Effects of a Collaborative Gamification on Learning and Engagement of Children with Autism

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Effects of a Collaborative Gamification on Learning and Engagement of Children with Autism

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Abstract

Gamification, i.e., the use of game elements in non-game contexts, is an effective tool to help children learn using educational technologies. When properly utilized together with pedagogical approaches that foster students’ interactions with learning materials, gamification has consistently been shown to increase students’ participation, motivation, engagement, and learning gains. Nevertheless, when we consider children with autism, there is little evidence about the benefits of gamification for learning. In addition, to develop gamified educational technologies for this public, it is necessary to know a method of psychology, and few practitioners in this area have this knowledge. A collaborative design in which the collaborators come from different knowledge backgrounds, known as co-design, may deal with this issue. We conducted a single-subject design experiment to assess the effect of a gamified co-design. In this co-design, one practitioner in game design and two psychology experts in autism elaborated a prototype of an application, and DTT (Discrete Trial Training) approach was used to support the learning activities. DTT is a psychology method that demonstrated effectiveness in children with autism, and it
is based on the use of response to stimuli through repetition and reinforcement. Findings indicated that the developed prototype fosters correct answers, reduces undesired behaviors, follows ABA (Applied Behavior Analysis) skills, and presents positive behaviors. We concluded that co-design is a promising approach to be used in gamification in a context that requires expert knowledge, as ASD (Autism Spectrum Disorder).

Keywords: Co-design, Process, Gamification, DTT, Autism.

1 Introduction

Autism Spectrum Disorder (ASD), also known as autism, is a neurodevelopmental disorder that affects one in every sixty children born worldwide [1]. It can be divided into three levels: mild, moderate, and severe. Each has different degrees of difficulty in communication and social interaction, and the presence of restricted and repetitive patterns [2].

Autism affects the process of social and intellectual development, including the lack of skills such as verbal and non-verbal language, important for the literacy process [2, 3]. This occurs due to the brain processing information in a different way due to the existence of a deviation in its functioning [4].

To assist these individuals, psychology brings together targeted interventions methods to aid in the development of academic skills [5, 6]. Among these methods, the Discrete Trial Training (DTT) shows results that prove its effectiveness in acquiring new skills and improving learning, thus being a widely used intervention [7, 8]. DTT has five distinct stages, namely: (1) Cue: The therapist introduces the child to what will be done during the intervention; (2) Prompt: The therapist helps the child to answer the question correctly; (3) Response: The child answers the question (correctly or incorrectly); (4) Consequence: If the answer is correct, the child receives positive reinforcement (praise, gift, etc). If the answer is no, the therapist says the answer is incorrect or removes teaching materials from the intervention; (5) Intertrial interval: After the consequence, the therapist takes an interval before starting the next test [7]. However, it takes time to provide consistent results. Furthermore, it is costly to access, as intensive treatment is required until the pre-set goal is achieved [9, 10].

Given this problem, the growth in the use of technologies as a potential to minimize the deficits resulting from autism has been gaining space [11]. However, despite several initiatives in this direction, there is a lack of studies on Gamification, a recent research area defined by the use of game elements in non-game contexts [12]. These elements have a significant impact with respect to learning, cognitive development, and motivation [13]. Moreover, they play a significant role in the development of social and psychological skills, stimulating students’ interest in constant learning [14].
Gamification and DTT when applied separately have common outcomes, such as improved learning. The DTT is suitable for teaching new skills [7], while Gamification stands out for increasing engagement [12]. In this regard, the overall aim of this study is to assess the effects of a gamified co-design in the learning and engagement of children with autism in the literacy context. Two research questions were developed and will be answered at the end of this study. They are: **(RQ1) Do technology-supported Gamification and DTT increase the engagement of children with autism in the literacy context?** and **(RQ2) Do technology-supported Gamification and DTT improve learning for children with autism in the literacy context?**

Based on the exposed, the main contributions of this study were: (i) a process to direct the development of educational technologies for children with autism; (ii) a co-design that associates gamification and the DTT (psychology method) to assist the develop educational technologies for children with autism, and; (iii) five intellectual properties, being: one patent application (CC-PI-2021-0056) and four computer program registrations (CC-PC-2019-0016, CC-PC-2019-0027, CC-PC-2019-0028, CC-PC-2019-0029) that are in progress by the AUSPIN - USP Innovation Agency. Regarding the instruments developed, one can mention the (i) formative study scripts for psychologists developed with an HCI expert to guide the co-design process and the (ii) contents of the pre-test, post-test 1 and post-test 2 that were developed taking into consideration the criteria established by the Autism and Speech Therapy expert. Finally, a paper on systematic mapping was published in the *Interactive Learning Environments* [15].

## 2 Related Work

A systematic mapping was conducted to identify technological approaches used in the literacy process of children with autism [15]. This mapping searched studies from the area of Computer Science and the five keywords and synonyms were used in the search string: (1) autism, autistic; (2) teaching, learning; (3) literacy. In order to guide this mapping, the following research question was devised: “What are computational approaches to solving literacy-related challenges for children with autism?”.

The study by Cabielles-Hernández et al. (2017) [16] brings the application Chain of Words, responsible for acting in the functional area of communication for children with autism. An experiment was carried out with eleven children aged 3 to 7-years-old, in which analyzes have presented that claim that the skills related to the articulation of words and sentences through the application developed by them are improved. They improved their skills related to articulating words and sentences, in addition to being more motivated when using the Chain of Words. The authors do not explain the use of a Psychology method, but the developed application shows evidence that a method known as PECS was used. Two reinforcements are used, audio and video.
Mendonça (2016) [17] presents a platform on which caregivers create activities according to the individual characteristics of each child. An initial study was conducted with a male child who has autism and is 7-years-old. In this study, the author informs that she uses reinforcement, but he does not specify which reinforcement was used. It is shown that the participant selected the correct answer twice consecutively in the intervention and the post-test, the latter without the use of reinforcement. It is clear that when there is no reinforcement, the participant does not hit any question after four consecutive attempts. This study shows us that the presence of reinforcement is relevant and can indicate a positive point for learning, but Mendonça (2016) [17] does not use methods to design and validate the insertion of reinforcement in its approach, as presented in this paper through the gamification design. It can also be observed that this study does not use Psychology’s intervention method when developing its approach, unlike this paper that is supported by DTT.

Cole (2003) [18] feature an animated agent for vocabulary learning. In the study, it is highlighted that the students learned basic concepts, such as insect names, and also showed content retention. Regarding the learning of more abstract concepts, the authors emphasize that the presented approach is not indicated. The study in question is a pilot with the participation of six children with autism. There are no further details about the number of activities, the number of hits and misses. Unlike the present paper, in the study of Cole (2003) [18] Psychology intervention methods were not used in the developed approach. The author explains that five of the six participants used the tool independently, corroborating the literature regarding the advantages of the technology when applied to the target audience. Although Cole (2003) [18] use avatars to represent the animated agent and taking into account that an avatar can be used as a game element, the authors explore the scope of Human-Interaction Computer and not Gamification.

Winoto (2016) [19] and Belmonte et al. (2016) [20] presents a pilot study. In the first, an approach based on a game that uses virtual reality was developed, in which a room is simulated in 3D. This room contains some objects common to people in general. The child wears virtual reality glasses and, when he moves his head and looks at an object for a time of 5 seconds, the system pronounces the name of that object in English or Chinese. The second study was based on encouraging the student to enhance their abilities to point-drag objects and pronounce words through the Point OutWords application. It is designed for use with children with autism who are assisted by their therapists, parents and/or caregivers. The aim of this approach was to boost the development of manual motor learning skills, in addition to oral motor skills used to improve communication. As a result, the application’s lights and colors would grab the student’s attention. For both studies, only the observation performed is insufficient to infer, requiring in-depth monitoring and analysis by experts in the field.

