



# Enhancing Autism Therapy through Smart Tangible-Based Digital Storytelling: Co-Design of Activities and Feasibility Study

Arzu Guneyasu  
arzuo@kth.se

The Department of Biomedical Engineering and Health Systems, CBH, KTH  
Sweden

Sanna Kuoppamäki

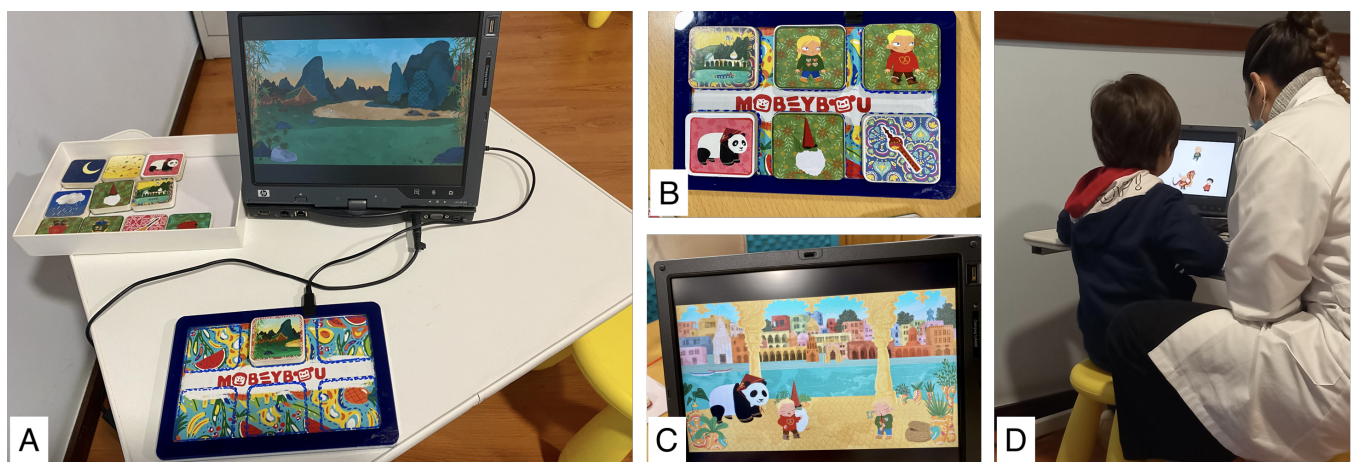
The Department of Biomedical Engineering and Health Systems, CBH, KTH  
Sweden

Helena Reis

The Center for Translational Health and Medical Biotechnology Research (TIBO), ESS, Polytechnic of Porto  
Portugal

Cristina Sylla

The Research Centre On Child Studies, ITI/LARSyS,  
University of Minho  
Portugal



**Figure 1:** A: The platform with smart tangibles including a screen with the visual representation of the story content connected with a cable to the tangible board where the child puts the blocks on. Various tangible blocks are inside the box on the up-left part of the table. Tangible board has one landscape tangible block and the corresponding landscape is reflected on the screen. B: An example co-designed activity, Using Magical Objects as a Substitute of Strategy for a Negative Situation: 1 landscape + 2 children + 1 animal + 1 antagonist and 1 magical object on the tangible platform. C: Example output of co-design session with the corresponding digital story projection on the screen. D: The therapist is independently using the system within a therapy session of a child with ASD.

## ABSTRACT

Storytelling is an effective evidence-based practice as an accepted intervention by therapists for the therapy of children with autism spectrum disorder (ASD). Digital storytelling, particularly using

smart tangibles, offers a structured, interactive and engaging environment for children with ASD allowing for repetition, offering feedback with visual supports, and giving the child more authority over the learning experience.

This study presents a co-designed approach to digital storytelling for autism therapy, aimed at enhancing multiple social and behavioral skills. Through co-design sessions with therapists, activity flows and scenarios were developed to target specific skill improvements. These include free play exploration, positive stimulus introduction, fostering cooperation to address disturbances, and incorporating magical objects to facilitate peer turn-taking. Additionally, real-life connections were emphasized to promote emotional regulation and multicultural understanding while further activities are designed to overcome routine issues, build tolerance to change, and enhance cognitive structuring.

