Un entorno gamificado apoyado en realidad aumentada para potenciar la competencia comunicativa en alumnado con TEA: diseño y validación

A gamified environment supported by augmented reality for improving communicative competencies in students with ASD: design and validation

Nerea López-Bouzas.
University of Oviedo.
lopeznerea@uniovi.es

M. Esther Del Moral Pérez.
University of Oviedo.
emoral@uniovi.es

RESUMEN.
Este estudio tiene como objetivo diseñar y validar un Entorno Gamificado Aumentado (EGA) para potenciar la competencia comunicativa del alumnado con TEA. La metodología es mixta: a) *cualitativa*, centrada en el estudio de caso único para describir el proceso del diseño del EGA. El entorno parte de una narrativa de aventura pirata que integra actividades gamificadas apoyadas en realidad aumentada. Se potencia un aprendizaje inmersivo mediante actividades que impulsan las habilidades sociales, lingüísticas y cognitivas ligadas al juego simbólico. Y b) *cuantitativa*, apoyada en el método Delphi, donde expertos (N=12) evalúan el entorno utilizando 14 indicadores asociados a 4 dimensiones: adaptabilidad a los ritmos de aprendizaje, idoneidad del soporte y códigos para presentar el contenido, potencialidad didáctica para el desarrollo competencial y adecuación del proceso de gamificación al alumnado con TEA. Finalmente, las valoraciones expertas contribuyeron al refinado del EGA, incrementando su adaptabilidad, flexibilidad y funcionalidad, incorporando actividades versátiles y aplicaciones de realidad aumentada que propician el desarrollo lingüístico y socio-emocional del alumnado de forma lúdica en un entorno inmersivo.

PALABRAS CLAVE.
Trastorno del Espectro Autista, entorno virtual, gamificación, realidad aumentada, competencia comunicativa.

ABSTRACT.
The objective of this study was to design and validate an Augmented Gamified Environment (AGE) for improving communicative skills in students with ASD. The study used a mixed methodology: a) qualitative, focused on a single case to describe the AGE design process. The environment uses a pirate adventure story which includes gamified activities supported by augmented reality. It promotes immersive learning through activities that encourage social, linguistic, and cognitive skills linked to symbolic play; and b) quantitative, based on the Delphi method in which experts (N=12) evaluated the environment using 14 indicators in four dimensions: adaptability to the pace of learning, suitability of the base and code for presenting the content, didactic potential for developing competence, and the suitability of the gamification process for students with ASD. The expert assessment helped to improve the adaptability, flexibility, and functionality of the AGE, which incorporated versatile and

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augmented reality activities and applications to provide the student with playful linguistic and socio-emotional development in an immersive environment.

KEY WORDS.
Autism Spectrum Disorder, virtual environment, gamification, augmentative reality, communicative skills.

1. Introduction.

According to the DSM-5™, people with Autism Spectrum Disorder (ASD) have persistent deficits in social communication, reciprocity, and non-verbal communication, etc. (American Psychiatric Association, 2013). They also have limitations in language development, presenting difficulties in acquisition within the critical natural period (Marzo and Belda, 2021). These problems can often cause feelings of loneliness and social exclusion (Baixauli et al., 2017). According to the European Parliament and Council (2006), these limitations can directly affect communicative competence, which is understood as the human capacity to communicate in various contexts, have tolerant and empathetic attitudes, and understand different points of view, among other things. Early education interventions to alleviate these difficulties are carried out in clinical and educational settings, based on individual characteristics.

Over the last ten years, many interventions for these students have been produced that use digital resources, which are usually noted for their versatility, flexibility, and adaptability (Durán, 2021; López-Bouzas & Del Moral, 2022; López-Meneses & Fernández-Cerero, 2020). Software systems -such as mobile and multimedia applications- have been created specifically for people in this group (Alharbi and Huang, 2020; García Guillén et al., 2016; Sánchez, 2021). More specifically, the growth in augmented reality (AR) resources over the same time has driven the development of software that takes advantage of AR's potential as a technique that can take social therapy into the virtual world, increasing students' intrinsic motivation (Adnan et al., 2018; Khowaja et al., 2020).