In the last study, Rahman et al. (2011) [14] brings an approach based on the AClass software desktop. It was noted that after the intervention, participants
were more interested in the classes. This is an indication of a positive impact on the engagement of these students, but it is necessary to use instruments to measure this increase or the analysis of experts in the area. In addition, the authors bring the concept of games as a suggestion for future work, which is addressed in this paper.

All related works found in the literature target children with autism. Despite using reinforcement as a positive stimulus for students to continue learning, they do not employ a method as in this paper, which used DTT. Furthermore, despite being a good strategy, all reinforcements do not take into account the motivational aspect and engagement of the participants, unlike this paper that uses gamification through a co-design to take into account these aspects that were not found in the works mentioned above.

It was possible to identify two main gaps: (i) lack of a process to direct the development of educational technologies for children with autism and; (ii) lack of a gamified co-design that associates the psychology method to assist the development of educational technologies for children with autism.

3 Methodology

The creation of the process to guide the development of educational technologies was conducted from (i) an Co-design with Experts and the (ii) Design of Gamification. To instantiate it, four prototypes were developed.

3.1 Co-design with Experts

3.1.1 Planning

To develop a process aligned with the needs of the target audience, a co-design with experts area was carried out [21, 22]. Co-design encompasses three important points: (i) it is oriented to a specific context that needs attention; (ii) involves collaboration between the participants; and (iii) has an iterative approach [23]. People directly involved with the problem to be solved are inserted in this process, to contribute with solutions according to their points of view. These people are inserted in all phases of the process, not only after it is finished [24].

To initiate the co-design, an initial version was designed with support from an ASD expert. Pets were chosen as a thematic of the version, as it is common content in children’s early learning stage (Figure 1a). The game components used in this early version were points, represented by stars, and badges, represented by medals. For each hit, the participant would receive a star (Figure 1b). When adding up three or more hits, a medal was presented (Figure 1c).

Four sessions were held, each lasting an average of 45 minutes. The two ASD experts from the University of Lisbon (Portugal). All sessions were recorded in audio format with the experts’ permission. With the support of the HCI expert, Training Study Guides were prepared for the Psychologists to guide
3.1.2 Execution

In the first session, the initial version designed in University of Lisbon (Portugal) was presented without the use of computer technology. A4 size sheets were used to exemplify the structure of a tablet and color images of printed game objects and components to simulate the interactions.

The improvements suggested in the first, second, and third sessions of co-design were still carried out without the use of technology. For the fourth session, when the ideas discussed were becoming more stable, a prototype version was implemented and presented. The tool used to implement the prototype was Axure RP 8\textsuperscript{1}.

After the fourth session, some changes were still made. Due to the lack of availability of experts, it was not possible to schedule more in-person sessions. However, the last contacts took place via email, such as sending the final implemented version (Figure 3).

\textsuperscript{1}https://www.axure.com/
3.1.3 Co-design' Results

According to the interactions held in the co-design sessions, seven criteria were identified to guide the development of educational technologies:

(i) **Age group:** In the presentation of the initial version, the age group was defined between 03 to 14-years-old. The interval was purposely large, as the objective was to gather a greater number of individuals in carrying out the experiment (presented in the Section 4), given the restricted characteristics of the target audience for which this work is directed. However, as exemplified by one of the experts, a 14-year-old teenager who has autism and is not yet literate is likely to have some other associated neurodevelopmental disorder. Therefore, this would not be a potential individual to participate in the study in question, due to the fact that they have another disorder in addition to autism.

The age range for this project has been reset to 5 to 7-years-old. This choice was based on being the age that comprises the moment at which the participants are acquiring prerequisites for literacy.

Note: After conducting the pilot study, it was verified in practice that the participants aged 5 and 6-years-old did not have developed readiness skills, which made it difficult to understand what was being explained. Thus, together with experts, the age group was changed again to 7 to 12-years-old of age.

(ii) **Level of autism:** Initially, the application was aimed at children with mild autism. In an informal interview with experts, it was explained that children with this degree of autism generally do not have difficulties in reading and writing. Transcribing what was said during the second session of co-design:

“Choosing the milder degree of autism, normally these kids don’t have difficulty learning to read and write. And so let’s imagine this is a tool that’s going to be used in therapy, they’re probably in therapy, but not for that reason. But if it’s in more severe cases of autism, then yes, it starts to work on these issues of association of the word with the image, the first sounds.”

“In this case, level 2 (moderate) would be required here to test this question”.

Following the observations made and meeting the experience of professionals in the field, the level of autism was reset to moderate level.

(iii) **Rewards:**
a) Unappealing rewards: Stars (short cycles of gamification design), medals (long cycles of gamification design) and praise in audio format were used to act as rewards. One of the observations is that these game components (stars and medals) are unappealing. According to one of the experts:

“Autism is very visual. So, the more auditory or visual stimuli, both at the same time, the more chances we have of achieving better attention from the child, right!? But, there has to be, above all, a very appealing visual part, I would say. That in the sense of reaching as many kids as possible”.

It would be necessary to choose rewards that are more dynamic and that strongly play the role of engaging and motivating the child with autism to persist in the task, until the end. Examples such as GIF (Graphics Interchange Format), games, cartoons, were some of the reward suggestions given by experts.

In this step, the game components were redefined to GIFs. The choice was based on the fact that it is not necessary to direct the child outside the application (e.g. watching a cartoon). Considering this choice, it is possible to measure more precisely the time that the child will remain in the application and control the variables to be investigated.

Due to the limitation of free GIFs in terms of attractiveness and different movements from the conventional one, designer Henrique Barone\(^2\) gave his GIFs to be used in this research.

With regard to compliments, experts advised to choose compliments by categorization, such as: “You got it right! Congratulations! Very good!” These choices were made by experts.

b) Personalization of rewards: Many individuals with autism have specific interests. Thus, the rewards used in psychological interventions tend to be personalized. A collection of interests is carried out so that the reward is reinforcing and promotes the participant’s motivation and engagement, and consequently, learning.

When developing a technological application for this audience, it would be ideal to carry out a collection of interests. Since this is an early-stage study, two avatars represented by GIFs were made available, so that participants could choose the one they prefer at the beginning of the application (Figure 4).

Even giving the customization of rewards, the experts gave some warnings:

“I was thinking about the autism spectrum and with kids so small, I don’t know if the answer is not forthcoming: I don’t like any of them. Well, what now, no!?”.  

“...now, it might be some [kid] who doesn’t react to anything at all”.

As highlighted, this can happen even if a larger number of avatars are made available to customize the reward at the start of the application. Due to the complexity of this issue and because it is not included in our research scope,

\(^2\)https://henriquebarone.com/
we suggest, in terms of future work, an in-depth study on the personalization of rewards in the context of gamification aimed at the target audience.

c) **Relation of rewards with correct answers:** When explaining how the approach works, experts warned about the distribution of game components according to the participants’ correct answers.

Regarding the medals in the initial version presented, when the participant hit three or more tasks (maximum of five hits), they won a medal. According to the expert’s observation:

“What would be the motivation to get four or five tasks right, since with just three right answers he already gets the reward?”.

According to this observation, there was a change in this item. In order for the participant to win the long cycle game component (which was changed from badges, represented by medal, to avatars, represented by GIF), they would have to get all five tasks right. If they got at least one wrong, it was necessary to repeat the five questions again, until they got them right.

