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Kiki: designing a socially assistive robot with Bangla augmentative and alternative communication (AAC) for children with mild to moderate (levels 1 and 2) autism

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Kiki: Designing A Socially Assistive Robot with Bangla Augmentative and Alternative Communication (AAC) for Children with Mild to Moderate (Levels 1 and 2) Autism

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14 December 2025

Dissertation submitted in partial fulfillment for the degree of Bachelor of Science in Computer Science & Engineering

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Testimonial

We are aware of the fact that plagiarism is strictly prohibited and it conflicts with our university's rules and regulations. We assure that our work is authentic. We used some copyrighted material and models from legitimate sources in our project and gave them proper credit according to international standards.

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Acknowledgement

We start by thanking our creator with sincerity for the strength, perseverance and ability to work hard which has helped us through with our senior project. We thank our supervisor, Dr. Mohammad Shidujaman, Assistant Professor at independent university, Bangladesh. His incredible leadership, his dedication, and perseverance, have assisted us in getting through the highs and lows of our project and to deliver this report. Through his expert advice, our project proceeded with ease and his advice was essential at all times. We are pleased to acknowledge the committee members who made the effort of making the defense meeting enriching and fruitful. Their comments and recommendations are of great importance which enhanced the quality of our work.

We owe a great debt of gratitude to therapists, educators, and children at the ASD centres in Dhaka to let us take part in our study and support our study. Their time, insights, and feedback helped us build kiki with the user-centered design. We also appreciate our family and friends for their ongoing support and encouragement during our B.Sc. program, especially during the difficult times of our final project. Besides that, we would also like to thank Independent University Bangladesh to provide an challenging senior project program which has been incredibly helpful for us.

In addition, we would like to express our gratitude to Independent University Bangladesh for offering a stimulating senior project program that has been vital in helping us build our skills and prepare for the challenges in the research field.

Letter of Transmittal

Mohammad Shidujaman, PhD
Senior Project Supervisor, Assistant Professor
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Independent University, Bangladesh.

Subject: Senior project report on "Kiki: Designing A Socially Assistive Robot with Bangla Augmentative and Alternative Communication (AAC) for Children with Mild to Moderate (Levels 1 and 2) Autism."

Dear Sir,
We are truly honored to present our senior project report on **"Kiki: Designing A Socially Assistive Robot with Bangla Augmentative and Alternative Communication (AAC) for Children with Mild to Moderate (Levels 1 and 2) Autism."**

Working on the Kiki robot under your guidance has been a very satisfying experience. It allowed us to integrate technical skills with great sense of social purpose. This project taught us important lessons about human-centered design and working across disciplines, and the challenges of making technology for vulnerable people. From the initial idea to the final working prototype, Kiki demonstrates the knowledge that we acquired and the effort that we invested in each of the steps.
Your constant support and expert guidance also helpful feedback helped to deal with the challenges of the project and kept us going. We owe a lot of gratitude for your help on this process and in our university semesters.

We hope this final report shows and demonstrates how much we worked on Kiki robot, and we will meet your expectations. It has been a real privilege to learn from you, and to be able to help in an avenue that has so much great impact.

Your Regards,
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Abstract

Children with Autism Spectrum Disorder (ASD) in low-resource settings often do not have access to engaging, culturally relevant therapeutic tools. This paper introduces "Kiki" a Socially Assistive Robot developed to a communication and educational companion for Bangla-speaking children, including those with level 1 and 2 ASD children (nonverbal and minimally verbal). Kiki was created in close collaboration with local therapists, with a culturally responsive approach at its core. It consists of a touchscreen Bangla Augmentative and Alternative Communication (AAC) interface inspired by the Picture Exchange Communication System (PECS). Kiki uses this interface, featuring with daily quiz learning, and empathetic, AI-driven interactions to provide a supportive environment for children to build vocabulary, express emotions, and practice social communication. A thorough evaluation in several autism centers in Dhaka showed strong acceptance and engagement Therapists praised the robot's easy-to-use Bangla interface, while children formed a special bond with Kiki, showing increased focus and motivation during sessions. As a proof of concept made for a fraction of commercial robots, Kiki provides a caring and scalable model for helping children with ASD in diverse linguistic communities around the world.

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Chapter-1

Introduction

Autism Spectrum Disorder (ASD) is a disorder that children face severe problems with communication and social interaction. Such problems are even more acute in low-resource locations where the availability of therapy tools is restricted. Socially Assistive Robots (SARS) and assistive technologies have been very promising in assisting in communication. Nevertheless, many of the communities in the world cannot access them due to their high-prices, language barriers and cultural irrelevance. One of such places is Bangladesh where thousands of children with ASD fail to get the assistance they deserve. This thesis introduces Kiki, an affordable, Bangali-speaking, Socially Assistive Robot that seeks to fulfill this critical requirement by designing it culturally appropriately and evaluating the key features practically.

1.1 Background and Motivation

Autism Spectrum Disorder (ASD) is a complex condition that affects how a person develops neurobiologically [1]. It often leads to ongoing difficulties in social communication, interaction, and repetitive behaviours [2]. To the millions of children with the diagnosis, the issues can severely affect the educational development of ASD all over the world, social competencies, and general well-being [3]. One of the most difficult things a non-verbal person (or a person with minimum verbal skills) has to cope is initiating and continuing communication [4] with verbal children with ASD. This barrier can distract their learning process, expressing their needs and feelings, and relationship development. Augmentative and Alternative Communication (AAC) can be used to overcome challenges.

The systems are now important in treatment [5] These devices assist in aiding or substituting verbal language and provide a very important means through which people can express themselves. One of the Picture Exchange Communication System (PECS) is most developed AAC strategies.[6] PECS also trains the learners to begin a conversation by providing a visual representation of what they desire to a partner. It has a structured and visual format that is effective with a large number of children with ASD.

Nevertheless, the conventional PECS requires the use of physical cards and binders that may be complex to plan, perform, and maintain. Although digital AAC apps have been developed to resolve such issues, they can be associated with significant limitations. These are the apps that are majorly oriented belonging to English, may be costly, and generally not as engaging and interactive needed to sustain the attention of children with ASD. They tend to require continuous assistance from a person to be effective.

