An analysis of interventions with students with Autistic Spectrum Disorder (ASD) using gamified geometric thinking

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***Abstract*—Studies have been indicating the use of digital resources for interventions with children diagnosed with Autism Spectrum Disorder (ASD), especially when it comes to supporting communication and social interaction. However, there is research that suggests the use of digital environments not only in these aspects but also to assist them in their academic knowledge, such as in their mathematical skills, specifically related to geometric thinking. From this context, Active Methodologies point to various ways of rethinking traditional teaching, one of them being gamification, which can be understood as the use of game elements in non-game situations. Gamification has shown significant benefits for this audience, proving to be an effective tool to aid in the development and learning of these individuals. Therefore, this article in its complete form presents an excerpt from a doctoral thesis that seeks to understand the geometric thinking of nine autistic participants through gamified activities in their real mode. The research is divided into two stages: the first stage involves a preliminary survey with five teachers through structured interviews, aiming to investigate the demand for gamified activities for students with ASD, as well as indicating possibilities for such activities. From the Discursive Textual Analysis (DTA) of these interviews, three categories emerged: opportunities, skills, and limitations. As for the second stage, conducted with nine participants, who are students with ASD, interventions were carried out with these activities in their real mode, which will be implemented digitally later. Through the researcher's observation analysis, based on recorded videos of the interventions, three subcategories related to the initial categories can be identified: potential interactions (opportunities); strategies for geometric thinking (skills); and gamification in the real mode (limitations). The first subcategory emerged due to the need to describe how students with ASD interacted both with the researcher and with the activity. Given the need to showcase how the students solved the activities, as well as the strategies they employed to complete the pairings correctly, the second subcategory emerged. Lastly, the third subcategory arises from limitations that were observed during the interventions, which were still in the real mode and should be taken into account when implementing the digital phase. Therefore, it is evident that there are some points to consider for the activity in its digital mode: implementing gamified activities that incorporate elements from the participants' daily lives (ADLs); understanding the strategies employed by the participants to solve gamified activities; being mindful of the weaknesses of the gamified activity in its real mode, allowing for the provision of resources in various formats.**

***Index Terms*—Gamification, Autism Spectrum Disorder, Geometric Thinking**

I. Introduction

A survey conducted every two years in the United States (USA) by the Center for Disease Control and Prevention (CDC), which monitors the prevalence of ASD, is carried out at 11 sites of the Autism and Developmental Disabilities Monitoring Network (ADDM) with 8-year-olds. The report published in 2023 reveals that one in every 36 children is diagnosed with ASD in these US territories. A recent survey released in 2023 [1] indicates that 1 in 36 children in this age group is diagnosed with Autism Spectrum Disorder (ASD). In the Brazilian context, the only data we have on the prevalence of ASD are from a pilot study [2], conducted with children between 7 and 12 years old, residents of the city of Atibaia/SP. This study found that one in every 367 children within this age group had a diagnosis of ASD. Although this data is now considered outdated, it is believed that the prevalence of ASD cases worldwide is attributed to the increase in research dedicated to studies on this disorder, as well as to the deepening of studies by professionals who conduct such diagnoses. According to [3], the core features of ASD include persistent impairments in reciprocal communication and social interaction, as well as restricted and repetitive patterns of behavior, interests, or activities. Based on the same manual,