Another point discussed was about showing the resolution of the task when the participant chose the wrong option. In the simulation of execution of the approach, when the participant made a mistake, they were directed to the next task. As the approach was developed using the concepts of DTT, reinforcements cannot be punitive [7]. In this way, the participant could be guided as to what the correct answer would be.

It was decided to direct the participant to a resolution screen, in which the correct answer is highlighted and soon after another question is presented.

(iv) **Teaching context:** The tasks chosen for the approach in its initial version were presented, related to the context of teaching literacy. The tasks were divided into three levels:

1) **Identity tasks:** Participants were asked to select identical geometric shapes for training and familiarization with the application to be developed. This level was used as training.
2) **Associate an image with words:** A reference image and three words were presented. The participant was asked to choose the word that described the image being presented.

3) **Associate a word with images:** A reference word and three images were presented. The participant was asked to choose the image associated with the word.

After presenting the teaching context and task levels, the experts asked:

> “Let’s assume that the child already knows how to read. So what is the advantage of this exercise?”

Regarding the association of word-image/image-word, the expert continued:

> “But why? If you already know... I wonder if we are already assuming that the child can read, this application, I don’t know if it’s useful or I don’t know if it’s interesting for the child”.

As the prototype was being aimed at participants who were in the literacy process, probably if they got the task right, it would be through trial and error and not because they understood it.

Literacy is very broad and complex. Its process depends on the development of several skills, such as reading and writing acquisition. After researching the literature and with the guidance of experts, it was possible to verify that the phonic method brings satisfactory results when used in children with autism in the acquisition of prerequisites for the literacy process. To develop phonological awareness is to develop skills so that the participant is able, for example, to associate and recognize letters and sounds [25, 26].

Complementing with an explanation from one of the experts:

> “When [the participant] is directed to reading and writing, there is a lot of grapheme-phoneme association. Therefore, letter-sound, we started working there. We started working on the first sound of each word, what I was that is, to associate images that start with the same sound or with the first syllable”.

In order to continue conducting research for the context of literacy, as recommended by the teachers at Exceptional Parents Association (APAE), Phonological Awareness was chosen as a way to develop the prerequisites for literacy.

**(v) Structure of the approach:** To elaborate an approach with increasing complexity, the three levels presented in the initial version were maintained. The difference between each level is in the way the sound is articulated [27].

As explained by the experts:

> “We draw your attention to the fact that these exercises obey levels of complexity/difficulty for children if they choose to do it this way. For example, in the case of identifying words with the same initial sound, it is important to start with more sounding sounds (such as vowels or consonants “s”, “ch” among others) and then less
sounding (such as the case of stop consonants - for example “p” or “q”).

Each level has five questions and their divisions are explained below:
1) Associate images that start with the same vowel;
2) Associate images that start with the same ringing consonant (e.g. M, N, R);
3) Associate images that start with the same non-sounding consonant (e.g. V, S, B, T, P).

(vi) Content for testing and application: When searching for instruments for phonological awareness training, the need to make some more adjustments was verified. The existing batteries of tests for phonological awareness [28] work all the points for the development of this skill, thus becoming a complete instrument to be worked on for a longer period.

For this paper, it is very ambitious to aim to cover every point of phonological awareness. Like literacy, developing phonological awareness is not trivial.

According to the expert:

“In my opinion, the ideal would be to use words with consonant-vowel structure, short (di or trisyllabic) and not use target words with the same initial syllable, since it works as a help”.

Thus, words were collected from articles, dissertations, and theses aimed at the development of phonological awareness [29–32]. During the elaboration of the instrument, the words were sent via email to the Speech Therapy expert, a participant in the co-design. This process was carried out until the words were within the criteria defined by the expert.

The words are distinct and were used in the tests (pre-test, post-test 1, and post-test 2).

(vii) Additional information (color of images, audio instructions, duration and number of sessions):

a) Color of images: Regarding the images, we chose color images and that had the same size or approximate. The experts were asked whether it would not be more appropriate to use black and white images so as not to influence the participant in choosing the answer. According to them:

“If I had an experiment to do from the point of view of cognitive psychology, selective attention, perceptive, whatever, I would put the stimuli in black and white, ok!? Why? so as not to precisely influence the target’s stimulus choice, ditrator, by color, etc, so I would do something like that. But I want to believe that this is not the question here and therefore, I can make it more motivating”.

“Even, because, in an attempt to take this issue of preference, right, the most appealing color, because it’s an animal and he likes animals more. Afterwards, with training, he starts realizing that he doesn’t have the positive reinforcement then, you will learn that you have to focus your attention on the sound and not on the preferences it has”.

b) Audio instructions:

c) Duration and number of sessions:
All images collected are copyright free.

b) **Audio instructions:** When asking the experts how best to explain the tasks, they said it was to provide instructions in audio format. Some examples are: “Select the image that starts with the same sound as [word]”.

As the application will work a small skill of phonological awareness that can help in the development of literacy, instructions in audio format were recorded.

c) **Duration and number of sessions:** Experts advised not to hold very long sessions, so as not to cause lack of interest on the part of the participants. Given the numerous existing technology applications, whether games or serious games, there is no standard in terms of duration for sessions.

It was decided that the ideal time to apply the approach, operated by the prototype, would be on average 10 minutes.

As well as the duration of sessions, there is a shortage in relation to the ideal number of sessions to carry out. This is due to the same problem mentioned above. The applications are diverse, making this standardization difficult. Given this situation, it is also important to emphasize that even with partnerships with institutions, there are many setbacks to be considered. Due to the availability of experts from [anonymized] to monitor all stages of the experiment, three sessions were held, divided between Monday, Wednesday and Friday.

### 3.2 Gamification Design

To develop an approach using Gamification, a design is required. The gamification design (or gamification strategy) is an artifact in the design phase that consists of planning and interaction of game elements with each other or with educational activities [33, 34]. It is an essential step in order to avoid harmful effects on participant learning [35].

According to the result of [36]’s systematic review, frameworks targeting special education are scarce. For this reason, the framework 6D [37] was chosen, due to it being the most widely used.

The gamification design for this paper is available at https://bit.ly/3ohSxvT. The validation was carried out by five gamification experts, one being a post-doctoral researcher, one PhD, and three PhD students, all from the area of Computer Science. To do this, a document was prepared to simplify the understanding of the use of game elements. This document was sent via e-mail along with the link of the prototype and explanations about the context of this research. The experts sent their observations via email, which were analyzed and compared with the results of the sessions with autism experts. The changes that were in agreement with the experts from both fields were executed.

Some observations were made, such as the need for participants to get all the tasks right before advancing to the next level. As explained by one of the gamification experts, this could discourage participants, depending on the difficulty of each one to answer the questions. This requirement was set by the autism experts during the design process and for this reason it was not changed.
However, in the execution of the experiment, it was not possible to apply all three levels of the prototypes due to the time spent by the participants, as pointed out by the gamification experts. Thus, for the replication of this work, it is necessary to adjust this question.

The relationship between the project objective B1) *Stay focused on activities* and the target behavior B1) *Improve the time the participant stays on activities* was pointed out as inadequate by one of the experts, because a longer time on the activity does not mean that he is really focused. Thus, the goal was changed to *Keep Attentive in Activities*.

One other observation was pointed out, this time to the goal B2) *Ask questions regarding the activities* and related target behavior B2) *Identify participants’ interactions with psychologists regarding the activities being performed*. According to the expert:

“The B2 relationship seems to me to be more extended in the behavior than in the target, since in the behavior it talks about interaction and in the target it talks about Questions. It is interesting to standardize, leaving the objective B2=”Perform interactions regarding the activities” or something like that”.