At the same time, the area of Socially Assistive Robotics (SAR) shows great promise in autism therapy [7]. Robots like NAO, Kaspar, and Milo provide a predictable, patient. This can help lessen the social anxiety that sometimes comes with human-led therapy. Research consistently shows that children with ASD often display increased attention,

motivation, and new social behaviors, such as trying to imitate and making eye contact, when they interact with robots.



Figure 1: children interacting with kiki robot

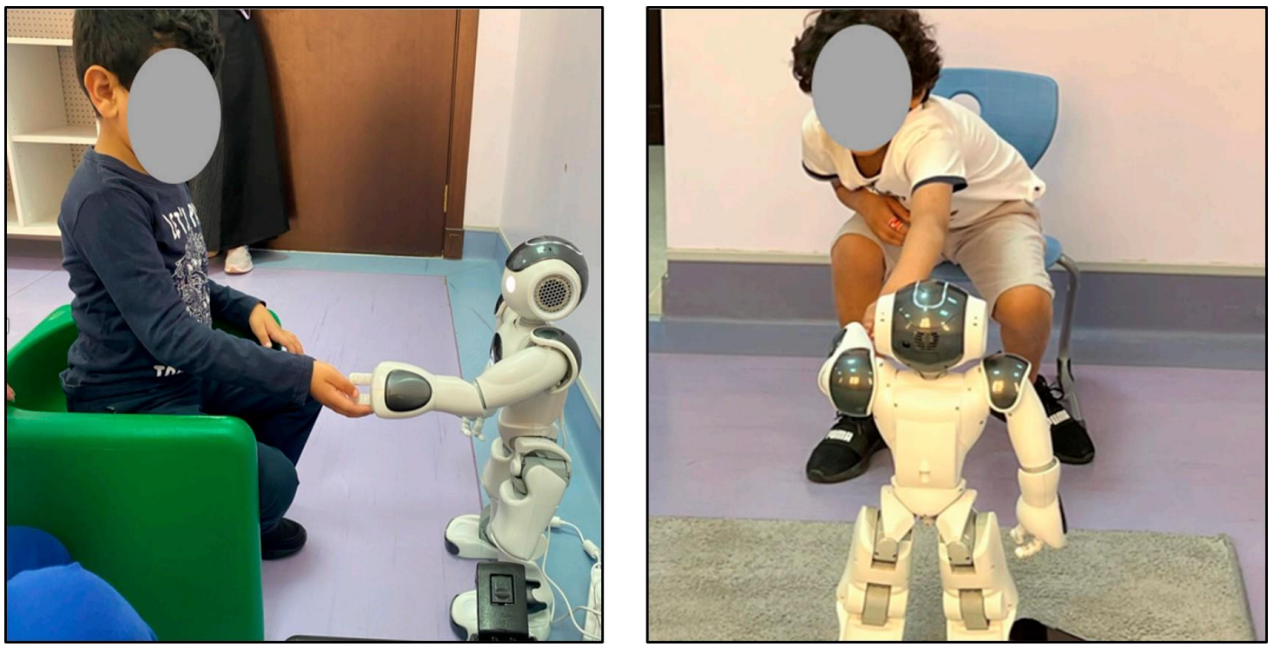


Figure 2: Examples of ASD robots which were developed and tested on ASD Centres[39]

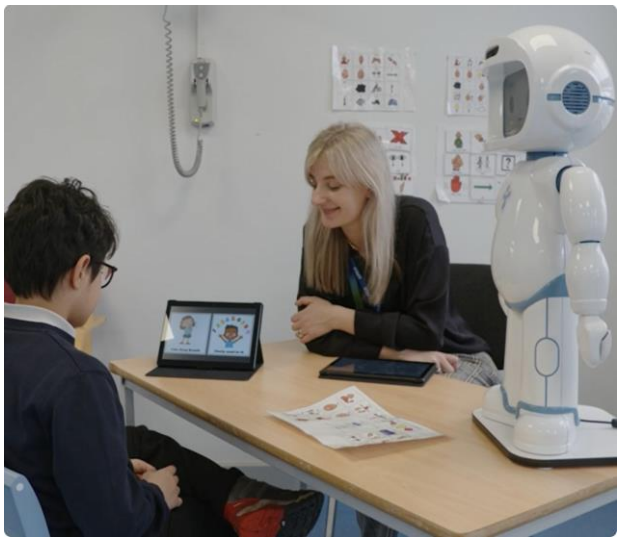


Figure 3: Examples of ASD robots which were developed and tested on therapy

Source: https://luxai.com/.



Figure 4: Rachel, Speech Therapist, Maple Grove School

Source: https://luxai.com/.

Despite this potential, access to these technologies is severely limited globally. The majority of sophisticated AAC instruments and commercially available SARs are created in Western nations [8]. As a result, non-English speaking communities' linguistic and cultural needs are not satisfied by the solutions. This poses a significant issue in resource-poor areas like Bangladesh. Many people cannot afford commercial robots due to their high cost, which is frequently over $ 10,000. Furthermore, the current tools are ineffective due to language barriers[9]. Because of this, a lot of children with ASD don't get the regular, culturally relevant help they require to thrive.



Figure 5: Bruno, Director of Sessad center for special needs education

Source: https://luxai.com/

1.2 The Challenge of Autism Support in Resource-Constrained Contexts

The case of Bangladesh is a bright illustration of the worldwide problem of granting equal access to assistive technology to everyone [10]. The nation is in dire need of cheap, culturally-sensitive therapeutic aids. The gap was indeed identified in a scoping review, which indicated a sense of urgency among solutions that are specific to the context. Challenges can be of many different kinds:

Financial Barriers: The high cost of imported assistive devices and robotics can no longer be afforded by most of the families and therapy centers.

Linguistic Mismatch: Most of the Bangla-speaking children do not cope with tools mostly used in English, as they cannot easily use them and comprehend them immediately.

Cultural Irrelevance: The pictures, symbols and social scripts within Western instruments are usually not appealing to the Bangladeshi children. This makes them less useful and demoralising to interact with. Numerous existing solutions need one-on-one continuous attention of a therapist or caregiver, which is a strain on already limited human resources. This set of problems results in a major unmet need, as the children with ASD in Bangladesh and elsewhere are deprived of the means to acquire the necessary skills of social and communication growth. This requirement served as the foundation for the Kiki project.