In general, these augmented reality resources are used to stimulate communication competence. Some aim to stimulate students' socio-emotional skills using activities based on social reciprocity (Chung and Chen, 2017), improve understanding of non-verbal behaviour (Chen et al., 2016), alleviate limitations due to the complexity of facial processing (Adnan et al., 2018), or improve social interaction as a whole (Lee et al., 2018). Others aim at stimulating linguistic skills using augmented communication methods (Taryadi and Kurniawan, 2018; Sahin et al., 2018), or at stimulating reading skills (Kolomoiets and Kassim, 2018) and literary skills (Arief and Efendi, 2018). In addition, active methodologies and techniques such as gamification—which uses the mechanisms and dynamics of games in non-play contexts (Zichermann and Cunningham, 2011)—are leading to successful interventions that use games as the setting (Malinverni et al., 2017).

Presenting missions and challenges, and offering rewards and incentives, allows educational objectives to be achieved. It also increases student motivation and involvement, producing meaningful learning (Rodrigues da Silva et al., 2019). Gamification helps increase motivation in therapeutic sessions and helps change behaviour in the long term (Malinverni et al., 2017; Van Dooren et al., 2019). It helps in adapting content to the student regardless of their

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developmental level, providing experiences linked to the real world they can identify with (Mubin et al., 2020). Using gamified environments with these students helps their personal growth though extrinsic motivation, activating their emotional intelligence and encouraging their interpersonal relationships (Arzone et al., 2020). Incorporating digital resources into these virtual environments makes it easier to have gamified activities (Kousar et al., 2019), increasing engagement and motivation via emotional linking (Kang and Chang, 2019). In addition, recreating situations, and people from the real world in playful settings reduces the intrinsic cognitive difficulty of acquiring learning associated with the rules that guide interpersonal relationships and the interiorization of social norms (Malinverni et al., 2017).
The convergence of gamification and AR is an opportunity for promoting these students' communicative competence, as the motivation provided by the mechanics and dynamics of the game, supported by the digital settings, are a source of multisensorial stimuli that help students interpret meaning in communication processes and social interaction.

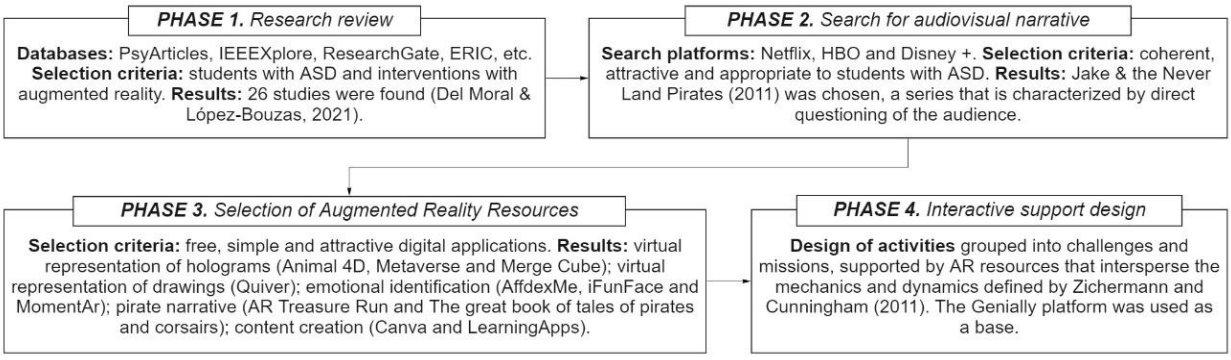
2. Method.

The objective of this study was to design and validate an Augmented Gamified Environment (AGE) to promote communicative competence in students with ASD, providing a playful, didactic, interactive experience. The study used a mixed methodology: *qualitative*, focusing on a single case study describing the environment design process; and *quantitative*, collecting expert assessment through the Delphi methodology to validate and refine it.

The design process for the environment.