Thus, the expert’s suggestion was followed.

Regarding the loops of activities:

“About the short cycle loops, we basically have two: Progress bar and GIF. Well, the progress bar seems adequate to me because it indicates the participant’s progress in the activity. Maybe showing the percentage of progress on the bar would be interesting”.

As the participants are in the literacy process, they cannot interpret these numbers. Thus, the progress bar was kept.

About the progress bar, it was explained:

“The progress bar image is very hidden at the top of the screen. I think that if it was not on the edges, it would be more visible and readable for the user. Another thing I noticed is that the sequence of questions ends even with the bar incomplete, that is, the bar represents the hits and not the progress. As the number of questions is fixed, it is interesting to leave the bar advancing with each answer, to signify progress. Maybe put a green color on hits and another color on misses, I don’t know”.

We chose to round the corners of the progress bar to make it easier to see.

Regarding the color, according to the target audience, it could happen that two colors are inserted in the progress bar and the participant would identify himself with the color that represented the task answered incorrectly. In this case, it could generate a problem in the analysis of the results, because it would not know if the participant made a mistake in the task or made the choice just because he liked the color that would appear in the progress bar.

Regarding the GIFs, the experts explained:
“The GIF at the end to congratulate also looks cool. I just don’t know if presenting 2, 3 GIFs is interesting. Maybe presenting modifications of the same GIF would be better”.

As explained to the expert:

“For an activity to be considered reinforcing for children with autism, it is important that they choose what is rewarding for them. Despite being on the same spectrum, each child has their own particularities. Therefore, at the beginning of the prototype two different GIFs are made available for the participant to choose their preferred one. Unlike the free ones, the paid GIFs are much more attractive and dynamic. So a designer has released the GIFs he makes, free of charge. The problem is that there is only one template of each, and it is not possible to submit the requested modifications. If different GIFs are inserted than the one the participant chose, it can have a negative effect”.

Anyway, since only the first level of the prototype was applied, it was not possible to evaluate if the number of GIFs influences the participant’s engagement and learning.

About the padlock, present in the long cycle loops, it was observed that asking the child to click on the padlock is not a mission. A mission would be, for example, to ask him/her to complete a set of questions without making mistakes, or to spend x amount of time answering questions.

Regarding the levels, it was noted that the levels are nice, but it is not clear how the participant goes from one level to another.

“What are the requirements to pass the level? Usually points are used, but in your context I believe points is not ideal”.

In response to the experts, the relationship between the representations unlock content and level was explained. For the participant to unlock a mission, he needs to click on the lock. After that, he needs to answer all the questions correctly to fulfill the mission and progress to the next level of tasks. The expert agreed and asked only that an instruction be inserted in order to guide the participant. Together with the ASD experts, during the co-design, the following instructions in audio form were defined:

1. Start of the application: “Shall we begin? We will have three levels. Click on the lock to go to the first level”.
2. All tasks answered correctly: “You got all the questions right! Click on the padlock to go to the next level”.
3. From zero to four correct answers in the tasks: “You got X questions right. Let’s try again!”.

Balloons, also used in the long cycles, are seen as interesting. The experts suggested adding medals, in the form “Got 2 wins bronze medal, got 4 wins silver, and got them all wins gold”. However, medals were included in the initial version and deleted after the co-design. Autism experts stressed that children
have no idea that a gold medal is better than a silver one, for example. In the same way that ten points (in numbers) is better than two points.

The last observation made was in relation to the screen that shows the participant the resolution of the incorrectly answered task. The expert thought it would be interesting to insert a motivating message at this point. However, along with gamification, the psychological intervention strategy known as DTT is being used. In this strategy, the participant receives positive reinforcement only when he or she gets the task right. When they get it wrong, they receive no punishment, but no reinforcement either. They are only shown what the correct response is.

Figure 5 illustrates the process to guide the development of educational technologies for children with autism, drawn from a co-design with experts and the gamification design.

![Fig. 5 Process to Guide the Development of Educational Technologies for Children with Autism.](image)

3.3 Prototype Development

The Axure RP 8 tool was used to develop the prototypes. An API, using the PHP programming language, was developed in order to capture information such as number of clicks, number of task hits and time spent on the activity. This information was recorded in the MySQL database.

The training prototype without gamification and training prototype with gamification have only one level with five tasks and the content about geometric shapes. The difference between the two prototypes is that only the second one has game elements. The intention was for the participants to become familiar with the technology and the format of the tasks that would be presented later in the intervention prototypes.

As the goal of this research is to assess the effects of a gamification co-design in the literacy context, the intervention prototype without gamification
Table 1 Links of Prototypes.

<table>
<thead>
<tr>
<th>TITLE</th>
<th>LINK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training Prototype without Gamification</td>
<td><a href="https://laizaribeiro.github.io/treino-dtt/">https://laizaribeiro.github.io/treino-dtt/</a></td>
</tr>
<tr>
<td>Training Prototype with Gamification</td>
<td><a href="https://laizaribeiro.github.io/treino-gamificado/">https://laizaribeiro.github.io/treino-gamificado/</a></td>
</tr>
<tr>
<td>Intervention Prototype without Gamification</td>
<td><a href="https://laizaribeiro.github.io/dtt/">https://laizaribeiro.github.io/dtt/</a></td>
</tr>
<tr>
<td>Intervention Prototype with Gamification</td>
<td><a href="https://laizaribeiro.github.io/gamificado/">https://laizaribeiro.github.io/gamificado/</a></td>
</tr>
</tbody>
</table>

is implemented with only DTT, without game elements. In this prototype, only rewards in audio form are used, categorized by praise.

The gamified intervention prototype was developed using game elements and praise as rewards. It was also implemented based on DTT, this time coupled with gamification.

Both intervention prototypes have three levels, each with five tasks, as presented in item 5 of Section 3.1.3. For this work, only the first level (association of images in which their sounds begin with the same vowel) was applied, due to the time spent by the participants during the experiment. The prototypes can be accessed through the addresses available in Table 1.

4 Assessment

In this section the evaluation of this research is presented, as well as all the planning elaborated for the execution of the experiment. The purpose of this assessment is to verify if there has been an improvement in learning and increased engagement of the target audience.

An analysis from a qualitative point of view is carried out individually. Due to the limited number of participants, justified by the difficulty in finding children who meet the selection criteria, statistical analyzes were not performed. This study was approved by the Ethics Committee in June/2018.

4.1 Experimental Design

According to Behavioral Science, Single-Subject Designs (Single-Subject Design) are supported by various behavioral researchers, such as [38–41]. It stands out for the way it perceives the results obtained, analyzing the particularities arising from each human being. This type of design is used in contexts related to reinforcement and behavioral modification, and can also be applied to other areas of research [42].

Among the various existing Single Subject Designs (A-B, ABAB or reversal, multiple baseline, among others), the Repeated Measures Design, also known as Intra-Group, was chosen to be used in this research.

Two experts who work directly with the target audience at [anonymized] participated in this study, helping throughout the process. The first is Graduated in Psychology, ABA expert and has 5 years of experience. The second
Table 2 Description of Participants.

<table>
<thead>
<tr>
<th>ID</th>
<th>AGE</th>
<th>GENDER</th>
<th>TIME ATTENDING APAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>9y</td>
<td>Male</td>
<td>1y7m</td>
</tr>
<tr>
<td>P2</td>
<td>11y</td>
<td>Female</td>
<td>6y8m</td>
</tr>
<tr>
<td>P3</td>
<td>7y</td>
<td>Female</td>
<td>4y1m</td>
</tr>
<tr>
<td>P4</td>
<td>12y</td>
<td>Male</td>
<td>9y5m</td>
</tr>
</tbody>
</table>

has a degree in Pedagogy, Special Education, ABA, Neuropsychology, and Autism’s experts and has 6 years of experience.