1.3 Significance and Scope

The Kiki project would be a major progress towards increased access to assistive technology among children with ASD. This project aims at developing a wide, expandable, and culturally sensitive model of autism care as opposed to designing a robot. The project is important in a number of aspects:

Cultural and Linguistic Adaptation: Kiki was developed specifically to help Bangla speaking individuals mostly children. It makes sure that the tool is available and



Figure 6: Social robot Vector (by Anki)

Source: ankicozmorobot.com/vector-robot.



Figure 7: EMYS (by emys.co).

Source: ankicozmorobot.com/vector-robot.

relatable to its intended users as soon as possible by incorporating a digital AAC board with symbols relevant to the culture and the presence of clear Bangali voice output.

Affordable and Accessibility: By leveraging affordable, off-the-shelf components (e.g., Raspberry Pi, 3D-printed body) and open-source software, Kiki is designed to be a fraction of the cost of commercial SARs, making it a viable option for widespread deployment in schools and therapy centers.

Multimodal Engagement: Kiki moves beyond a simple AAC device by incorporating gamified learning, attention duration recognition, and progress tracking. This multi-modal approach is designed to maintain a child's attention and cater to different learning styles, increasing the potential for therapeutic benefit.

A Practical Framework: The project provides a valuable input in the form of a



Figure 8: Miko robot.

Source: https://miko.ai

practical blueprint on how to design low-cost and culturally-appropriate SARS and this input can be utilized in other resource-constrained settings in the global context.

The lifecycle of the development of this thesis includes the entire process of Kiki development: the identification of user requirements by means of the extensive interaction with therapists and educators; the user-oriented design of the prototype hardware and software; the realization of the main functions, i.e. the Bangla AAC, attention duration recognition, and gamified modules; and the strict testing of the impact of the prototype using the 3-week user study in the real-world autism centers in Dhaka.

1.4 Research Objectives and Questions

The research objectives and questions are outlined below: The main purpose of the study is the design, execution and evaluation of a cheap, culturally sensitive Socially Assistive Robot that can effectively facilitate communication and social development of ASD children in Bangladesh.

The objectives that were set to help guide this research are: To create and develop the full hardware and software structure of the project ”Kiki” a miniature SAR that incorporates a Bangla AAC system, a game base quiz learning experience, Human and robot attention duration and progress tracking.

In order to make the design culturally and linguistically relevant to the children speaking Bengali language, to conduct a collaborative, user-centered approach where the design process is done in collaboration with local therapists and educators.



Figure 9: Kiki operating in an environment with proper supervision

To perform a comprehensive assessment of the usability and engagement of Kiki and its perceived effectiveness within the context of actual therapy methods using direct observation methods and feedback.

To obtain and express a scalable framework of the development of affordable, contextually relevant assistive robots. These are operationalized on the basis of the following research questions (RQs):

- RQ1: To what extent do children with autism spectrum disorder (ASD) interact with a socially assistive robot (SAR), who speaks the Bangali language, to enhance their communication skills?
- RQ2: What about the robot attracts children with ASD, the therapists, and families during the sessions to like or dislike? How do they express their preferences in interviews and focus groups?
- RQ3: Based on user feedback, what features could enhance the effectiveness and cultural relevance of a low-cost Bangla-speaking SAR?

By addressing these questions, this research seeks to contribute a validated, practical solution to the global challenge of providing scalable and equitable autism support, positioning Kiki as a transformative tool in the landscape of assistive technology.