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Feasibility was demonstrated through integration into therapy sessions of five children, where therapists independently utilized the system, fostering immersive and interactive storytelling experiences. Overall, the co-designed activities offer insights into enhancing therapy interventions for children with ASD beyond specific contexts, contributing to the broader design of autism therapy activities.

## CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); **Activity centered design**; • **Applied computing** → **Interactive learning environments**.

## KEYWORDS

children with autism, ASD therapy, digital storytelling, smart tangibles, co-design

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## 1 INTRODUCTION

Narrative discourse is an essential skill that children use to organize their experiences and communicate them to others [2]. It plays an important role in social interactions and academic achievement [1]. Narrative competence is based on a variety of linguistic and cognitive skills. In terms of language, it is considered a "high order" task in which all aspects of language play an important role. In addition, coherent narratives require the ability to link a series of events and actions according to temporal and causal principles. In terms of cognition, understanding and producing narratives requires a variety of skills, such as perceiving the shape of a complex stimulus, inferring abstract ideas from concrete details, and considering the listener's perspective, known as the Theory of Mind (ToM). Because of the multiple skills associated with narrative production, the analysis of narratives produced by typically developed children with and children with developmental disabilities has become a widely used measure of communicative and cognitive skills.

In autism spectrum disorder (ASD), analysis of narratives is particularly important because many of the prerequisites for narrative production are impaired [7]. Previous research indicates that social stories might increase a child's understanding of the social world [19] while decreasing the behavior-related anxiety of children on the autism spectrum [12, 14]. Consequently, storytelling is an effective evidence-based practice as an accepted intervention by teachers for children on the autism spectrum [13, 16, 20].

Compared to traditional storytelling activities digitally mediated social stories benefit individuals with social interaction difficulties by a) offering a more invariant and structured environment, b) allowing for repetition, c) providing feedback with visual supports, self-monitoring, and rewards, and d) handing the child more authority over the learning experience [6].

On the other hand, integrating tangibles into educational activities can enrich the learning experience since they offer unique

benefits in learning by providing sensory experiences [5], promoting hands-on engagement, supporting spatial reasoning, fostering collaboration [4, 11, 18], enhancing memory retention, and increasing motivation and engagement, particularly for younger learners, by capturing their interest and curiosity [8, 10].

We believe that by combining the interactive elements of digital storytelling with the tactile engagement of tangible learning, children can immerse themselves in dynamic educational experiences. This innovative approach not only provides a rich storytelling experience but also offers tangible interaction that children can manipulate, enhancing their understanding and retention of key concepts. Through this combined approach, children with ASD can explore narratives, develop social skills, and strengthen their overall learning outcomes in a supportive and engaging environment.

## 2 MATERIALS AND METHODS

This study involves a co-design phase of two sessions with two therapists and the integration of the system into occupational, speech and/or language therapy sessions of five children with ASD at the Association for the Inclusion and Support of the People with Autism (Associação para a Inclusão e Apoio ao Autista).

At the beginning of the co-design phase, we introduced the platform to the experts to elicit their initial reactions and perceptions regarding the potential benefits of digital storytelling with tangibles in autism therapy. Subsequently, they created flows and possible therapy scenarios targeting specific skill improvements. Two co-design sessions are scheduled, with a one-week interval in between, allowing therapists to independently explore the system at their own pace within those two weeks. After the design, therapists utilized the application in their therapy sessions themselves with full autonomy.

The study was carried out in accordance with the Declaration of Helsinki. Approvals were obtained from the ethics committee of University of Minho, Portugal and The Research Ethics Committee of the Politécnico de Leiria, Portugal. Written informed consent was obtained from all children's parents and therapists.