Participants are children with moderate level of autism, aged 7 to 12-years-old, in the literacy process, who attend APAE and regular school every day, have the ability to follow simple instructions and lack of behaviors that cause harm physicists.

The experts indicated a total of six children who met the criteria mentioned above. In September/2019, the consent form was sent to those who were legally responsible for the children. Four responsible allowed and two did not respond to the request sent. The Table 2 presents the descriptions of the participants.

The participants were divided into two different orders, both with the same steps. In order 1, the participant took a pretest to check learning before starting the experiment, followed by a training prototype. Then, they performed the activities of the intervention prototype with gamification and then took post-test 1. Next, they took the activities of the intervention prototype without gamification and post-test 2. For order 2, we changed only the sequence of application of the prototypes (Figure 6). The training content and prototypes were discussed in Section 3.3.

5 Results

In this section, the individual results of each participant are presented, in addition to the results related to the learning and engagement of all participants.
together. The intention was to verify if there was an improvement in learning and an increase in the engagement of the participants.

To measure learning, data from the pretest, post-test 1 and post-test 2 were used. Engagement, in turn, was related to the satisfactory behaviors of the participants. To verify, it was based on (i) analyses by psychology experts, using the ABA Guide [43] and (ii) average clicks and dwell time on the prototypes.

### 5.1 Participant P1

Participant P1 is a 9-years-old male and had been followed up at APAE for 1 year and 7 months. He agreed to carry out the activities.

#### 5.1.1 Pretest, Post-test 1, and Post-test 2

Before starting the pretest, the expert talked to the participant, guiding him to sit in the chair and explained that he would later “play” with the tablet. The participant sat in the chair, but kept his head down. The expert explained that this behavior was to attract attention and suggested that the test be started with participant P2. The student sat down and answered the two pretest questions with his head down, not looking at the support cards with the printed words. The expert interrupted saying: “P1, remember our arrangement?”. At that moment, the participant raised his head, answered the questions and repeated the words that the researcher pronounced, showing attention and understanding. When finished, the researcher invited the student to “play” on the tablet (training prototype) and he accepted.

In post-test 2, he appeared a little dispersed due to knocking on the living room window. The participant said “They’re knocking on the window”, and then the researcher invited him to continue the activities. Despite this, he also showed understanding in the answers given.

Table 3 shows the test results. The average number of correct answers for the sets of words beginning with vowels was calculated by the total number of these sets.
Table 4  Skills Worked in the ABA Guide - Participant P1.

<table>
<thead>
<tr>
<th>SKILLS WORKED IN THE ABA GUIDE</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Track objects visually</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shared attention</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Visual contact</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Imitation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow instructions</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td>Asked to drink water</td>
<td>Sound imitation</td>
</tr>
</tbody>
</table>

5.1.2 Intervention Prototype

In the prototype with gamification, P1 presented all the skills observed according to the ABA Guide. He identified the sound with the image, talked to the researcher asking them if the avatar doll was blue in color and asked to drink water. It was necessary for the researcher to point to the image and repeat their names. When performing this action, the participant repeated the sound. P1 did not show negative interactions, repetitive behaviors or avoidance during this application.

In the intervention prototype without gamification, no observations were recorded regarding identification and following instructions, pertaining to ABA skills. This can be explained by the negative interaction presented at the beginning of the application followed by evasion. Upon entering the room, P1 refused to sit in the chair and went towards the door. The expert spoke with P1 and he agreed to participate in the first application of the prototype. In the second application, he showed a repetitive behavior represented by shaking the chair in which he was sitting. In the last application, there was no more resistance. The participant performed the activities, presented sound imitation and smiled. Table 4 presents the data referring to ABA skills, identified by the experts.

Regarding an overview of the data collected in the application of the prototypes, the average of correct answers and time are the same, with only the number of clicks being smaller for the prototype without gamification, as shown in Table 5. Although it is not possible to verify significant differences from a general data point of view, the same is not true when performing a specific analysis. In the prototype with gamification, there is an increase in the number of hits from the first to the last application, which does not happen with the prototype without gamification. In the third application, although the number of clicks is almost identical to the prototype without gamification, in the prototype with gamification, a greater time and number of hits is observed.

5.2 Participant P2

Participant P2 is a 11-years-old female and attending APAE for 6 years and 8 months.
5.2.1 Pretest, Post-test 1, and Post-test 2

In the pretest, the participant repeated the words that the researcher pronounced, but had difficulty understanding the explanation. During post-test 1, there was an understanding of the activity. Eventually, the researcher asked: “Sword starts with? Apron starts with?”, and the participant answered correctly. In post-test 2, P2 answered “Yes” to all questions, not understanding what was being asked. The participant was impatient with the paper test and showed it by looking around and at the floor as she answered the question. In the end, she helped the researcher to organize the paper cards used to support post-test 2. The data are presented in Table 6.

5.2.2 Intervention Prototypes

Similar to the the results of P1, participant P2 presented all the skills worked on in the ABA while performing the activities of the prototype with gamification, with imitation being observed only in the last application. As positive interactions, P2 showed interest when performing the activities in the first application. The participant also noticed that the color of the researcher’s enamel was the same color as the nail image shown in the second activity of the prototype. Regarding negative interactions, in the third application, she showed avoidance, asking to drink water and go to the bathroom, and she had already gone before starting the application. There was no evasion of the activity.

Table 5 Prototypes Data - Participant P1.

<table>
<thead>
<tr>
<th>Application</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click</td>
<td>Hit</td>
</tr>
<tr>
<td>1st</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>2nd</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>3rd</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Average</td>
<td>13,4</td>
<td>1,4</td>
</tr>
</tbody>
</table>

Table 6 Pretest, Post-test 1, and Post-test 2 Data - Participant P2.

<table>
<thead>
<tr>
<th>Set of Words</th>
<th>Hits</th>
<th>Set of Words</th>
<th>Hits</th>
<th>Set of Words</th>
<th>Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avô - Oca</td>
<td>0</td>
<td>Avelã - Abajur</td>
<td>1</td>
<td>Melão - Milho</td>
<td>1</td>
</tr>
<tr>
<td>Bebê - Bota</td>
<td>0</td>
<td>Espada - Avental</td>
<td>0</td>
<td>Casaco - Dominó</td>
<td>0</td>
</tr>
<tr>
<td>Dado - Pena</td>
<td>0</td>
<td>Amigo - Abelha</td>
<td>1</td>
<td>Relógio - Raquete</td>
<td>1</td>
</tr>
<tr>
<td>Solar - Saco</td>
<td>1</td>
<td>Amora - Iguana</td>
<td>0</td>
<td>Camelo - Pogueira</td>
<td>0</td>
</tr>
<tr>
<td>Telhado - Tapete</td>
<td>1</td>
<td>Arroz - Íman</td>
<td>0</td>
<td>Morango - Minhoça</td>
<td>1</td>
</tr>
<tr>
<td>Copo - Doce</td>
<td>0</td>
<td>Escada - Urubu</td>
<td>0</td>
<td>Nave - Ninho</td>
<td>1</td>
</tr>
<tr>
<td>Fumaça - Camisa</td>
<td>0</td>
<td>Fita - Mola</td>
<td>0</td>
<td>Anel - Alho</td>
<td>1</td>
</tr>
<tr>
<td>Pijama - Palhaço</td>
<td>1</td>
<td>Rolo - Rede</td>
<td>1</td>
<td>Eu - Atum</td>
<td>0</td>
</tr>
<tr>
<td>Ombro - Onda</td>
<td>1</td>
<td>Colher - Lupa</td>
<td>0</td>
<td>Urso - Um</td>
<td>1</td>
</tr>
<tr>
<td>Gelado - Fivela</td>
<td>0</td>
<td>Mapa - Casa</td>
<td>0</td>
<td>Vaso - Vila</td>
<td>1</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>0,50</td>
<td>AVERAGE</td>
<td>0,34</td>
<td>AVERAGE</td>
<td>0,67</td>
</tr>
</tbody>
</table>
In the prototype without gamification, behaviors referring to imitation were not identified. The participant was more dispersed and clicked on several items of the prototype (answer options, help items, etc.) without discriminating the correct answer. P2 clicked on the three answer options in order, before the prototype emits the sound for each one of them. In the third application, she lost interest, got up, moved the printer, hugged and kissed the researcher, returning to the activity. When the participant selected an answer, she clapped her hands whether the answer was correct or not. There was no understanding of the activities performed. The observations regarding ABA skills are presented in Table 7.