The Augmented Gamified Environment (AGE) is an immersive digital space that combines fun learning with activities supported by AR, encouraging student immersion in the learning process through interaction with digital devices (Del Moral & López-Bouzas, 2021). More specifically, the environment in *From Cabin Boy to Captain: in search of the lost treasure* provides a personalized intervention for students with ASD to stimulate their communicative competence. The design phases are summarized below (Figure 1).

Figure 1. Phases of the design process. Source: elaborated by the authors.



This proposal prioritizes the visual design of the game and the presence of a mediator when doing the activities (Ben-Sasson et al., 2012; Guisti et al., 2011). The Genially platform was

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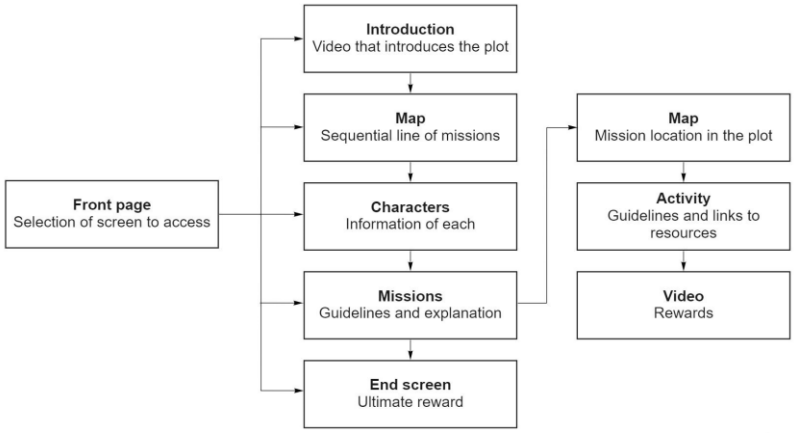
selected as the base for the environment, as it allows for the creation of scenarios for finding clues, solving challenges, and doing missions with an educational goal (Grande de Prado et al., 2021; Trejo, 2019). The activities are sequenced based on an appealing story that makes it easy for the students to move through the environment (https://n9.cl/zh1od). AR resources were also included which invite interaction and mission execution via gamification mechanics and dynamics. The internal navigation map is shown in Figure 2.

Figure 2.
AGE navigation map. Source: elaborated by the authors.



Faces of animated characters particularly capture students' attention and make them more interested in psycho-pedagogical activities (Soares et al., 2017). To that end, the Disney animated series, *Jake and the Never Land Pirates* was used as the setting for incorporating gamified activities. The adventure aesthetic and the two- and three-dimensional modelling invite the students to immerse themselves in educational activities, and the characters become the main drivers of the plot, which are presented through speech and speech bubbles. Although the *missions* are independent activities, they all combine digital resources and AR applications. Each mission is accompanied by YouTube videos which make it easier for the student to be immersed in the virtual environment. The activities are organized into flexible levels, adapting to different levels of development. There are also *prizes* and *rewards*: gold doubloons for advancing through the story, rewards for completing each mission, which get better as the plot advances (a spyglass, a hook, a pirate hat), and finally, a downloadable diploma with the student's name on it. The environment also has its own feedback system, provided by the characters themselves. In line with Cabrera (2020), this feedback is: *prescriptive*, indicating what the subject has to do or avoid doing; *evaluative*, as it provides justification for the score of the completed tasks; *descriptive*, as it explains how to do each task correctly; and *interrogative*, as it invites reflection about how the tasks were done.

Delphi validation.
The Delphi method was chosen to validate the potential of the Augmented Gamified Environment designed to stimulate communicative competence in students with ASD. The criteria established by Linstoney and Turoff (1975) were followed: identification of the problem,

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creation of a panel of experts, presentation of the problem and request for responses; summary of responses and specific statements; and final configuration of the resource. In the field of education research, López-Gómez (2018) suggests selecting experts based on the following criteria: 1) training in the field of special education; 2) working teachers with experience of students with ASD. The final selection comprised twelve teachers from special education schools who voluntarily agreed to participate in this study.