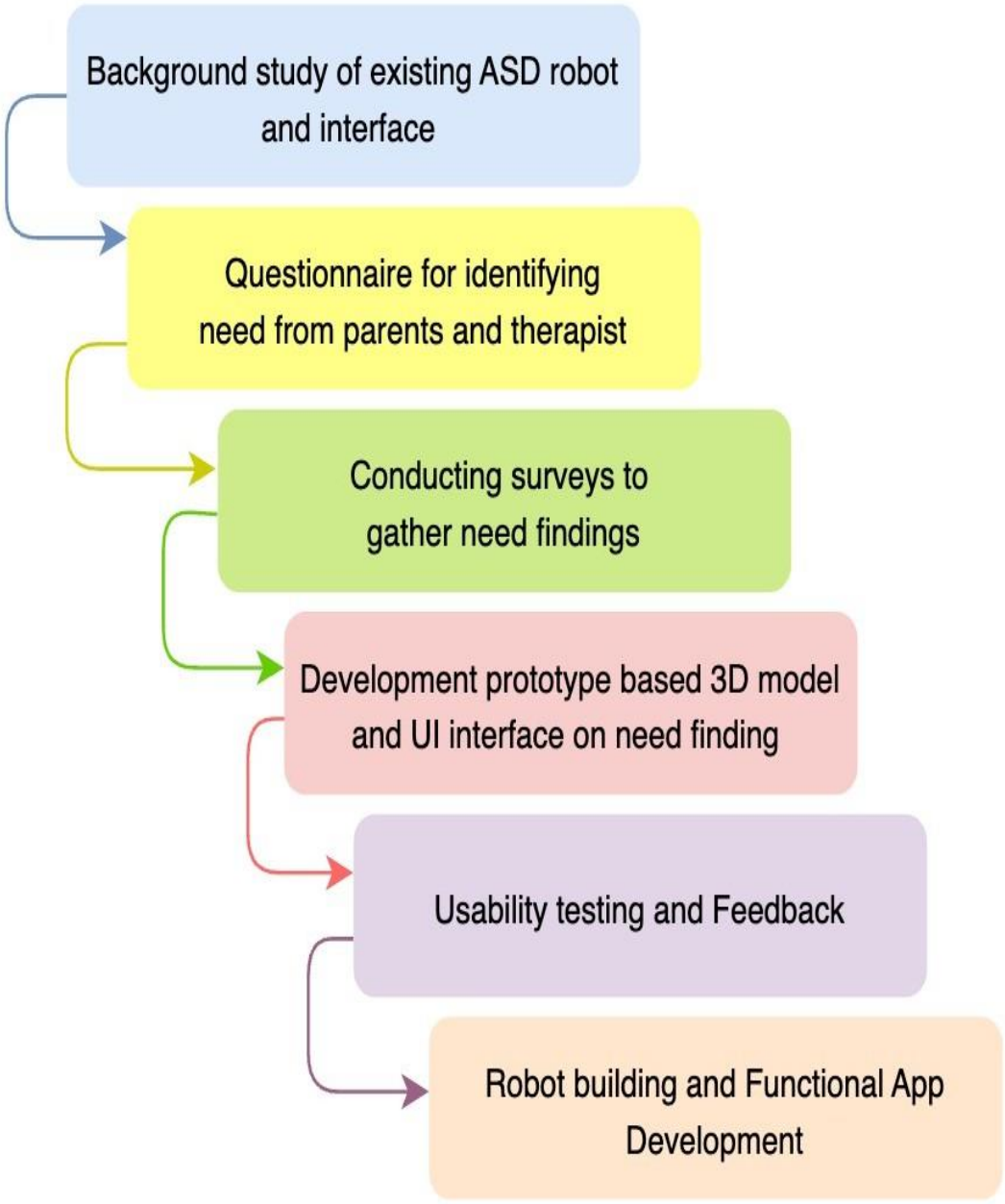


Figure 10: Research Methodology

Chapter-2

Literature Review

2.1 Autism Spectrum Disorder (ASD) and Communication Challenges

Autism Spectrum Disorder (ASD) is a multifactorial neurodevelopmental disorder that is defined by incessant lack of social communication and social interaction in diverse settings as well as limited, repetitive behavioral, interests or activities patterns or patterns of activities of interest [11]. In a large percentage of people with ASD, these issues are reflected in the form of severe problems with verbal interaction. Studies have shown that 25-30% of children with ASD do not talk or talk little and as such, a small number or none at all talk [12]. These communication barriers go beyond being symptoms to becoming major barriers to education, social integration and quality of life. Children with ASD tend to have high frustration steads because they do not have good channels of communicating their need, desires, and emotions, a factor that contributes to problematic behaviors in children with the condition [13]. Moreover, the lack of the possibility to establish the social interaction hinder the formation of the peer relationship and restrict the learning opportunities dependent on the social exchange mediated by it [14]. This is why offering effective communication support is not a side service but one of the main and absolute elements of intervention of many people with ASD.

2.1.1 DSM-5 Levels of Autism Severity

Level 1: Requiring Support Social Communication: The individual can develop problems in social communication, i.e. trouble initiating social communication and responding abnormally or ineffectively to social communication by others. Restricted, Repetitive Behaviors: Behavioral inflexibility can result in great dysfunction in at least one situation. He or she might find it hard to alternate activities.

Level 2: Requiring Substantial Support Social Communication: There are significant deficits in verbal and nonverbal skills of social interactions in individuals, despite the support they get. Their interactions in the society are restricted to very small and specific interests.

Repetitive, Restricted Behaviors: Inflexibility and restricted behaviors are pervasive to the point of being noticeable to others and disruptive in a number of situations. They feel upset and/or incapacitated with the switching of attention or activity.

Level 3: Requiring Very Substantial Support Social Communication: There are

gross failures in verbal and nonverbal social communication amongst the individuals, which result in gross functional impairment. Their initiation of social interactions are very low and their response to social overtures is also low.

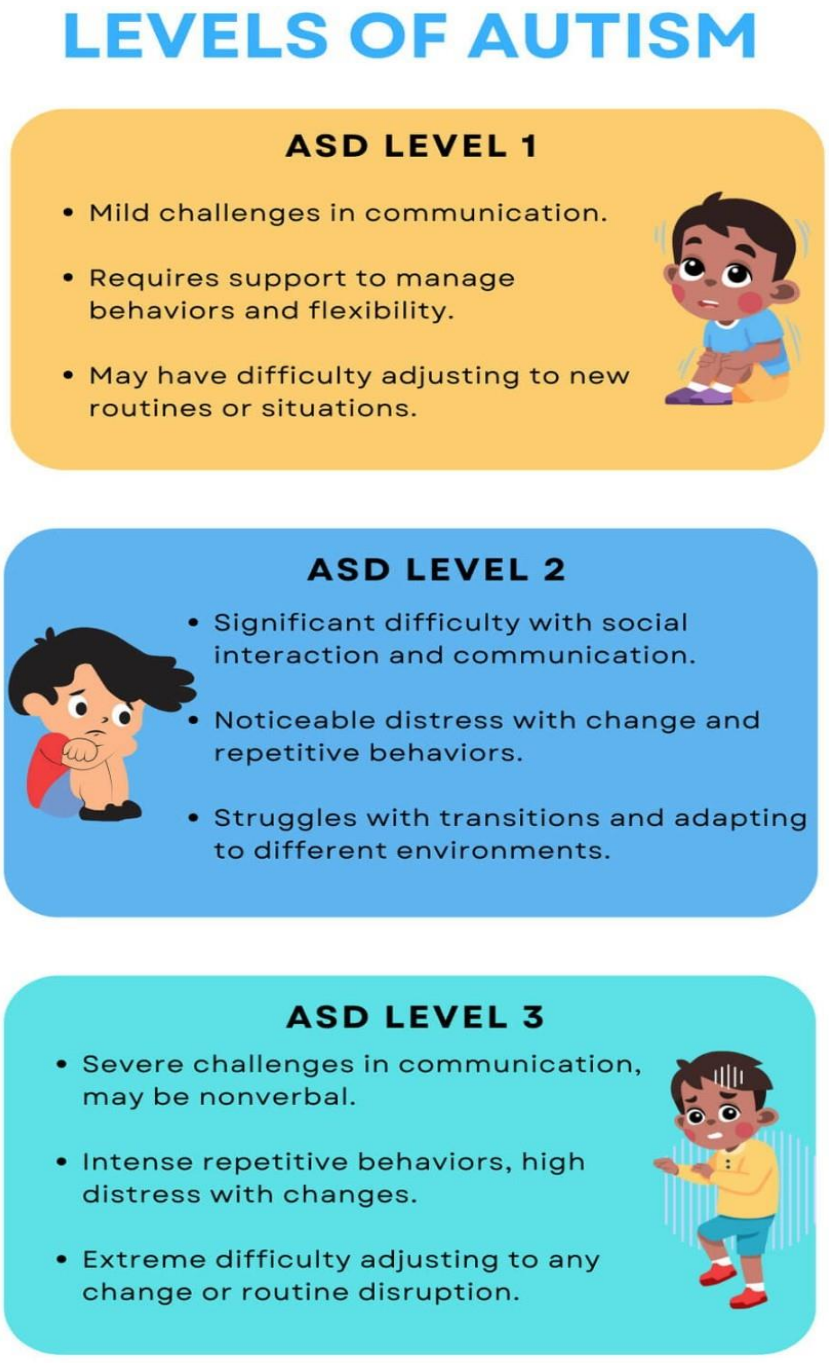


Figure 11: Levels of Autism

Inflexibility of Behavior- Repetitive Behaviors: Inflexibility, severe inability to deal with change, and other restricted behaviors significantly disrupt functioning in all spheres. They find it very painful to switch attention or action.