### 2.1 Smart Tangibles for Digital Storytelling

The digital manipulatives that are used in that study were previously developed to foster children's narrative and social competencies by assisting them in the production of intercultural stories [3, 15, 17]. The tool uses physical blocks to manipulate the digital content and is composed of an electronic platform that connects to a computer via USB, and 60 blocks. Each block represents a story element. Placing the blocks on the electronic platform triggers its digital representation on a device's screen as can be seen in Figure 1A. The digital story elements interact with each other on the screen according to a set of previously defined interaction rules, displaying specific animations and different actions depending on the combination of blocks that are placed on the electronic platform (see Figure 1C) [9].

The story environment represents multiple world cultures, such as Portugal, India, Brazil, and China. The cultures are organized in cultural sets, each comprising a landscape, two protagonists (a boy and a girl), an animal, an antagonist (such as a mythical creature), a musical instrument, and a magical object. The elements of each

culture are representative of native components of the country or are inspired by its folklore, traditions, or mythology. For instance, the animal in Indian culture is an elephant which is designed by inspiration from the decorated animals of the Elephant Festival in Jaipur [15].

The children can freely mix all elements to create their narratives independent of the culture. To customize the stories, there are blocks that represent weather conditions: rain, storm, wind, snow, and night. Children can use these in their stories to influence the weather, e.g., when connecting the thunder block the digital elements on the screen are hit by lightning, or connecting the rain block triggers a flood. The story elements act as triggers for children's storytelling, and the visual narratives unfold according to the combination of blocks that the children use, while they verbalize their stories. The story engine of the Digital Manipulative has the following interaction rules:

- The animals are portrayed as friendly creatures that will help the protagonists in case of danger [15] therefore animals and protagonists are friends;
- Animals and antagonists fight;
- More than two “good characters” scare the antagonists;
- The antagonists attack the protagonists;
- The magical objects protect the protagonists from the antagonists;
- The musical instruments stop every fight and make everyone happy.

### 3 RESULTS OF CO-DESIGN SESSIONS WITH EXPERTS

During the co-design phase, two sessions are completed with 2 experts with a one-week interval. After initial exploration of the materials, application, and digital platform, they co-designed multiple activity flows and scenarios with the materials to promote specific skill improvements for autism. The experts created the following activity sequences and scenarios with the materials:

**Allow Free Play in Exploration Phase.** At first put together a landscape, a girl and a boy with similar characteristics that are from the same theme to explore peer interaction. Give children some space to explore and to see how it works therefore they can understand that they can take one block out and put another one. This also helps younger children to have the possibility of working on manipulation issues (fitting, functioning, magnetic attraction, etc.). For instance, for a 4-year-old boy with interaction and socialization difficulties, the strategy would be putting the protagonists together and trying to create a scenario: “We have two children. What do they say to each other?”; “The boy just arrived, what shall he do?”. This allows for promoting social rules learning such as saying hello, goodbye, I'm leaving (by taking the character out and simulating the farewell). Verbal competencies can be explored with the children too.

**Start with Positive Stimulus.** Introduce an animal (funny element, positive stimulus) and see children's reactions during the interactions because, in the first session, the aim is to introduce small pieces of information with less noise. At first contact, the possibility of putting an antagonist and seeing that the protagonists



**Figure 2: An example co-designed activity for multiculturalism. In the left picture 1 landscape + 2 children blocks (with different ethnicities) on the tangible platform. In the right picture, the corresponding digital story projection is on the screen.**

are scared may cause an adverse reaction in children, so it is chosen not to do it.

**Together We Can Make a Difference: Introduce Elements Causing Disturbance with Peer Support.** Introduce the antagonist which is the element that causes a disturbance. Two options would be possible. The first one is putting multiple children with one antagonist. The justification for this selection is children with ASD are often self-centered and prefer to play by themselves. The idea here is to show that together children can make a difference: “The boy is scared, but with his friends near him he can beat his fear”; “If we help each other out, we can face the evil guys”. The second option would be putting together 2 protagonists, 1 animal, and 1 antagonist. The animal as a positive stimulus and antagonist support each other whereas the animal defends the children.