The index of Expert Competence (K) was assessed (Barroso and Cabero, 2013) using the parameter: K= ½ (Kc + Ka), where Kc is the expert's *Coefficient of knowledge* according to pre-established criteria and Ka is the *Coefficient of argumentation* or self-assigned score about their own mastery (on a scale of 0-10, multiplied by 0.1). In this study the competence of the experts was K=0.865, which is considered to be high influence, as K >0.8.

Instrument.

The instrument was produced following the guidelines from Madariaga et al. (2016) for assessing quality educational software: adaptability, functionality, reliability, and usability. Four dimensions were included with fourteen variables in total. Experts gave their assessments using a Likert-type scale (very much=4, to a large extent=3, a little=2, not at all=1) along with any suggestions they had via open response fields. *Google Forms* was used to create an *ad hoc* form which was completed by each of the experts during January 2022. Table 1 shows the variables and categories making up the validation instrument.

Table 1.

Variables and analysis categories.

Dimensions	Analysis categories (1=not at all, 2=a little, 3=to a large extent, 4=very much)
(A) Adaptability to learners' different styles of learning	A1. The setting promotes personalized intervention with the student A2. The selected app offers user-friendly, intuitive navigation
(P) Content presentation	P1. The Genially platform is a suitable base for the activities P2. The environment includes various codes (visual, verbal, auditory) for accessing content
(D) Competence development	D1. The selected apps stimulate communicative competence D2. The linguistic activities include perception tasks and visual and auditory discrimination of pictograms, images, and icons. D3. The identification and association tasks help stimulate acquisition of vocabulary, semantic comprehension, and phonetic improvement D4. The socio-emotional activities help in identification and recognition of emotions
Suitability of gamification strategies for students with ASD: (M) mechanics	M1. Awarding points contributes to completing missions M2. The scaling of different levels encourages adaptability to the students' level of development

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(D) dynamics	M3. The missions and challenges get progressively more difficult D1. The story and the plot encourage immersion D2. The characters and the plots encourage emotional involvement D3. The student being able to see how they are advancing in missions helps them to self-regulate their learning

Source: elaborated by the authors.

3. Results.

Following collection during the validation process, the experts' assessments are summarized below (Table 2).

Table 2.
Percentage distribution of teachers' opinions about the AGE.

Indicators	1 Fre(%)	2 Fre(%)	3 Fre(%)	4 Fre(%)	X	SD
A1. The setting promotes personalized intervention with the student	0(0.0)	0(0.0)	5(41.6)	7(58.3)	3.5	0.5
A2. The selected app offers user-friendly, intuitive navigation	0(0.0)	1(8.3)	3(33.3)	8(66.6)	3.5	0.6
P1. The Genially platform is a suitable base for the activities	0(0.0)	0(0.0)	0(0.0)	12(100.0)	4.0	0.0
P2. The environment includes various codes (visual, verbal, auditory) for accessing content	0(0.0)	0(0.0)	6(50.0)	6(50.0)	3.5	0.5
D1. The selected apps stimulate communicative competence	0(0.0)	0(0.0)	2(16.6)	10(83.3)	3.8	0.3
D2. The linguistic activities include perception tasks and visual and auditory discrimination of pictograms, images, and icons	0(0.0)	5(41.6)	4(33.3)	3(33.3)	2.8	0.8
D3. The identification and association tasks help stimulate acquisition of vocabulary, semantic comprehension, and phonetic improvement	0(0.0)	6(50.0)	4(33.3)	2(16.6)	2.6	0.7
D4. The socio-emotional activities help in identification and recognition of emotions	0(0.0)	4(33.3)	4(33.3)	4(33.3)	3.0	0.8
M1. Awarding points contributes to completing missions	0(0.0)	1(8.3)	7(58.3)	4(33.3)	3.2	0.6
M2. The scaling of different levels encourages adaptability to the students' pace of development	3(33.3)	5(41.6)	2(16.6)	2(16.6)	2.2	1.0
M3. The missions and challenges get progressively more difficult	2(16.6)	4(33.3)	3(33.3)	3(33.3)	2.5	1.0
D1. The story and the plot encourage immersion	0(0.0)	0(0.0)	5(41.6)	7(58.3)	3.5	0.5
D2. The characters and the plots encourage emotional involvement	0(0.0)	0(0.0)	0(0.0)	12(100.0)	4.0	0.0
D3. The student being able to see how they are advancing in missions helps them to self-regulate their learning	0(0.0)	0(0.0)	7(58.3)	5(41.6)	3.4	0.5

Source: elaborated by the authors.