ASD is categorized into three levels: Level 1 - Requiring support; Level 2 - Requiring substantial support; Level 3 - Requiring very substantial support. Although these levels do not specifically manifest academic knowledge difficulties, research indicates the importance of interventions for students with ASD to enhance their mathematical skills [4]. According to [5], the instruction of academic skills to students with ASD has received limited attention from researchers, possibly because the disorder's classic deficits, such as communication and social interaction difficulties, are prioritized. In light of this, other studies highlight the use of digital technologies, which represent one of the areas of interest for these students [6]. According to [7], these technologies, by aiding in the teaching and learning process for students with ASD, offer a variety of opportunities as they are an effective means of delivering academic content and fostering the creation of creative and constructive environments. Mathematical skills, specifically geometric thinking, for students with ASD, can be addressed through Digital Technologies using Active Methodologies, which are considered alternative approaches to teaching and learning processes. According to [8], unlike traditional teaching, the fundamental principles of these methodologies are associated with the student's role in their learning, transforming them from passive listeners into active learners and producers of knowledge. Among the possibilities for intervention from the perspective of Active Methodologies, there is gamification, which, according to [9], is a methodology based on thinking and acting as in a game, applying the systematic and mechanical elements of playing in a non-gaming context. Therefore, [10] highlight one of the emerging solutions that has been increasingly used to enhance learning environments: gamification. In this regard, it can be stated that gamification involves the utilization of game elements in non-playful contexts to motivate students with ASD to engage with the activity. In alignment with [9], [11] emphasizes that gamification enhances learning through game elements, fostering increased engagement and interest among students, which is rooted in teaching and learning processes while focusing on skills, with mathematics being the central focus of this study. Therefore, as stated by [12], gamifying mathematics involves incorporating mathematical content and winning strategies into a motivating and appealing environment, utilized to facilitate the development of children with various types of disorders, such as ASD in our study. To develop activities aimed at stimulating the geometric thinking of students with ASD, the present study was divided into two stages. In the first stage, structured interviews were conducted with five teachers from a special school to comprehend the demand for these activities, from which three categories emerged: opportunities, abilities, and limitations. The second stage involves the implementation of these activities in a digital format, which are connected to gamification through mechanics, dynamics, and aesthetics.

II. Related Searches

They developed ALIZA [13], which comprises gamification-based activities for assessing mathematical skills, including counting, number identification, and writing. [14] presented the development of a mobile application designed to enhance the mathematical skills of the same target audience. [15] created 32 activities referred to as LEMA, focusing on the learning of geometric shapes, enabling participants to analyze their characteristics and relationships. [16] conducted a comparison in teaching numerical relationships between dictated numbers, Arabic numerals, and quantities using manipulative materials and computerized activities. Additionally, [17] established 'Strong' for assessing students with ASD through digital games that involve the concepts of numbers and geometric shapes. As children with ASD primarily learn through visual means, as stated by [18], interventions based on the use of Digital Technologies are well-received by this population. This is due to the predictable and structured environment they offer, which helps maintain routines and enhances their learning, as indicated by [19] and [14]. According to [20], the utilization of technological resources presents a pedagogical alternative in working with ASD, as it engages them in computerized activities, facilitating the development of mathematical concepts that might not be attainable in non-digital environments. This viewpoint is supported by [21], who assert that the use of Digital Technologies can improve attention span, social behavior, interactions with peers, the ability to argue, and academic performance. In addition, [22] adds that game-based interventions for students with ASD have shown to expedite their learning process, with several advantages associated with the use of gamification for these students, including: a positive impact on participation and engagement; motivation to complete activities they might typically avoid; enhancement of teamwork and social skills. Concerning the development of gamified activities, [14] argue that feedback assists students with ASD in maintaining their focus and gradually improving their skill levels. To gamify, it is necessary to conduct a preliminary assessment of the necessary requirements to ensure that the activity meets the demands of the research participants. This initial step is recommended by [17], as it was possible to create a suitable activity based on the students' preferences and the requests presented by their parents and teachers, aligning it with the needs and abilities of the students. According to [23], in their study on the cognitive development and learning of children with ASD, gamification involves the utilization of elements such as scores, rankings, prizes, avatars, challenges, among others, outside the context of the game. Regarding this process, [24] outlines several steps for implementing gamification, including determining learner characteristics, defining learning objectives, creating educational content, and integrating game elements. Concerning the use of game elements in gamification, [19] highlight their effectiveness, showing a positive correlation with engagement and being