Regarding the data collected in the prototype without gamification, the average number of correct answers was higher. Regarding interaction (clicks and dwell time), the prototype with gamification stands out, according to the data presented in Table 8. In this same prototype, P2 started by hitting two tasks, followed by zero hits in the second and one hit in the last application. Even though in the prototype without gamification the participant reached a higher average of correct answers, in the first and second applications this number was constant and in the last one it was equal to zero.

5.3 Participant P3

Participant P3 is also a with 7-years-old female and attending the APAE for 4 years and 1 month.
Table 9 Pretest, Post-test 1, and Post-test 2 Data - Participant P3.

<table>
<thead>
<tr>
<th>PRETEST</th>
<th>POST-TEST 1</th>
<th>POST-TEST 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set of Words</td>
<td>Hits</td>
<td>Set of Words</td>
</tr>
<tr>
<td>Avô - Oca</td>
<td>0</td>
<td>Avelã - Abajur</td>
</tr>
<tr>
<td>Bebê - Bota</td>
<td>1</td>
<td>Espada - Avental</td>
</tr>
<tr>
<td>Dado - Pena</td>
<td>0</td>
<td>Amigo - Abelia</td>
</tr>
<tr>
<td>Solar - Sacu</td>
<td>0</td>
<td>Amora - Iguana</td>
</tr>
<tr>
<td>Telhado - Tapete</td>
<td>0</td>
<td>Arroz - Íman</td>
</tr>
<tr>
<td>Copo - Doce</td>
<td>0</td>
<td>Escada - Urubu</td>
</tr>
<tr>
<td>Fumaça - Camisa</td>
<td>1</td>
<td>Fita - Mola</td>
</tr>
<tr>
<td>Pijama - Palhaço</td>
<td>0</td>
<td>Rolo - Rede</td>
</tr>
<tr>
<td>Ombro - Onda</td>
<td>1</td>
<td>Colher - Lupa</td>
</tr>
<tr>
<td>Gelado - Fivela</td>
<td>1</td>
<td>Mapa - Casa</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>0,50</td>
<td>AVERAGE</td>
</tr>
</tbody>
</table>

5.3.1 Pretest, Post-test 1, and Post-test 2

During the pretest, the participant had difficulties in understanding the activities. She looked at the researcher, repeated only part of the words and showed delay in answering the questions asked. In post-test 1, P3 repeated the words pronounced, but did not demonstrate understanding the activities. In post-test 2, P3 was a little dispersed, observing objects outside the research such as pencil and sheet that were on the table and for the researcher’s pants and blouse. Still, she showed understanding in the activities. When the researcher showed the card referring to the set of words “Casaco - Dominó”, the participant pointed to the letter C and said: “C de Choro”. Table 9 presents the detailed data of the tests performed by participant P3.

5.3.2 Intervention Prototypes

According to the experts’ analysis, unlike P1 and P2, P3 presented all ABA skills in the without gamification prototype. Before starting the application, the participant cried wanting her parents. The teacher talked to her and the researcher showed the tablet, making the student stop crying and get involved in the activity. During the application, P3 interacted positively with the researcher. This happened when the researcher asked P3 if the choice made starts with the same sound referring to the reference image or when the researcher pointed to the image and the participant pronounced the name. Regarding negative interactions, a tendency to click on images referring to animals was observed. For example: in the first task, the student clicked on the rhea image 6 consecutive times; in the fourth task, she clicked 3 times on the sheep image; and in the last activity she clicked 9 times on the elephant image. This behavior was reduced in the second and third applications, where 1 click on the rhea image, 1 click on the sheep image and 3 clicks on the elephant image were registered. The participant was distracted by the wheel chair she was sitting on and also by the back of the door that fell to the floor during the application. P3 did not leave the environment, but was distracted by these two objects.
Table 10  Skills Worked in the ABA Guide - Participant 3.

<table>
<thead>
<tr>
<th>SKILLS WORKED IN THE ABA GUIDE</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Track objects visually</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shared Attention</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Visual contact</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Imitation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Identification</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Follow instructions</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11  Prototypes Data - Participant P3.

<table>
<thead>
<tr>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Click</td>
</tr>
<tr>
<td>1st</td>
<td>24</td>
</tr>
<tr>
<td>2nd</td>
<td>12</td>
</tr>
<tr>
<td>3rd</td>
<td>16</td>
</tr>
<tr>
<td>Average</td>
<td>17,4</td>
</tr>
</tbody>
</table>

In the prototype with gamification, the ABA’s follow instructions ability was not observed. The participant interacted with the researcher during all three applications, repeating the name of the image she had chosen, laughing and making eye contact. She showed avoidance behavior, random speech and pointed to objects that were not part of the research. The student was dispersed, with difficulty in understanding the instructions, resulting in random choices or according to interest. For example, an airplane image was the reference, in which the bee was one of the options of choice. P3 chose the bee because it has a wing, “just like the plane”. In this case, the participant got the question right, but did not understand that the correct answer was because both words started with the same sound.

According to Table 11, the prototype with gamification presented the general and specific data better than the data from the prototype without gamification. When analyzing the average of correct answers, the prototype with gamification presented more satisfactory results. Regarding the average clicks and time, which show the student’s engagement in the tool, they were better in the prototype without gamification. From a more specific observation, the prototype without gamification presented a constant number of correct answers for the first two applications, but the result was not maintained in the last one. In the prototype with gamification, P3 started with zero hits, followed by three hits. In the last application, there was a drop of a hit, but it was still better than the last application of the other prototype.
5.4 Participant P4

Participant P4 is a 12-years-old male and attended the APAE for 9 years and 5 months.

5.4.1 Pretest, Post-test 1, and Post-test 2

In the pretest, the participant remained seated, showed attention to the activity, but did not understand it. In post-test 1 and post-test 2, P4 identified the words, repeating them after they were pronounced by the researcher, but also did not understand the activity. On all tests, P4 answered “yes” to all the questions, and consequently hit some of them by chance. Table 12 presents the explained data.

5.4.2 Intervention Prototypes

P4 presented all the skills worked in the ABA Guide in both prototypes, as shown in Table 13. He also did not show avoidance or repetitive behavior. In the prototype with gamification, there were three positive interactions: the student’s interest in the avatar, which chose the doll in both applications, and supergirl in the last one. Showed attention in the activities performed and independence in the last one. Showed attention in the activities performed and independence in the last one.