Once the data was collected, it was clear that the best assessments were about content presentation (75%) related to the interactive base and the inclusion of a variety of codes

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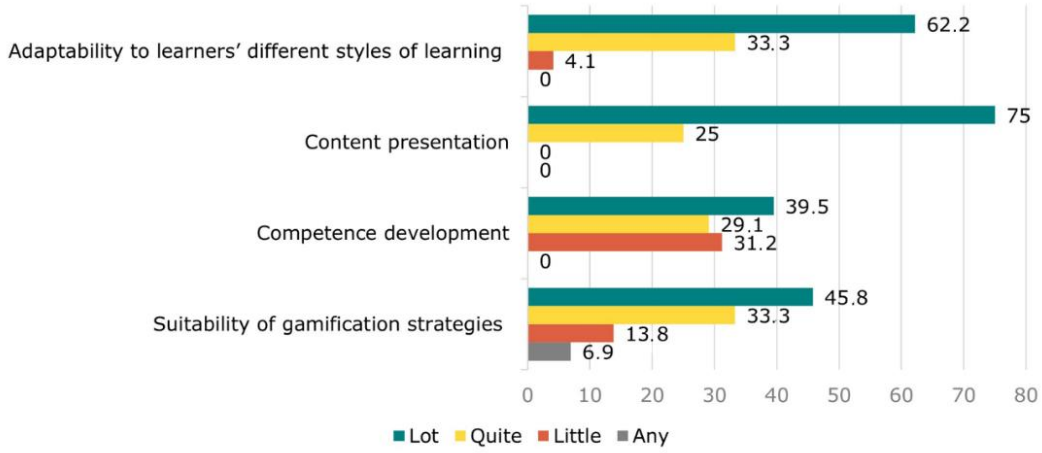
(visual, verbal, and auditory), promoting adaptation to each individual student. In addition, the assessment of adaptability to learning styles (62.2%) suggests that the environment encourages personalized interventions in which the app offers user-friendly, intuitive navigation (Figure 3). There were lower scores for the suitability of the AGE in gamification strategies, particularly in terms of the level scaling the design and presentation of challenges and missions.

Figure 3.
Percentage distribution of the suitability of the AGE by dimension of analysis.



Source: elaborated by the authors.

The experts' suggestions gave additional clarification linked to the visibility, validity, and adaptability of the environment. Some noted the need to adapt the presentation of the content: E3, "…perhaps it would be interesting for the screens to have fewer elements; they can sometimes act as distractors for these students."; E7, "There shouldn't be too many pictograms, as occasionally they can be a dissuasive element that puts the student off the task to be done"; E8, "with regard to the instructions for the activities, it would be interesting if they adapted to the developmental level of the student". Other experts suggested the need to adapt the content to the competence level of the students: E10, "There should also be a lower level of difficulty, as it's hard to cover such a diverse set of students with only two levels. Many won't fit in either of them…"; E5, "…it may be interesting to include activities that are at a lower difficulty level, related to grouping or association". Finally, and although the resource was conceived of for use in pre-determined interventions, one teacher added: E11, "It is a very interesting resource. It would be a shame if it couldn't be used in other contexts. Would it be possible to include explanations of the activities on the screen? That way anyone could use it…".

Once the clarifications and suggestions from the experts had been incorporated, and following improvements to the environment, a final version was produced. The definitive AGE had two types of activities: 1) *Shared activities* -regardless of level- initially identifying characters, who students had to visualize with AR to identify their qualities from a QR. Additional interactive

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tasks start with watching YouTube videos, with students given rewards (gold doubloons) which enrich the narrative by gamifying the plot. There are also tasks linked to advancing through the environment by passing through screens that go on to the missions. 2) *Activities assigned to each level*, which adapt to the students' starting point and level of learning. Guidelines were added for doing activities and elements and activities were reorganized -avoiding distractors- with the addition of a third level (Table 3).