widely employed with promising outcomes. Hence, [13] suggests that due to the strong visual processing skills of children with ASD, the utilization of imagery and technology may prove to be more effective in enhancing their learning skills compared to traditional methods. Similarly, [25], in their study, emphasize that Digital Technologies intended for students with ASD should be customizable, as the disorder encompasses a spectrum of diverse needs. [26] mention four reasons for the acceptance and effectiveness of using Digital Technologies in this context, which are: computer programs are predictable and familiar; tasks can be easily repeated without significant alterations; they eliminate complex social interactions with third parties; and educational software can offer a structured, individual learning environment. Lastly, [27] emphasize that the primary goal of gamified activities is to enhance participants' engagement and performance in task completion. Therefore, it is crucial for the researcher to pay attention to all these elements when implementing gamification with the autistic audience.

III. Theoretical Reference

In addition to the references already mentioned in the article, it is necessary to highlight that for the development of gamified activities, we drew upon the studies of [28]. In their work on geometry, the author proposes an important model for fostering geometric thinking through the concept of 'apprehensions,' which, according to the author, represent students' interpretations when interacting with figures, based on various forms of representation. [28] identifies four categories of apprehensions, namely: perceptive, discursive, operative, and sequential. Consequently, each apprehension encompasses distinct manifestations of students' geometric thinking. Therefore, the gamified activity, employing both concrete and digital materials (the latter of which is still under development), aims primarily to cultivate in students with ASD the concept of perceptive apprehension. As per [28], this concept enables students to recognize shapes by distinguishing their distinct mathematical properties. Recognizing that a triangle is a three-sided figure, while a square and rectangle are figures with four sides, although not all sides are of the same length, is connected to the apprehension highlighted by [28]. Furthermore, the author suggests that it should be possible to distinguish them based on their geometric characteristics (two-dimensional) or their composition as objects (three-dimensional). This notion is supported by [15], who assert that there are instances demonstrating that children with ASD can often exhibit greater accuracy in areas like measurement. Nevertheless, they may encounter specific challenges in generalizing their understanding of geometric shapes and comprehending representations in both 2D and 3D formats. Hence, the gamified activities developed for this thesis project will incorporate both flat geometric shapes and three-dimensional objects. Participants will be required to apply their mathematical skills to distinguish these characteristics accurately in order to complete the pairings correctly, with the goal of attaining the perceptual apprehension concept proposed by [28].

IV. Methodology

This article is an excerpt from an ongoing doctoral research that has already passed a qualifying exam. Concerning its approach, the research falls within the qualitative paradigm, as [29] suggests that this type of research aims to address very specific questions. In essence, it delves into the realm of meanings, motivations, aspirations, beliefs, values, and attitudes. As a research methodology, it is structured as a case study, in which [30] asserts that, typically, case studies are the preferred strategy when questions like "how" and "why" arise, especially when the researcher has limited control over events, and the focus is on contemporary phenomena situated within a real-life context. Considering the above, the research is divided into two main stages: the first one involves a preliminary survey with five teachers from a Special School, during which data collection was conducted through structured interviews. As [31] indicates, a structured interview is one in which the interviewer follows a pre-established script, and the questions asked to the individual are predetermined. It is carried out in accordance with a well-defined format and is preferably conducted with individuals selected based on a specific plan. This survey aimed to comprehend the requirements for gamified activities intended to stimulate geometric thinking in students with ASD. As [32] point out, this type of interview is employed when the objective is to attain consistent results among the interviewees, enabling direct comparisons. As a data analysis technique, in addition to the emerging categories, Discursive Textual Analysis (DTA) was employed. [33] asserts that qualitative research has progressively employed textual analysis, whether starting from existing texts or producing analytical material from interviews and observations. Qualitative research aims to interpret the phenomena it investigates based on a rigorous and discerning analysis of this type of information. On the other hand, the second stage of the present study involves the development and implementation of gamified activities, utilizing both concrete materials and digital formats, with the objective of exploring the perceptual apprehension of students with ASD in relation to geometric thinking. During this phase, data will be collected through observations. According to [31], observation is a data collection technique used to gather information and relies on the senses to capture specific aspects of reality. It involves not only seeing and hearing but also scrutinizing facts or phenomena that one aims to study. This article will now present the results and discussions of the interventions with nine participants with ASD and the gamified activities using concrete materials, as the digital format is still in the implementation phase. For the selection of game elements, we drew inspiration from the studies of [34], where they highlight that the mechanics of a game system comprise various components, among which the following are prominent: points, levels, scoreboard, challenges, missions, engagement loops, customization, reinforcement, and feedback. However, in designing the gamified activity,