In Table 14 it is observed that the number of clicks per application and the total average were equal for both prototypes. In the prototype with gamification, the hit average was higher. Although the average clicks were the same for both prototypes, the time for the prototype without gamification presents greater signs of user engagement, as the user spent more time interacting with the tool. It is also possible to observe in the prototype without gamification, that there was an increase of three correct answers from the first to the second application, keeping this value constant in the last application.

5.5 Learning

The results regarding learning showed that three participants showed comprehension (with asterisk) on the test tasks only after using the gamified intervention prototype. It was also possible to observe a higher mean score of hits on the tasks in the gamification prototype (order 2) (Table 15).

For participants P1 and P2 who performed the experiment in order 1, gamification showed an indication of improved learning when P2 showed understanding on post-test 1, applied right after the gamification prototype. Although P1 showed understanding, the results of post-tests 1 and 2 were lower than the pre-test.

For participants P3 and P4, it is also possible to observe a hint of improved learning during the use of the prototypes. Both participants had higher average correct answers in the prototype with gamification. In addition, P3 showed comprehension on the test after using the prototype with game elements.

Checking in the literature, studies show an improvement in learning using technology. However, it is possible to observe the lack of studies regarding the improvement of learning using gamification associated with a Psychology intervention strategy. In this research, a systematic process was developed to
design and apply gamification and DTT, supported by technology, to improve the learning of children with autism in the age group between 07 and 12 years.

5.6 Engagement

Regarding engagement, it can be seen that regardless of whether the prototype has game elements or not, when applied first all four participants achieve a higher average click-through and dwell time on their tasks (Table 16). This can be explained by the novelty of the technology insertion, as shown in the studies of Ploog et al. (2013) [44] and Chandler (2016) [45], which brings new possibilities to support initiatives targeting autism. However, when the prototype is applied a second time, the presence of gamification shows better results than when the prototype without gamification is applied.

For both prototypes applied on the first day of the experiment, all participants showed ABA Guide Skills (e.g. following instructions, pointing, eye contact) and positive interactions. Regarding negative interactions, it was only absent for one participant while performing the activities in the prototype with gamification (order 1).

Repetitive behaviors and avoidance were not observed when the gamified prototype was being used, regardless of the order in which it was applied. Compared to the prototype without gamification, when applied after the gamified prototype (order 1), both repetitive behavior and avoidance were observed for all participants. Even when the prototype without gamification is used first, although no avoidance is identified among the participants, repetitive behavior is observed for one of them (Table 17).

Related work encompassing computational approaches to measure learning in the literacy context does not verify participant engagement using ABA Handbook skills [43], positive and/or negative interactions, repetitive behaviors, and escape through Autism expert analysis. Data from the tools used, such as the number of clicks and time were also not presented. The studies by (author?) [14, 19, 20] aim to contribute to increased engagement but do not

**Table 16** Engagement - Average Clicks and Time.

<table>
<thead>
<tr>
<th>ORDER 1</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLICKS</td>
<td>TIME (s)</td>
</tr>
<tr>
<td>P1</td>
<td>13.4</td>
<td>155.4</td>
</tr>
<tr>
<td>P2</td>
<td>5.7</td>
<td>154</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ORDER 2</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLICKS</td>
<td>TIME (s)</td>
</tr>
<tr>
<td>P3</td>
<td>17.4</td>
<td>168.4</td>
</tr>
<tr>
<td>P4</td>
<td>5</td>
<td>90.4</td>
</tr>
</tbody>
</table>
Table 17  Engagement - Appropriate (with asterisk) and Inappropriate.

<table>
<thead>
<tr>
<th></th>
<th>Second Day</th>
<th>Third Day</th>
<th>Second Day</th>
<th>Third Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prototype with Gamification</td>
<td>Prototype without Gamification</td>
<td>Prototype without Gamification</td>
<td>Prototype with Gamification</td>
</tr>
<tr>
<td><strong>ABA Guide</strong></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Positive Interactions</strong></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Negative Interactions</strong></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Repetitive Behaviors</strong></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Escape</strong></td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Table 18  Engagement of P1 and P2 (Order 1).

<table>
<thead>
<tr>
<th>ENGAGEMENT</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td><strong>ABA Skills</strong></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Positive Interactions</strong></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Negative Interactions</strong></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Repetitive Behaviors</strong></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Evasion</strong></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

present explanations of the results obtained in their studies to evidence such gains.

As can be seen, there is a lack of studies in the literature that investigate the increase in engagement for the target audience in question. On the other hand, in the experimental study presented in this research, a set of measures are used in order to verify if Gamification increases the engagement of children with autism between 7 to 12-years-old.

6 Discussion

After explaining the results obtained from the experimental study, the research questions are answered. In order to facilitate reading, it is important to remember that participants P1 and P2 performed the experiment in order 1 (prototypes with and without gamification). Participants P3 and P4 performed the experiment in order 2 (prototypes without and with gamification).

Research question RQ1 investigated whether technology-supported gamification and DTT increase engagement in children with moderate autism aged 7 to 12-years-old. There are signs of increased engagement when the prototype with gamification is applied first (order 1). For the prototype without gamification (order 2) in this condition, the results are inconclusive. These signs come from the analysis of experts, present in Table 18 and Table 19. In these tables, cells with asterisk show proper behavior, while inappropriate behaviors are empty. According to the prototype data, the results are also inconclusive, since the average of clicks and time is higher for the prototype that is applied first.
In this work, engagement refers to the behavior of the participants during the experiment. Due to the lack of instruments consolidated in the literature aimed at the target audience in the context of this research, it was necessary to define, together with the experts in the field, ways to verify engagement. The ABA Guide [43] was used to verify seven behavioral skills. In addition, observations related to positive and negative interactions, repetitive behaviors, evasion and prototype data such as number of clicks and stay time were also analyzed.

Regarding the experts’ analyses, P1 and P2 presented all ABA skills when carrying out the activities of the prototype with gamification (Table 18). Positive interactions, such as conversation with the researcher, observation of the researcher’s enamel color, interest in the avatar’s color, attention to the activity, hugging the researcher and smiling could be verified for both participants. Regarding negative interactions, for P1 they were not observed. However, for P2 there was avoidance behavior, in which the student asked to drink water in order to distance herself from the activity. Repetitive behaviors and avoidance were not identified for both participants.

In the prototype without gamification, ABA’s ability to identify and follow instructions for P1 and imitate for P2 did not occur. Positive interactions, such as those mentioned in the previous paragraph, were also observed. Regarding negative interactions, P1 showed resistance to perform the activity in the first application, partially accepted in the second application, and only in the third application did it show good acceptance. P2 was dispersed while performing the tasks. Repetitive behaviors were also present. P1 showed agitation while sitting in the chair and P2 clicked on several items of the prototype, without discriminating the correct answer. Regarding evasion, P1 retreated to sit at the beginning of the application and P2 got up to leave the environment.

According to the average number of clicks and time, for both P1 and P2 the prototype with gamification shows an average of clicks and execution time higher than those presented in the prototype without gamification (Table 5 and Table 8).

For participants P3 and P4, the prototype without gamification was applied first. All ABA skills were observed and positive interactions were noted for both participants, such as: interest in choosing the avatar, interaction with the researcher, attention to activities and independence in responding to them. In negative interactions, P3 was distracted by the wheelchair and the back of

### Table 19 Engagement of P3 and P4 (Order 2).

<table>
<thead>
<tr>
<th>ENGAGEMENT</th>
<th>PROTOTYPE WITHOUT GAMIFICATION</th>
<th>PROTOTYPE WITH GAMIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P3</td>
<td>P4</td>
</tr>
<tr>
<td>ABA Skills</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Positive Interactions</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Negative Interactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetitive Behaviors</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Evasion</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
the door that fell to the floor. P4, in turn, lost focus on activities. Regarding repetitive behaviors, P4 gave the same answer in all activities. Evasion was not observed in this first phase.