Table 2.1: Characteristics, severity, and diagnosis of different types of Autism Spectrum Disorder (ASD).

Type	Characteristics	Severity	Diagnosis
Classic Autism (Autistic Disorder)	Significant challenges in social interactions, communication, and a high level of repetitive behaviors and restricted interests.	Often considered the most severe form on the spectrum.	Typically diagnosed in early childhood.
Asperger Syndrome	Difficulties in social interactions and repetitive behaviors, but without significant delays in language or cognitive development.	Considered a milder form of ASD.	Often diagnosed later in childhood, sometimes even in adolescence or adulthood.
Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS)	Individuals exhibit some but not all of the characteristics of classic autism or Asperger syndrome.	Varies widely, from mild to severe.	Typically used when the full criteria for classic autism or Asperger syndrome are not met.
Childhood Disintegrative Disorder- der (CDD)	Normal development for at least the first two years followed by a significant loss of previously acquired skills (language, social, and motor skills).	Considered a rare and severe form of ASD.	Typically occurs between the ages of 3 and 4.
Rett Syndrome	Normal early development followed by a loss of purposeful use of the hands, slowed head growth, and intellectual disability	Severe, primarily affecting girls.	Often diagnosed between 6 months and 2 years of age.

2.2 Augmentative and Alternative Communication (AAC) Systems

AAC involves a broad spectrum of methods and instruments that serve to assist or substitute verbal communication among people with intricate communicative requirements. In the case of ASD children, AAC systems can be crucial in allowing them to express themselves and to interact with people around them [15].

2.2.1 The Picture Exchange Communication System (PECS)

The Picture Exchange Communication System (PECS) stands as a well-established, evidence-based AAC methodology specifically designed for individuals with ASD and other social-communication deficits [16]. Created in the context of applied behavior analysis, PECS trains the learners to use it to initiate the communication process by picking and giving a picture of a desired item to a communicative partner physically. Its pictorial character suits well with the learning style of numerous children with ASD and most of them tend to excel in visual processing.[17] Six stages make up the system where simple single- picture exchange then develops to commenting and answering questions, thus creating the foundation and advanced communication skills.

2.2.2 Autism Spectrum Disorder (ASD) and Communication Challenges

Limitations of Existing Digital AAC Tools While digital AAC applications have emerged, transitioning physical PECS cards to tablet-based interfaces, they often inherit limitations from their predecessors or introduce new challenges [18, 19]:

High Cost: Many commercial AAC applications remain expensive, creating significant barriers to access for families and institutions in resource-constrained settings [20].

Linguistic Inaccessibility: The vast majority of these tools maintain English-centric designs, with limited or no support for languages like Bangla [21].

Lack of Embodied Engagement: Digital apps on tablets lack the physically present, engaging nature of social robots, which has demonstrated unique capabilities in capturing and maintaining the attention of children with ASD [22, 23].

Dependence on Facilitation: Both physical PECS and many digital applications frequently require continuous, one-on-one human facilitation to maintain child engagement and guide interactions, placing substantial burdens on therapists and caregivers [24].

2.3 Socially Assistive Robots (SARs) in Autism Therapy

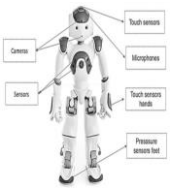
Socially Assistive Robotics (SAR) represents a fast-growing area that is aimed at creating robots which could offer aid based on social interaction as opposed to physical contact [25]. To ASD children, SARs offer a very interesting medium which has a number of benefits over conventional methods of treatment.

2.3.1 Robots for Social Skills and Engagement

Low-stress can be achieved through the predictable, patient and non-judgmental character of robots in learning conditions, which is effectively alleviating the social anxiety which is normally related to human-led therapy sessions [26, 27]. Without the need to repeat, robots are capable of doing so on a regular basis. expressing frustration, thus, providing. [28].

2.3.2 Comparative Analysis of Commercial SARs

Multiple robotic platforms have been investigated for therapeutic applications, each demonstrating distinct characteristics and capabilities:

Research/Robot	Robot and Application	Robot image
Kaspar	A social companion robot aimed at improving communication and social interaction in children with ASD using simplified facial expressions and predictable behaviors.	
Moxie	Conversational AI to support emotional, social, and communication development in children with ASD.	
NAO	Applied in therapy, education, and research to support learning, communication, and social engagement.	
Milo	Specialized autism-therapy robot focusing on emotional recognition, social skills, and structured communication training.	
Pepper	Humanoid robot used for social interaction, emotional engagement, and educational activities.	

QTrobot	Child-friendly humanoid robot for ASD therapy targeting communication, attention, imitation, and learning.	
Sanbot	General-purpose service robot explored for assistive and educational interactions.	
KIKI	Low-cost, Bangla-speaking socially assistive robot with integrated AAC for culturally relevant autism therapy.	

NAO & Pepper: These advanced humanoid robots have been successfully deployed to teach social cues, emotions, and even complex behaviors like imitation [29, 30]. However, their high degree of human-likeness may intimidate some children, while their substantial cost presents barriers to widespread adoption [31].

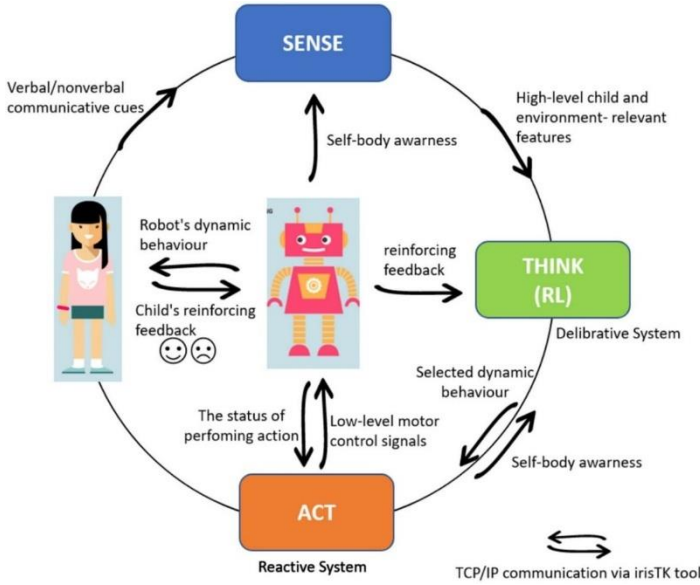


Figure 12: Kaspar's deliberative-reactive control architecture (Sense-Think-Act) for semi-autonomous CRI[32]

Kaspar: Specifically designed with simplified, less intimidating features, Kaspar has proven effective in teaching turn-taking, imitation, and basic social skills [32, 33]. Its

design philosophy prioritizes approachability and safety, making it particularly suitable for therapeutic settings.