we opted for the use of points, reinforcement, feedback, and levels as game elements for the activity's creation. Levels were incorporated because, as participants progress, they earn rewards, represented by stars of various colors, namely white, bronze, silver, and gold, corresponding to the levels achieved. These rewards motivate participants to engage in activities with the goal of earning stars, including the highly coveted gold star. Similarly, the feedback boards (correct or incorrect) are crucial for participants with ASD to comprehend whether they are making progress or encountering challenges in their interactions with the activity. Finally, whenever a participant successfully completes a pairing, they receive a point. The activities were designed with four different pairing levels, using four flat geometric shapes as a foundation: the square, the rectangle, the triangle, and the circle. These levels are categorized into the following pairings: figure/figure, figure/nomenclature, figure/characteristic, and, lastly, figure/object. The last level introduces the concept of three-dimensionality, aligning with the goals of our theoretical framework [28] concerning perceptual apprehension.

V. Results and Discussions

As mentioned earlier, observation was employed as a data collection technique. According to [32], observation allows for a personal and close connection between the researcher and the phenomenon under investigation, which offers several advantages. This direct experience undeniably serves as the most effective means to confirm the presence of a specific phenomenon, with knowledge and personal experiences serving as aids in this process. Furthermore, as indicated by [32], when the observer accompanies the participants' daily experiences on-site, they can attempt to grasp the participants' worldview, including the significance they attribute to the reality that envelops them and their own actions. This approach is considered viable, particularly when the participants are students with ASD, as using alternative data collection methods, such as interviews, for instance, may not yield the expected responses from some individuals. To document the observations, video recording was employed during the interventions with students with ASD, in addition to the researcher's notes. In this context, observation unveiled the behaviors exhibited by the students during the interventions, along with their level of engagement and interaction with the proposed activities. This notion is supported by [32], who emphasize that observation enables data collection in situations where other forms of communication are unfeasible, such as with participants with ASD who face challenges in communication and social interaction. Participants who are not to be identified will be referred to by the initial letter 'P' followed by a number from 01 to 09. Through these observations derived from video recordings, the researcher's interactions with the participating students, and the interpretation of transcripts from the recordings, three subcategories emerged, intertwined with the initial categories: potential interactions (opportunities), strategies for geometric thinking (skills), and gamification using concrete materials (limitations).