During the application of the second prototype, this with gamification, only P4 showed all ABA abilities. For P3, the ability to follow instructions was not identified. Positive interactions were also verified at this stage of the experiment. Regarding negative interactions, P3 showed avoidance behaviors, random speech and paid attention to objects that were not part of the research. P4 did not show understanding of the activities performed. Repetitive behaviors and avoidance were not observed for any of the participants.

Regarding the average clicks and time of P3 (Table 11) and P4 (Table 14), it was possible to observe a higher value in the prototype without gamification than in the prototype with gamification.

Given the discussion carried out, it is possible to verify that, regardless of whether the prototype has game elements or not, when applied first, all participants achieve all ABA skills and also a higher average of clicks and time spent in the activity. This can be explained by the novelty in the insertion of technology, as shown in the studies by Ploog et al. (2013) [44] and Chandler (2016) [45], which brings new possibilities to support the treatment of autism. However, when the prototype is applied for the second time, the presence of gamification presents better results than the absence of game elements, as shown in Table 18 and Table 19.

All participants had positive interactions, regardless of the prototype used. Regarding negative interactions, it was only absent for one participant while performing the activities in the prototype with gamification in order 1.

Repetitive behavior and avoidance were not observed when the prototype with gamification was being used, regardless of the order in which it was applied. Regarding the prototype without gamification, when applied after the prototype with gamification (order 1), both repetitive behavior and avoidance were observed for all participants. Even when the without gamification prototype is used first, although no evasion is identified among the participants, the repetitive behavior is observed for one of them.

Related works that encompass computational approaches to measuring learning in the context of literacy do not verify participant engagement using ABA skills, positive and/or negative interactions, repetitive behaviors, and avoidance through analysis by autism experts. Tool data such as number of clicks and time are also not displayed. The studies by Rahman et al. (2011) [14], Belmonte et al. (2016) [20], and Winoto (2016) [19] aim to contribute to increased engagement, but they do not provide explanations of the results obtained in their studies to show such gains.

As can be seen in Section 2, in the literature there is a lack of studies that investigate the increase in engagement for the target audience. On the other hand, in the experimental study presented in this paper, a set of measures are used in order to verify whether gamification increases the engagement of children with autism aged between 7 to 12-years-old.
Research question RQ2 investigated whether technology-supported gamification and DTT improve learning in children with moderate autism aged 7 to 12-years-old. The results presented show signs of improvement in learning with regard to the understanding of activities after using a prototype with game elements. It can also be observed a higher average of hits in the tasks of the prototype with gamification (order 2).

To answer the research question RQ2, an analysis of the results obtained through the pretest, post-test 1 and post-test 2 was performed. The number of correct answers achieved via prototypes was also discussed.

In order, P1 and P2 performed the tests in the following order:

- Day 1: Pretest;
- Day 2: Prototype with gamification and post-test 1;
- Day 3: Prototype without gamification and post-test 2.

Participant P1 showed comprehension in all tests. There is a decrease in the mean from pretest (1) to post-test 1 (0.34) and a small increase in post-test 2 (0.67). Regarding the results obtained in the prototypes, the average of correct answers was equal in both (Table 5).

Participant P2 did not show comprehension in pre-test and post-test 2. An observation is that understanding occurred only in post-test 1, which was applied after the participant had performed the activities in the prototype with gamification (Table 6). Regarding the prototypes, the average of correct answers was higher in without gamification.

When reflecting on the results, gamification presents an indication of learning improvement when P2 shows comprehension in post-test 1, applied right after the prototype with gamification. Although P1 showed understanding, the results of post-test 1 and 2 were lower than the pretest.

In Order 2, P3 and P4 performed the tests in the following order:

- Day 1: Pretest;
- Day 2: Prototype without gamification and post-test 1;
- Day 3: Prototype with gamification and post-test 2.

For participant P3, understanding occurred only in pre-test and post-test 2, both with the same number of correct answers (Table 9). It is important to note that post-test 2 was applied after using the prototype with gamification, which may have influenced the understanding, as happened for P2. Regarding the prototypes, P3 had a higher average of correct answers in the with gamification (Table 11).

Participant P4 did not obtain comprehension in any of the tests performed. However, in relation to the prototypes, he obtained a higher average of correct answers in the prototype with gamification, hitting all the questions in the three applications (Table 14). As P4 did not show understanding of the activities, there is evidence that the result obtained in the prototypes was due to the participant’s visual memory.
For participants P3 and P4, it is also possible to observe an indication about the learning improvement during the use of the prototypes. Both participants had a higher average of correct answers in the prototype with gamification. Furthermore, P3 showed understanding in the test after using the prototype with game elements.

By checking the literature, studies show us an improvement in learning using technology. However, it is possible to observe the lack of studies regarding the improvement of learning using gamification associated with some intervention method in Psychology. In the study carried out, a systematic process was developed to develop and apply technology-supported gamification and DTT to improve the learning of children with autism aged between 7 to 12-years-old.

7 Validity Threats

The pre-test and training of participants P1 and P2 took place in the auditorium, but the place was occupied on the other days of the experiment. Thus, we changed the application location to the experts’ room.

During some applications, there was a recess next to the experts’ room, which may also have influenced the students’ behavior. Unfortunately, changing rooms would also pose another validity threat. As the break did not catch the attention the participants in such a way as to invalidate the experiment, it was decided to continue in the experts’ room.

As the two experts worked at APAE, they alternated between helping the researcher in the experiment and carrying out the institution’s work. Thus, it was not possible to obtain an analysis from both experts for all participants. If we could have two analyzes for each participant, carried out by different experts, it would be possible to analyze the behaviors presented in greater depth, which is part of our plans for future works.

Another factor that may have influenced the results is the experiment’s application turn. Three participants studied in the morning shift and one participant in the afternoon shift. The ideal would be to carry out the experiment in the same shift for all participants, but unfortunately it was unfeasible due to the willingness of parents to take their children and also due to attending regular school on the other shift.

8 Conclusion

This research aimed to assess the effects of a gamified co-design in the learning and engagement of children with autism in the literacy context. A process was created from a co-design, in order to expand the possibilities of making targeted choices for the audience with autism, and a gamification design, to ensure that the concepts of the field were applied appropriately. Prototypes were developed in order to instantiate the process and also to enable evaluation with the target audience. Due to the lack of methods used to create processes that guide the development of educational technologies for children with autism, all steps of
this research were followed and validated by experts in the areas of Autism, Gamification, and HCI.

As a way to evaluate the process created and instantiated, an evaluation was conducted with four children with moderate autism in the age range of 7 to 12-years-old. Engagement, related to behavior, was measured through expert analysis and average clicks and time on the prototypes. Learning was measured through the tests and average hit rates recorded on the prototypes.

From the expert analysis, evidence of increased engagement was recorded when the prototype with gamification was applied first (order 1). Regarding the prototypes’ data (average clicks and time), it is not possible to discern, since the number is always higher for the prototype applied first. For learning, indications were observed through the tests applied after the prototype with gamification associated with the DTT, in which three participants showed understanding when performing them.

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10 Declaration
Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References


fonológico, da consciência morfológica e dos processos subjacentes à nomeação seriada rápida para a leitura e a escrita no português brasileiro (2009)