Milo: This robot explicitly focuses on teaching social and emotional skills to children with ASD, demonstrating the potential for SARs to deliver structured curricula in consistent, repeatable manner [34].

Meta-analyses consistently report that children with ASD exhibit increased attention, motivation, and novel social behaviors—including spontaneous imitation and eye contact—when interacting with robots compared to human agents or computer-based interventions [35, 36].

2.4 The Critical Need for Cultural and Linguistic Adaptation

Even though symbols for Augmentative and Alternative Communication (SAR) technologies and Augmentative and Alternative Communication (AAC) tools show a lot of promise, there are big differences in how well it work and how easy they are to get throughout everywhere. The dominance of development in Western environments produced solutions that could be, and still are, predominantly English-centred, imbued with cultural references which are incongruent with users in other areas [37, 38].

Consequently, important barriers to adoption and efficacy are created in culturally di- verse settings. In Bangladesh, systematic reviews have been done to record acute deficits in affordable and culturally appropriate assistive technologies [39]. Products that provide English language outputs and incorporate Western iconography like hamburgers or snow images have a small relevance for children who live in rural Bangladeshi communities. Recent research proposes for an evolution from universal design frameworks to cultural adaptability, highlighting the significance of co-design processes that involve local ther- apists, caregivers, and users throughout phases of development [40, 41]. This strategy makes sure that the final artifacts are not only translated into other languages, but also fully adapted to the culture, taking into account local social norms, values, and aesthetic elements that people can recognize. This strategy makes sure that the final artifacts are not only translated into other languages, but also fully adapted to the culture, taking into account local social norms, values, and aesthetic elements that people can recognize.

2.5 Robotics and Accessible Design Frameworks

The high financial expenditure that comes with commercial robotic platforms like NAO as well as Milo creates a limitation to their usefulness in being accessible in the widespread deployment across the globe. This economic constraint has led to innovation in affordable robotic systems, benefiting from affordable platforms (e.g. Raspberry Pi and Arduino) in combination with additive manufacturing techniques for custom corporeal fabrication [42, 43]. Empirical studies of various Arduino based prototypes show that advanced robotic behaviours are achievable at a minimal fraction of standard commercial price [44]. Such methodologies deliberately focus on operational efficacy and accessibility, sacrificing the pursuit of high fidelity humanoid aesthetics that make them well suited to resource constrained environments.

2.6 AI in ASD Intervention: Attention Duration Recognition Personalized Learning

Recent advances in Artificial Intelligence (AI) are enabling increasingly sophisticated and personalized interactions in therapeutic settings. The integration of AI-powered modules offers several promising directions:

Robot Facial Emotion : Utilizing tools like OpenCV, robots can now express basic emotional states to children's facial expressions, allowing for adaptive responses to perceived emotional cues [45, 46].

Natural Language Processing (NLP): While challenges in maintaining a complex discourse persist, NLP methods promote the translation of primitive verbal commands to textual representations and support structured and responsive discourse in ethnically controlled therapeutic environments [47, 48].

Progress Tracking: AI-driven data logging systems can track children's interaction patterns, vocabulary use, and task performance over time, providing valuable data-driven insights to help therapists and parents personalize future interventions [49].

2.7 Research Gap and Kiki's Proposed Contribution

The literature review shows that there is a unique and important gap at the intersection of low-cost socially assistive robots (SARs) and integrated culturally and linguistically adapted augmentative and alternative communication (AAC) systems. While proven robots like NAO show efficacy in controlled environments, their prices are crippling to large-scale deployment [50]. On the other hand, although there are low-cost AAC ap- plications, they do not offer the embodied, enticing presence of social robots and often lack necessary cultural adaptations [51]. The Kiki project was created specifically to fill in this identified gap. Our work brings a practical framework for the development of an affordable and Bangla-speaking SAR with PECS-inspired digital AAC interface as its core therapeutic component. By following the philosophies of user-centered design from the early stages of the project and the linguistic and socio-economic specific con- text of Bangladesh, Kiki is attempting to offer a scalable and accessible solution with a balance between technological robustness and cultural resonance. The system synthesises the tried and tested methodology of PECS and the engagement potential of SARs, the affordability of maker movement technologies and personalization capabilities of today's brand of AI into a coherent system that is designed for populations who historically have been excluded from mainstream assistive technology development.

2.8 Human–Robot Interaction (HRI) and Social Robots in Therapeutic Contexts

Human-Robot Interaction (HRI) is a multidisciplinary field that studies the ways that human beings perceive, interact and form social relationships with robotic agents in a variety of settings. Within therapeutic and educational contexts, HRI plays a key role in evaluating the long-term effectiveness, acceptability and usability of Socially Assistive Robots (SARs). The quality of interaction between a child and a robot is determined

not only by technological factors, but also by psychological, developmental and cultural variables, which determine the way children interpret the behavior of the robot, communicative signals and physical presence of the robot[22, 23, 29]. Social robots designed for HRI generally include such features as small facial expressions, controlled gestures, predictable movement patterns, and affable voices, to create positive interactions. Empirical evidence suggests that children with autism spectrum disorder (ASD) tend to respond more reliably to structured, predictable agents as opposed to dynamic and spontaneous human partners; the sense of prediction allows sensory overload and anxiety to be reduced, allowing the child to focus on the interaction itself [34, 53, 65].