**Use Magical Objects as a Substitute of Strategy for a Negative Situation.** Introduce the antagonist with the magical object as a strategy/response that the protagonist uses to deal with a bad situation and transpose it to the child's reality. The therapists designed an example scenario with 1 landscape + 2 children + 1 antagonist + 1 animal and 1 magical object as can be seen in Figure 1B. The corresponding digital story projection of this scenario on the screen can be seen in Figure 1C.

Here, a magical object might be associated with a strategy by asking: “The boy's strategy is the magical object, and what is yours?”; “What could be your magical object?”, “Are you going to get a friend?”, “Do you ask the teacher for help?”, “Who else can help you?”, “Who would you choose to help you?”. Then the therapist can explore support networks too (children sometimes identify more with teachers than with peers).

**Create a “Real Life” Connection to Children's Reality.** Introduction of an antagonist can also be done by asking “When someone who you don't like arrives, what do you do?” This promotes working on emotional regulation/self-regulation because it is easier to talk about the stories since it is the character who is afraid, not the children. At the end, making the transfer with the help of this conceptual distance.

**Work on Multiculturalism and Fears.** The therapist suggests working on multiculturalism using stories by introducing different peers from different cultures. An example scenario designed by

therapists can be seen in Figure 2. In the therapy center, a non-verbal child expresses different behavior when he sees someone from another culture. For example, when he sees a person with a different skin color than him, he tends to look and stare (strangeness due to difference). Together with the therapist, they can question how the interaction would be since the child has difficulty and keeps staring. Introduce characters, refer to their differences, and discuss on the differences with the child. Realize social rules and train the interaction and emotional expression.

An example scenario would be a combination of multiple skills as follows: A girl who lives in country x meets a boy who looks similar to her. Ask the child “What do we say?”, “What do you want to do with the colleague/friend?” and give flexibility or make suggestions if it is a child with fixations (only playing the same game) – e.g. saying “The boy does not want to, what other game can we play? The boy suggests playing something different, is that ok?”.

Before taking the boy away, ask “The boy is leaving, what do we say? Let’s say goodbye, let’s say goodbye, see you tomorrow”. Then introduce another boy from a different ethnicity and say “Another boy has arrived and he’s different from the ones you know. What’s different?”. Possible answers would be skin tone, eye shape, clothes, hair, etc. Afterward ask the child: “What’s his name?”; “Let’s say hello!”; “This boy has some funny customs in his country! You see, he plays this game, do you want to try a new game?” and then try to introduce a new activity (therapist-child). Then go back to the narration, working on joint attention and doing those two things simultaneously.

**Promote Turn-taking and Peers Interaction.** Through using magical objects which are like toys that children share in daily life, some peer interaction skills can be promoted through storytelling. An example possible scenario would include two children with a pair of shoes (magical object). A pair of shoes is put on and one of the children wears it and the other waits). The therapist says “We only have one. We have to wait, don’t we?”).

Based on the children’s responses and the possibility of insisting on getting what they cannot have (for example: they want the shoes exactly now rather than waiting their turn), work with them on tolerance to frustration. Here the strategy is translating these ideas to real-life situations where it won’t be possible for them to have what they want right away such as there’s only one computer at home that’s being used, you do something else in the meantime; your friend is playing and we have to wait - and take the opportunity to work on empathy issues (friend is happy playing while the child waits: “Don’t you like to see him happy?”; “We see the friend playing and then we switch and then the friend too will watch us”).

**Overcome Routine Issues such as Repetitive Behavior.** When the child starts to explore, if the psychologist tells them “We have to put the landscape first and then we introduce the boy and the instrument”, the tendency will be “I always go for a landscape, I always go for a boy, I always go for an instrument”. The child will tend to repeat what the psychologist/therapist does.

The strategy to overcome this could be to show that if the blocks are not in a specific place, but in another position, it will create the same output. If it’s not the girl it can be the boy as well. Try to mix characters such as indicating that “We don’t always need to

have this one”; or “We can have two different boys”. This creates a possibility to work on cognitive flexibility (also giving flexibility to name the characters and to create activities).