A. Opportunities: Possible Interactions

This subcategory emerged due to the necessity of conveying how students with ASD interacted with both the researcher and the activity. Concerning the initial intervention involving P01, aside from the researcher (P) and the advisor (O), his Specialized Educational Assistance (AEE) teacher and his mother (M) were also present. P01 insisted on having his mother accompany him during the activities. However, it became evident that the presence of so many individuals, with only two being part of his daily life, triggered a crisis in P01, resulting in him crying throughout the entire intervention. However, it is noticeable that within a single interaction between one level and another, it becomes apparent that P01 was bothered by the simultaneous conversations of so many people. Interestingly, despite this behavior, P01 successfully completed half of the activities. Excessive stimuli, such as those encountered during this initial intervention, can overwhelm the sensory system, as [35] points out. Environments with many people talking, music, bright lights, or even itchy clothing can lead to sensory overload in children with ASD, resulting in disorganization and crying, as was the case with P01. In light of this, concerning the sensory crises experienced by P01, [35] asserts that these disruptions can evoke behaviors and emotions, thereby having a direct correlation with the characteristics of the disorder. They may lead to aggression, escape, stress, and anxiety. Given that the participants in this stage are students with ASD, it is inevitable to identify restricted and repetitive patterns of behavior associated with this disorder, such as motor or verbal stereotypes (echolalia), pronounced hyperfocus, challenges in recognizing and expressing emotions, and difficulty maintaining prolonged eye contact. With regard to verbal stereotypies, also known as echolalia, P01, P04, P06, and P07 exhibited this behavior, which, as stated by [35], can manifest as repetitive noises or sounds related to communication, the repetition of speech from drawings and movies, or the repetition of the same word multiple times. According to [35], stereotypies can manifest in situations where a person feels euphoric or frustrated and engages in repetitive movements to 'self-soothe.' Through the analysis of the videos, it becomes apparent that these participants frequently repeat what they hear others say in their vicinity. It is hypothesized that this behavior arises in response to the challenges presented by the activity, as they may not have anticipated the events of that particular day. Consequently, echolalia serves as a form of 'escape' from the sources of stress. Motor stereotypies are associated with repetitive limb movements or rocking motions of the body. Participants P01, P05, P06, and P07 exhibited this trait, which, as [35] notes, is also referred to as 'flapping.' This behavior is initiated and sustained by the sensory feedback it provides to the individual performing it, serving as a form of self-stimulation. As the participants experienced stressful situations due to the disruption of their daily school routines, it's worth noting that children with ASD, as mentioned by [35], prefer to adhere to established routines and resist changes in their schedules. Similar to echolalia,

motor stereotypies serve as a means for this population to attain emotional equilibrium when confronting challenges and prevent sensory crises. In this context, emotional skills also constitute a crucial aspect of interventions. According to [36], one of the primary challenges encountered by individuals with ASD pertains to their capacity to naturally recognize and express emotions displayed on a person's face. This aligns with the observation made by [35], who noted the difficulty these individuals face in comprehending non-verbal communication from others, including facial expressions, gestures, and eye, head, and hand movements. Participant P01 expressed sadness by crying throughout the intervention, while P04, P05, P06, and P07 were seen smiling, clapping their hands, and celebrating with sounds upon successfully completing the levels. However, P02, P03, and P09 remained neutral throughout the intervention. In contrast, P08, although shy and encountering difficulties in the activities, wore a protective mask to conceal her face but smiled with her eyes. However, when attempting to sustain prolonged eye contact, [35] suggests a potential lack of integration between verbal and non-verbal communication, including eye contact and body language. The participants, besides encountering challenges in recognizing the emotions conveyed by the researcher and the AEE teacher, generally did not maintain prolonged eye contact, which might have been mistaken for shyness, as observed in the case of P08. Hyperfocus, as defined by [37], is characterized by an intense level of concentration on a particular subject, topic, or task, and is commonly observed in individuals with ASD. During a conversation with the researcher, Participant P05 displayed an excessive interest in brands. Some important observations may not be directly transcribed from the recordings but are based on the researcher's notes. Participant P05 was constantly jotting down lists of brand names throughout the intervention. His teacher mentioned that he collects brochures and leaflets on various topics and brands, possesses knowledge of numerous addresses within the city, and exhibits a remarkable memory. Another noteworthy aspect to take into account, although it is not captured in the recordings, is P06's constant search for car magazines within the room where the interventions took place, indicative of his hyperfocus. In his notebook, there are self-drawn car illustrations, and his belongings are predominantly themed around cars. In consideration of the interests of children with ASD and reevaluating the subsequent stages of the research with their preferences in mind, [35] suggests that when instructing a child with a passion for cars, for instance, one can leverage this interest. Doing so can aid in sustaining their attention, making the activity more enjoyable, and potentially yielding positive learning outcomes. Therefore, it is of paramount importance that the upcoming gamified activities, to be implemented, incorporate elements of interest to the students from their daily life (ADL's). These elements can encourage participants to interact more and engage with the proposed activities.