Robots can act as "social mediators," delivering simplified social cues that support interaction and facilitate learning important social skills such as joint attention, turn-taking, imitation, and as a beginning with simple conversation[52, 56, 64]. A major focus in HRI research is on the issue of robot personality, which includes the way the traits of being warm, friendly, enthusiastic, or calm are expressed in appearance, voice, timing, and behavior. Studies have shown that children with ASD typically prefer robots that are nonthreatening, visually simple, and emotionally neutral or mildly positive, for example, to attend to them (see young children)[29, 57, 59]. This preference has informed the design of popular therapeutic robots like Kaspar, QTrobot and Moxie, which take great efforts to avoid being too human-like in appearance to avoid confusion or fear[52, 54, 55]. Another major critical area in HRI is engagement measurement. Researchers generally track eye gaze, facial expressions, task completion, response time, and interaction duration to assess a robot's capture and maintenance of attention. Robots with expressive faces and head movements and with responsive behaviours generally provoke higher engagement than static screens or noninteractive devices[11, 34, 49]. HRI also focuses on the concept of co-regulations, where the robot adjusts the behaviour depending on the emotional or behavioural state of the user. Recent findings have supported the idea that adaptable robots may be especially helpful for ASD interventions because they can adjust task difficulty, emotional expressions or vocal tone to match a child's comfort levels[22, 45, 66, 67]. Such adaptability helps to build trust and minimize the chance to experience distress when interacting with them.



Figure 13: Augmentative and Alternative Communication (AAC) Communication in English[70]

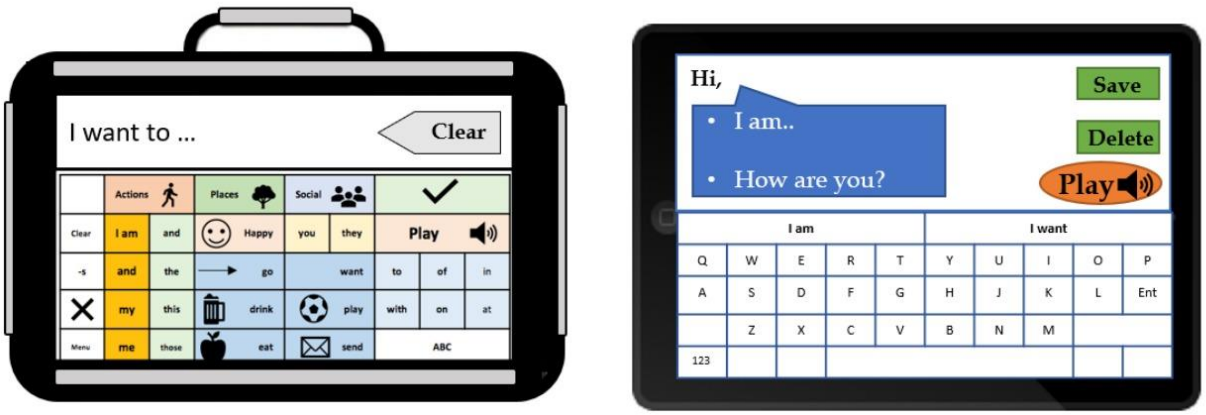


Figure 14: Dedicated Touch-based device and running AAC App speech generation capability [69]

In summary, HRI is providing useful information about design principles, behavioral patterns, and interaction strategies for robots to serve as effective therapeutic partners. These insights directly inform the development of Kiki, ensuring that its expressive face, predictable movements, Bangla speech, and simplified emotional signals follow established HRI guidelines for engaging children with ASD in safe and meaningful ways.[23, 33, 34, 64].

2.8.1 Comparative Analysis with TINY Robot

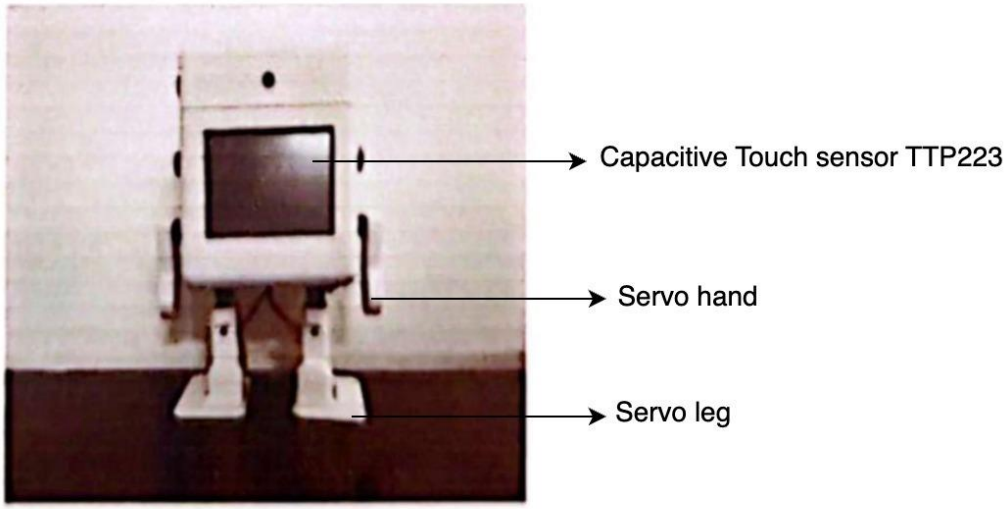


Figure 15: Physical configuration of the Socially Assistive Robot 'TINY'[68]

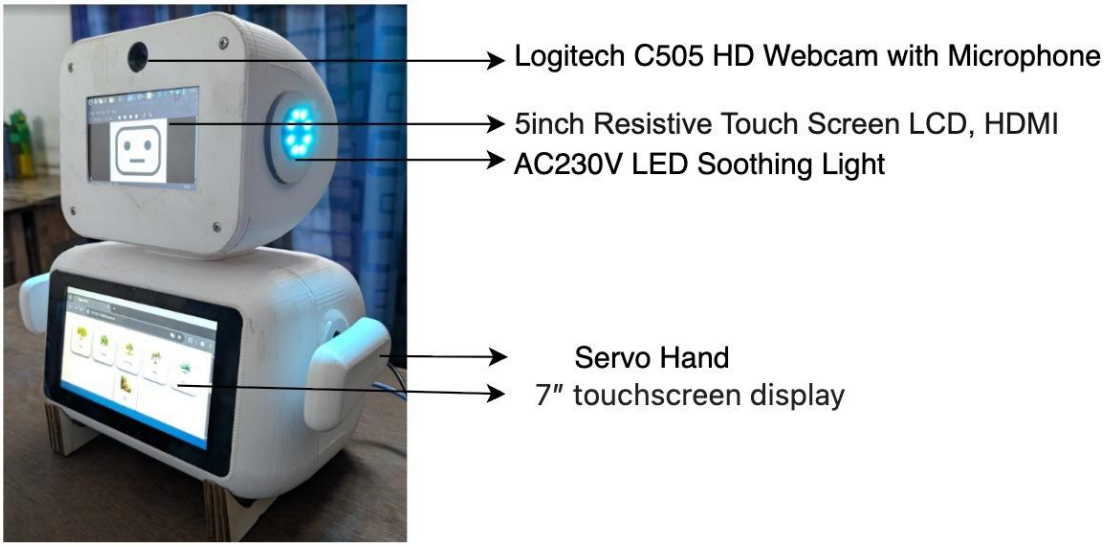


Figure 16: Physical configuration of the Socially Assistive Robot 'KIKI'