**Build Tolerance to Change: The boy who likes the meteorology.** Some children are sensitive to changes, for instance, there was a boy in a therapy session who doesn’t like rain and who is sensitive to changes in the weather. A strategy would be exploring weather issues and overcoming them by using the image of the fish that appears when it rains in the digital story and showing them that there are fun things in the rain (“Look! You can swim with the fish!”). Here the aim might be training not only frustration tolerance but also flexibility and acceptance.

**Categorization and Organization of Thoughts.** If the child particularly needs to organize his thinking/structuring or has a tendency towards notorious digression in reading and writing texts, A strategy would be keeping him focused, structuring a story, and writing what was structured in order. Another exercise would be putting the same types of blocks together such as landscapes, instruments, magic objects, etc by categorization of pieces by their backgrounds.

#### 4 FEASIBILITY IN THERAPY SESSIONS

The activity was integrated into multiple therapy sessions of five children with ASD and the therapists used the system independently without the help of the researchers as can be seen in Figure 1D. Storytelling as an interactive activity was used in collaboration with the child in therapy and the therapist, who often needed to start the session and propose questions to guide the activity. In this context, tangibles served as a concrete reference point and material to touch, try, and explore with.

Often therapists made direct suggestions on what to do with the characters, such as in some sessions the therapist started the session with a drawing of the child’s hand where each finger contained a question: “where, who, how, when, why” to give them clues to start the story. In some cases, children started by sorting the blocks by categories: weather, magic, animals, and objects. Often children were completely immersed in the construction of the narrative. While manipulating the tangibles, children were observed to be very expressive, verbalizing what the character does and what happens on the screen, making associations with real-life situations, naming the characters, showing curiosity by raising questions such as “what if we replace...” and “let’s see what happens...”, also performing experiments with the tangibles “I’m going to put all the weather blocks together and see what happens”. The therapists mentioned that the use of the materials promoted greater involvement of the child, as well as greater emotional expression, emotional regulation and maintenance of attention and focus.

Overall, initial observations of the feasibility study show the practical viability of incorporating smart tangible-based digital storytelling into autism therapy sessions. The interactive nature of these activities fosters meaningful engagement, promoting social interaction, and communication in children with ASD.

## 5 CONCLUSION

The results obtained from the co-design phase, where experts collaborated to design activities using smart digital manipulatives offer valuable insights that can be generalized for the broader design of activities in autism therapy. The activity flows and scenarios created during these sessions provide a structured framework for promoting specific skill improvements in children with autism.

For instance, allowing free play in the exploration phase not only facilitates peer interaction but also addresses manipulation issues, and verbal competencies. Similarly, starting with positive stimuli and gradually introducing elements causing a disturbance, such as an antagonist, helps children learn emotional regulation and coping strategies in real-life situations. Additionally, the incorporation of multicultural elements and magical objects serves to broaden children's perspectives and provide them with coping strategies for unfamiliar situations while working on multiculturalism and diversity awareness. Addressing routine issues and building tolerance to change through themed activities such as exploring weather issues demonstrates effective strategies for promoting flexibility and acceptance. Moreover, activities focusing on categorization and organization of thoughts help enhance cognitive skills, aiding children in structuring their thinking and communication.

These findings highlight the importance of personalized and interactive approaches in addressing the diverse needs of children with autism. Moreover, the successful integration of these activities into therapy sessions, as demonstrated by therapists' independent use, emphasizes our approach's feasibility and potential effectiveness. Children's engagement and interaction with tangible objects during storytelling sessions demonstrate the system's potential to facilitate creative expression and narrative development. With continued refinement and evaluation, smart tangible-based digital storytelling holds significant promise in increasing engagement and enhancing therapy outcomes for children with ASD.

In future design iterations, we will investigate involving children with ASD in the design process. Future work will also focus on long-term system integration into autism therapy and qualitative and quantitative triadic interaction analysis of the child, therapist, and the tangible platform.

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