B. Skills: Strategies For Geometric Thinking

This second subcategory emerged from the necessity to elucidate how the students resolved the activities and the strategies they employed to complete the pairings correctly, thereby revealing their geometric thinking. Initially, the analysis focuses on the participants' errors, not just the quantity but also the reasons behind these occurrences. At level 1, only P05 made an error while attempting the pairing, as he hesitantly stated that the triangle could be either a triangle or a rectangle. However, he promptly reconsidered his placement and corrected the mistake. In level 2, where students were required to match the figures with their corresponding names, P01 made three errors, while P05 made only one error. It is believed that P01's multiple errors may have been attributed to the sensory crisis he experienced during the intervention, which left him disoriented. This crisis was likely triggered by the disruption of his routine due to the presence of two additional individuals in the room who were not part of his daily life. At level 3, P01 made all the pairings incorrectly, while P02 and P03 each had two errors. They became confused between the square and the rectangle because both have four sides, but only the square possesses the characteristic of four equal sides. P04, on the other hand, made a mistake in matching the circle, incorrectly stating that this figure has four sides. Participant P07 missed three out of the four pairings at this same level, driven by his eagerness to complete the activity quickly and earn all the stars on the podium. In contrast, P08 made an error by comparing the length of the sentences rather than the figures. This not only highlights his challenge in expressing his geometric thinking but also his ongoing literacy difficulties. Finally, at level 4, where participants needed to match two-dimensional geometric figures with real three-dimensional objects, P01 made two errors: first, he was supposed to correctly match the golden cube with a square, but instead, he paired it with a circle; second, when matching the crazy spring with the circle, he placed it on a triangle. Initially, it was believed that this error could be attributed to the size of the spring, as it is small. However, even after changing the material, it became evident that P01 required additional assistance to correctly complete the pairing, which was provided by the AEE teacher, ultimately leading to the correct solution. Participant P04 made three mistakes: in the first, he confused the square with a rectangle; in the second, he was undecided whether to classify the rectangular pot of margarine as a triangle or a square; and in the third, he compared the perfume box to a square. However, in both incorrect pairings, P04 managed to correct his thinking quickly. However, P08 presented eight errors out of a total of 12 pairings. Since the participant was a new student at the school, there is no way to guarantee that before attending this current school, P08 had prior knowledge about geometric shapes. Therefore, it is believed that this lack of prior knowledge was the crucial factor for so many errors in their pairings. On the other hand, out of the nine participants, only two (P06 and P09) were the only ones who completed all the pairings of the gamified activity correctly. In addition to the