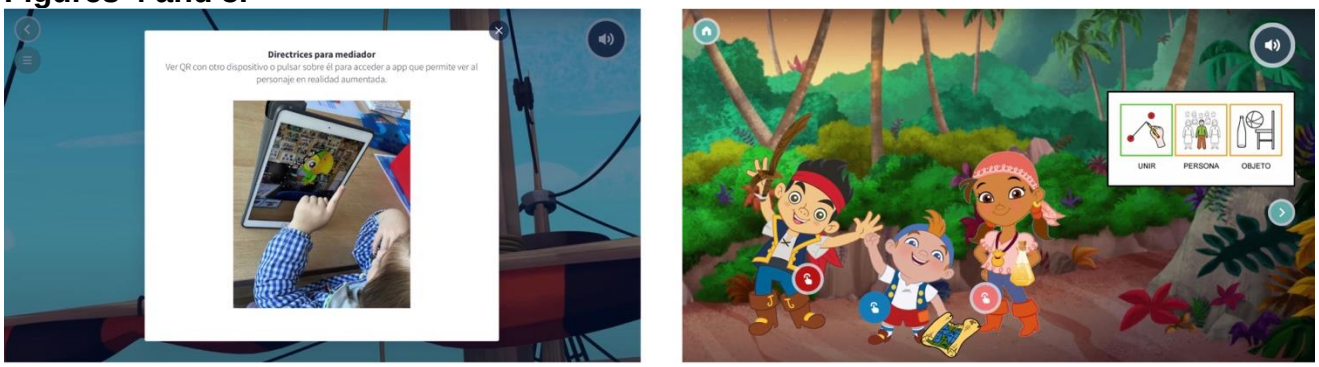
Table 3.
Modifications to the AGE following the teachers' suggestions.

Changes	Level (L1)	Level 2 (L2)	Level 3 (l3)
Clues and help for doing activities	An adult mediator presses a button, and a text box opens describing the task	The student listens to some speech supported by pictograms to do the task	The student listens to some speech to do the tasks
Screen elements	Simple environment and guiding characters	Nautical setting, pirate characters, and pictograms	Nautical setting and pirate characters
Type of activity	Exploration, colouring, association, and memory	Association through selective recall, exploration and manipulation of objects, identification of elements	Exploration and manipulation of objects to name, describe, and compare characteristics

Source: elaborated by the authors.

An information button was added to the upper left corner of the screen which opens a text box giving guidelines for doing the shared activity or level 1 tasks (Figure 4). Pictograms were added solely to level 2, created using the web page of Pictograms and Resources for Argumentative and Alternative Communication (ARASAAC) (Figure 5).

Figures 4 and 5.



Information screens and addition of pictograms in L2.

All the activities promote Universal Learning (Carrington et al., 2020); they present content incorporating various codes: written text, speech, information windows, and 2D and 3D images and video. The presentation of the information in the digital environment includes links

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to visual and audio-visual resources, resource sheets, cards, and books, etc. This gives the environment flexibility for acquiring learning and stimulating communicative competence. In addition, it makes it more interesting and motivating, as the AGE goes beyond the traditional use of pictograms or specific apps in order to immerse the student in a pirate adventure in which they are the protagonist. After modifying the environment based-on the teachers' suggestions, the missions and activities with AR were as follows (Table 4):

Table 4.
Missions, activity, and resources in the AGE.

