Mariano; SANTOS, Edméa. (Org.) Metodologia de pesquisa científica em Informática na Educação: abordagem qualitativa. Porto Alegre: SBC, 2021. (Série Metodologia de Pesquisa em Informática na Educação, v. 3) [Online] Available: ¡https://metodologia.ceie-br.org/livro-3/¿

[20] Gomes, Alex Sandro; Gomes, Claudia Roberta Araújo. Classificação dos Tipos de Pesquisa em Informática na Educação. In: JAQUES, Patrícia Augustin; PIMENTEL, Mariano; SIQUEIRA; Sean; BITTENCOURT, Ig. (Org.) Metodologia de Pesquisa Científica em Informática na Educação: Concepção de Pesquisa. Porto Alegre: SBC, 2020. (Série Metodologia de Pesquisa em Informática na Educação, v. 1) [Online] Available: ¡https://metodologia.ceie-br.org/livro-1/¿

[21] Francisco, Deise Juliana; Azevedo, Edjane Mikaelly Silva; Ferreira, Adilson Rocha Ferreira; Caitano, Alexandre Rodrigues. Análise de Conteúdo: como podemos analisar dados no campo da educação e tecnologias. In: PIMENTEL, Mariano; SANTOS, Edméa. (Org.) Metodologia de pesquisa científica em Informática na Educação: abordagem qualitativa. Porto Alegre: SBC, 2021. (Série Metodologia de Pesquisa em Informática na Educação, v. 3) [Online] Available: ¡https://metodologia.ceie-br.org/livro-3/¿

[22] C. Galeos, K. Karpouzis and G. Tsatiris, "Developing an educational programming game for children with ADHD," 2020 15th International Workshop on Semantic and Social Media Adaptation and Personalization (SMA, Zakynthos, Greece, 2020, pp. 1-6, doi: 10.1109/SMAP49528.2020.9248458.

[23] Varsha Koushik and Shaun K. Kane. 2019. "It Broadens My Mind": Empowering People with Cognitive Disabilities through Computing Education. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). Association for Computing Machinery, New York, NY, USA, Paper 514, 1–12. https://doi.org/10.1145/3290605.3300744

[24] Jie Ji, Christian Murphy, Brianna Blaser, and Jennifer Akullian. 2024. Experiences of Undergraduate Computer Science Students Living with Mental Health Conditions. In Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1 (SIGCSE 2024). Association for Computing Machinery, New York, NY, USA, 597–603. https://doi.org/10.1145/3626252.3630846.

[25] Waite, J. & Sentance, S. 2021 Teaching programming in schools: A review of approaches and strategies. Raspberry Pi Foundation Research Report. ISSN 2514-586X (19)

[26] Thompson, S. Where do I begin? A problem solving approach to teaching functional programming. In K. Apt,P. Hartel, & P. Klint (Eds.), First International Conference on Declarative Programming Languages in Education.Springer-Verlag, 1997.

[27] Qisheng Li, Josephine Lee, Christina Zhang, and Katharina Reinecke. 2021. How Online Tests Contribute to the Support System for People With Cognitive and Mental Disabilities. In Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility

(ASSETS '21). Association for Computing Machinery, New York, NY, USA, Article 10, 1–15. https://doi.org/10.1145/3441852.3471229

[28] K. Eiselt and P. Carter, "Integrating Social Skills Practice with Computer Programming for Students on the Autism Spectrum," 2018 IEEE Frontiers in Education Conference (FIE), San Jose, CA, USA, 2018, pp. 1-5, doi:10.1109/FIE.2018.8659252.

[29] Gelbar NW, Smith I, Reichow B. Systematic review of articles describing experience and supports of individuals with autism enrolled in college and university programs. J Autism Dev Disord. 2014 Oct;44(10):2593-601. doi: 10.1007/s10803-014-2135-5. PMID: 24816943.

[30] Molitor SJ, Langberg JM, Evans SW. The written expression abilities of adolescents with Attention-Deficit/Hyperactivity Disorder. Res Dev Disabil. 2016 Apr-May;51-52:49-59. doi: 10.1016/j.ridd.2016.01.005. Epub 2016 Jan 21. PMID: 26802631; PMCID: PMC5134244.

[31] S. Wille, J. Century and M. Pike, "Computer Science Principles (CSP) and students with learning differences: Expanding opportunities for a hidden underrepresented group," 2016 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT), Atlanta, GA, USA, 2016, pp. 1-8, doi: 10.1109/RESPECT.2016.7836160.