previous analyses, it is necessary to infer the strategies used by the participants to solve the gamified activities. The solutions can be summarized by elimination, counting the sides of the figures, or comparing the size of the figure and the object, as we will see next. In relation to resolution by elimination, this strategy is used by the same participant (P02) in two different levels (level 3 and level 4). When resolving level 3, in addition to the participant's choice to use elimination, he also compares the sizes of the sides of the square to confirm that this figure corresponds to the characteristic of having four equal sides. It highlights the importance of using the feedback board, as the student was able to recognize his mistake and articulate his new reasoning. The researcher also assists by using elimination to help the student identify which of the four pairings were already correct, allowing the participant to concentrate their attention on the ones that needed correction. In level 4, he employed the elimination strategy differently. He chose to leave the square for last, only using it after pairing all the other objects, ensuring its correct placement. At the level of pairing with characteristics (level 3), participants P02, P03, and P06 counted the sides of the figures. Participants P04 and P08 also utilized this strategy, with the researcher suggesting it as a helpful method, especially for students who are not yet fully literate. Participant P02, before adopting this strategy, inquired with the researcher about what constitutes the sides. After a demonstration involving counting the sides of a triangle, P02 employed this method to solve all pairings at this level. When P02 remarked that the circle has no sides and is 'only one,' it is assumed that he made an analogy to a single 'rotation' around the figure. This interpretation aligns with his previous counting strategy, which focused on well-defined sides, vertices, and edges in the other shapes, as he himself proposed throughout this level. P03, like many other participants, faced confusion while counting the sides of both the square and the rectangle. Both shapes have four sides, but only the square features sides of equal length. Although P03 initially mismatched both the square and rectangle, a brief explanation from the researcher helped him recognize the error, allowing him to rearrange the pairings accurately. Additionally, P06 employed this strategy to complete the activity. Initially, it is evident that P06 may not have considered this strategy, as nervousness and uncertainty led to silent rocking in the chair (motor stereotypy). When the researcher observed this posture, she encouraged the participant to count the number of sides of each figure together. P06 then adopted this strategy for the remainder of this level. Finally, the last strategy involves comparing the size of the two-dimensional figure with the three-dimensional object. Both P03 and P09 demonstrate this approach by attempting to fit the object inside the cardboard geometric shape. Participant P03 makes careful observations during this process, at times claiming that it doesn't fit because the object is larger than the geometric shape, while other times he places and removes it, denying that the pairing could be correct. P09, on the other hand, successfully completes the pairing; however, they continue to manipulate the square in an attempt to fit it inside the triangle. Both participants seem to be initially confused about the size of the figures relative to the objects. However, after receiving an explanation from the researcher, both are able to complete the pairings correctly, with a primary focus on matching the shape of the object. Therefore, this subcategory highlights the various ways of solving the pairings, either through strategies employed by the participants themselves or under the guidance of the researcher. It underscores the significance of engaging in activities that encompass geometric thinking, whether in two-dimensional or three-dimensional contexts.

C. Limitations: Gamification Using Concrete Material

This final subcategory has emerged due to the researcher's need to highlight certain limitations observed during the interventions involving concrete materials. These limitations should be taken into consideration when transitioning to the digital format of these activities. They include the researcher's lack of preparedness, the unpreparedness of the AEE teacher, resources that were not utilized in some interventions, misused resources, and participants with literacy challenges. Initially, we would like to emphasize the shortcomings of this stage, particularly regarding the researcher's preparation and, consequently, the lack of preparation on the part of the AEE teachers. During the initial interventions conducted at São Lourenço do Sul school, the researcher did not clarify to the AEE teacher how she would like her assistance in the interventions, resulting in improvised approaches during these sessions. In the second intervention, conducted at the school in Rio Grande, the researcher was better prepared. She brought the pre-gamified activities in advance to discuss with the AEE teacher, allowing them to allocate tasks collaboratively during the intervention with the participants. As a result, the teachers received support and clear guidance from the researcher regarding their roles during the intervention. The researcher took on the task of presenting essential questions, while the professionals assisted with managing the scoreboard and podium, which had been agreed upon in advance, particularly in the case of the second school. This highlights an aspect for reflection from the first intervention. As a result of this approach by the researcher, during the interventions with P01, P02, and P03, all the gamification elements proposed, including the scoreboard, feedback (error or correct boards), and rewards (podium), were utilized. However, as everything was managed solely by the researcher, it became confusing since there was no opportunity for the students to participate actively while the researcher handled the scoreboard, feedback boards, and stars on the podium. This highlights another important aspect to consider for the next stage of this study: having sufficient materials for everyone involved. In the interventions at the second school (P04 to P09), the responsibility for managing the scoreboard and podium rested with the AEE teacher. This arrangement allowed the researcher to engage in more in-depth discussions with the participants, facilitating increased interaction. However, the AEE teacher used the scoreboard intermittently, typically when transitioning between levels. She used a scoring system only up to four, matching the number