Mission	Level. Activity	Resources (access)
1	Level 1. Naming and association of each character and their colour	Genially
	Level 2. Naming and association of each element with their character	App iFunFace (Google Play: https://n9.cl/n7fuc; App Store: https://n9.cl/pbqst). Game on LearningApps (authors' creation, https://learningapps.org/)
	Level 3. Naming the nautical elements	Book El gran libro de relatos de piratas y corsarios (https://n9.cl/o4bbn). App Pirates AR (Google Play: https://n9.cl/1913; App Store: https://n9.cl/u2xor)
2	Level 1. Naming the emotions (emoticons) and association with the students' facial expressions	App AffdexMe (Google Play: https://n9.cl/vasnd; App Store: https://n9.cl/8tyx)
	Level 2. Associating emotions with their causes	Genially ad hoc complement (https://n9.cl/w09ic); App Moment AR (Google Play: https://n9.cl/a57ei; App Store: https://n9.cl/ce0l8; Merge Cube: https://n9.cl/hmfer)
	Level 3. Recognition of one's own emotion	App Colorear Online (Google Play: https://n9.cl/2j388; App Store: https://n9.cl/1ck5v)
3	Level 1. Naming animals	Quiver sheets (https://n9.cl/6sjla). App Quiver (Google Play: https://n9.cl/afse7; App Store: https://n9.cl/fc4an)
	Level 2. Identification and description of animals (size, colour, habitat, etc.)	App Merge Object Viewer (Google Play: https://n9.cl/eh93i; App Store: https://n9.cl/5k0pg; Merge Cube: https://n9.cl/hmfer)
	Level 3. Comparison between animals' characteristics	App Animal 4D (Google Play: https://n9.cl/21o7; App Store: https://n9.cl/t5gv; Downloadable cards: https://n9.cl/u55ze)

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4	Level 1. Simple treasure hunt (close to the student and visible) Level 2. Search for hidden treasure using a map with help Level 3. Search for hidden treasure following a map autonomously	App ARrrrrgh (Google Play: https://n9.cl/smtnz; App Store: https://n9.cl/k8rgb) App ARrrrrgh (Google Play: https://n9.cl/smtnz; App Store: https://n9.cl/k8rgb) App ARrrrrgh (Google Play: https://n9.cl/smtnz; App Store: https://n9.cl/k8rgb)

Source: elaborated by the authors.

4. Discussion and conclusions.

The AGE designed for this study brings together gamified activities and AR resources in a virtual environment to develop communicative competence in students with ASD. A playful story was created which incorporates various activities, seeking multisensorial involvement of the student from their immersion and engagement in the story, making them responsible for the outcome of the plot, which promotes growth of their communicative competence. It is a personalized intervention providing functional, spontaneous communication, promoting social, linguistic, and cognitive abilities linked to symbolic play

The experts noted the limitations of its use in the educational context and identified possible improvements. The AGE was modified as a result to increase its *adaptability*, by including three difficulty levels. The number of distracting elements was reduced based on the students' level to improve *flexibility*, and the activities were adapted to students' different developmental levels, increasing its *functionality*. That meant that the AGE became more flexible, adaptable, and functional for improving the communicative competence of students with ASD. The setting presented pop-up windows with multimedia elements (written text, voiceovers, images, videos -in 2D and 3D-) and incorporates links to visual and audio-visual resources, resources sheets, cards, books, etc. that stimulate the student immersion.

In addition, the proposed activities are motivating due to their playful component and can be carried out independently of the AGE narrative, which gives them great versatility. This gamified virtual environment could also be extrapolated to other contexts and educational stages and implemented in classrooms with subjects without Special Educational Needs. The creation of this type of resources requires the training of teachers in digital competence so that they know how to design and integrate emerging resources such as augmented reality from a didactic and evaluative perspective. Undoubtedly, this research is also a didactic strategy for training teachers as it gives guidelines for the design process, allowing new stories and intervention resources to be created.

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Future implementation of the environment, supported by AR resources, is expected to produce positive results in linguistic development, similar to Kolomoiets and Kassim (2018) and Taryadi and Kurniawan (2018), as well as to increase students' socio-emotional skills (Chen et al., 2016; Keshav et al., 2017). In addition, the use of gamified activities for stimulating emotional intelligence, as noted by Arzone et al. (2020), and encouraging social interaction (Mubin et al., 2020) ensures immersion in the environment. This prototype will be implemented in the near future, where its efficacy in activating communicative competence in these students will be tested in a real situation.

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