of levels, rather than up to 24, which represented the total points each participant could earn. Furthermore, it's worth noting that during the interventions at the second school (P04 to P09), the feedback boards were not utilized as intended. The researcher focused on the interventions and inquired about errors without making proper use of the boards. This aspect also merits consideration when planning the implementation in digital format. In the digital format, these feedback responses will be automated. When a participant makes a mistake or answers correctly, the activity itself will provide feedback, either confirming correct actions or warning about possible errors. Emoticons or facial expressions will be avoided in the feedback icons. Finally, it is important to emphasize the significance of considering the diversity of participants who may engage with the digital format in the future. During the interventions with physical materials, we encountered two participants (P04 and P08) who were not fully literate. This highlights the challenges faced by both the researcher in explaining the activities and the students in comprehending and successfully completing the pairings. A plausible justification for being attentive to the digital stage in this context, especially considering that participants may not be fully literate, can be found in the recommendations provided by [38]. They suggest, in the section on multimedia, that gamified activities should present information using various representations, including audio, to enhance comprehension of content and vocabulary. In the gamified activity with concrete materials, the only method for conveying the information contained in the activity elements to the participants was through the researcher's verbal explanations. The researcher explained the elements using simple language and associated the initial letters of the statements with the initial letters of other words that the participants were familiar with. Additionally, the researcher used numerical representations to correspond to the number of sides of the geometric figures. These strategies were employed to enhance understanding, particularly since two of the participants were not yet fully literate. In this context, it was observed that this is one of the weaknesses of the gamified activity using physical materials. In its digital format, it will be essential to provide information in audio format so that students can listen and understand the content whenever they find it necessary.

VI. Considerations

The first subcategory emerged from the need to describe how students with ASD interacted with both the researcher and the activity, focusing on restricted and repetitive patterns of behavior related to ASD, disruptions in routine, sensory crises, hyperfocus, and emotional skills. The second subcategory emerged from the need to illustrate how the students solved the activities, including the strategies they employed to complete the pairings correctly. These strategies encompass resolution through elimination, counting the number of sides, comparing the size of two-dimensional and three-dimensional figures, and establishing relationships between them. Finally, the third subcategory arises from limitations that were observed in the interventions involving concrete materials, and these should be taken into account when transitioning to the digital stage. These limitations include the lack of preparation on the part of both the researcher and the AEE teachers, participants' literacy issues, unused resources, and improper use of certain resources. From the analysis of these emerging subcategories, it can be seen that there are several points to be considered for the activity in its digital format, as new objectives outlined for this thesis. These include: Implementing gamified activities that incorporate elements of daily life (ADL'S); Understanding the strategies employed by the participants to solve the gamified activities; Addressing the weaknesses of the activity with physical materials, ensuring that resources are accessible through various formats in the digital version. Considering the aforementioned, it is essential to justify these objectives based on the analysis of interventions with AEE students and teachers. The first objective is to implement activities that incorporate elements from their daily lives. This allows participants to draw upon their existing knowledge of these elements, as we discovered through discussions with AEE teachers. By doing so, participants are more likely to engage actively in the proposed activities, taking into account their tendencies towards hyperfocus. The second objective is to comprehend the strategies employed by the participants in solving the gamified activities. This is done to facilitate a comparison with their subsequent strategies in the digital format. The aim is to observe whether, when digital activities are provided, the strategies remain consistent, if they exhibit more independent problem-solving abilities, or if they require additional support to complete them. The final objective is to address the weaknesses identified even with the use of physical materials, ensuring they are not repeated in the digital format. One such weakness was the researcher's challenge in explaining the activity to participants who are not yet fully literate. Therefore, in accordance with the recommendations of [38], the implementation of the digital format will incorporate elements that facilitate increased independent interaction of participants with the activity. This will be achieved through various digital resources identified as relevant for this specific audience by [38].

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