Although Kiki is a significant step towards accessible socially assistive robotics in Bangladesh, and it's essential to understand its contributions and design in comparison with other regional project initiatives, such as the TINY robot[68]. The two programs differ in their technology approach, treatment focus, and analysis approach, but they both aim at helping Bangla-speaking children with ASD through robotic platforms. A thorough comparison of both of these systems is given in the following table:

The current comparison illustrates some unique characteristics of KIKI. In contrast with TINY, whose focus lies in the more general educational interaction, KIKI has been specifically designed as a therapeutic instrument with an embedded AAC system, as a result of which it is uniquely suitable for non - verbal or minimally verbal level (1 and 2) mild to moderate children with an ASD diagnosis. Furthermore, the two screen interface and attention duration recognition that KIKI offers allows for a much richer, responsive form of social interaction, so that KIKI fits in very closely with what therapists and educators have identified as the requirements for ASD therapy based on our surveys of them. Moreover, KIKI was tested for a longer period of time and in several therapy centres, thus providing stronger proof for its real-life usability and therapeutic efficacy. While TINY provides a affordable and engaging educational platform, KIKI takes the discipline to a new level 1 and 2 of autism children by incorporating communication support, emotional intelligence, and therapist empowerment into a single affordable design architecture system that addresses a broader spectrum of ASD related challenges.

In summary, KIKI is better than other robotic platforms because it cannot simply reproduction therapeutic techniques (like speech therapy and PECS), but instead combines them into an interactive robotic platform. By presenting KIKI as a specialized assistive technology instead of a general educational robot and also its becomes a more focused and therapeutically useful tool for helping children who have autism in places where resources are limited.

Table 2.3: Comparative Analysis of KIKI and TINY Robots

Aspect	**KIKI Robot**	**TINY Robot**
Primary Objective	Kiki targets the minimally verbal and non-verbal child with ASD (Levels 1 and 2) who cannot reliably use speech. By prioritizing touch input on a visual AAC interface, Kiki solves the fundamental barrier of communication initiation for the most underserved population and supports them in voice therapy.	To function as an interactive educational tutor focused on voice-based learning for children with ASD, TINY's design failed to help children who cannot speak, the non-verbal group.
Core Technology	PECS-inspired digital AAC uses the OpenCV library for attention duration , interactive quiz learning modules, and picture-based learning in Bangla.	Bangla NLP, voice command processing, curriculum-based Q&A, one capacitive touchscreen interaction.
Hardware Design	Dual-screen setup (5" expressive face + 7" AAC touchscreen), camera for attention span tracking, servo-driven arms.	Single 4" display, no dedicated camera, capacitive touch and humidity sensors, simpler actuation.
Software Architecture	Google Cloud TTS/STT is a touch-based interactive UI system with progress tracker dashboards and a data store facilities and monitoring for the therapist.	Google Speech-to-Text, dialogue management, and educational activity modules.
Interaction Modalities	Touch (AAC symbols), voice commands, visual feedback (animated face), servo gestures, and LED relaxing lighting provide a soothing ambience, engaging and stimulating activities to relax, concentrate, and feel better.	Primarily voice-driven, supplemented by touch sensors.
Therapeutic Framework	Structured AAC therapy, emotion-responsive feedback, progress tracking for therapists.	General educational engagement, interactive learning.
User Evaluation	3-week longitudinal study across 6 ASD centers, 36 children, 15 therapists, mixed-methods analysis.	Pilot study with 10- 15 children in limited settings, observational and survey-based feedback, but no user interaction survey.
Cost (Approx.)	~ 33,312 BDT	~ 30,010 BDT
Key Innovations	Responsive culturally adapted AAC, emotion-aware SAR, helping children with voice therapy for minimally verbal and non-verbal children with ASD.	Voice interaction, educational content, and accessible design for children with high-functioning ASD.

Chapter-3

System Design of Kiki

The architecture and interactions of the Kiki robot system design are a key consideration to its development, defining how the system will operate as a therapeutic device to children with Autism Spectrum Disorder (ASD). The initial goal is the development of a socially adapted, engaging and Designing A Socially Assistive Robot (SAR) that facilitates communication, learning and emotional interactions. This chapter gives a comprehensive description of the architecture of the system, decomposing all hardware and software elements, presenting the subsystem design, detailing the flow of interaction, and describing the entire research and development approach, which was used in the development of Kiki.

3.1 Overall System Architecture of Kiki

Kiki architecture is well thought and designed to incorporate multiple components in a manner, which is most functional, is user interactive and cost effective. The design makes the robot effective in executing its therapeutic functions besides being pleasing to the eye, safe and ergonomically fit to interact with children.

3.1.1 Holistic Functionality and Therapeutic Goals

The system is structured around three key layers: the robot hardware, the software layers, and the communication interfaces, all designed to work in harmony to achieve the following therapeutic goals:

Build Vocabulary and Sentence Structure: Through the PECS-inspired AAC interface.

Encourage Self-Expression and Communication Initiation: By providing a clear, cause-and-effect interaction (tap symbol, get speech).

Maintain Attention and Engagement: Via gamified learning, attention duration, and a friendly, embodied presence [61, 62].

Enable Progress Monitoring: For therapists and parents to track development over time.

At its core is the Raspberry Pi 4B. It controls the AI modules, touchscreen interfaces, and sensors. This is simplified by an Arduino Uno, which provides events in real time like processing simple sensor data. To enable the robot to carry out its primary tasks, these parts come together to form a strong framework.

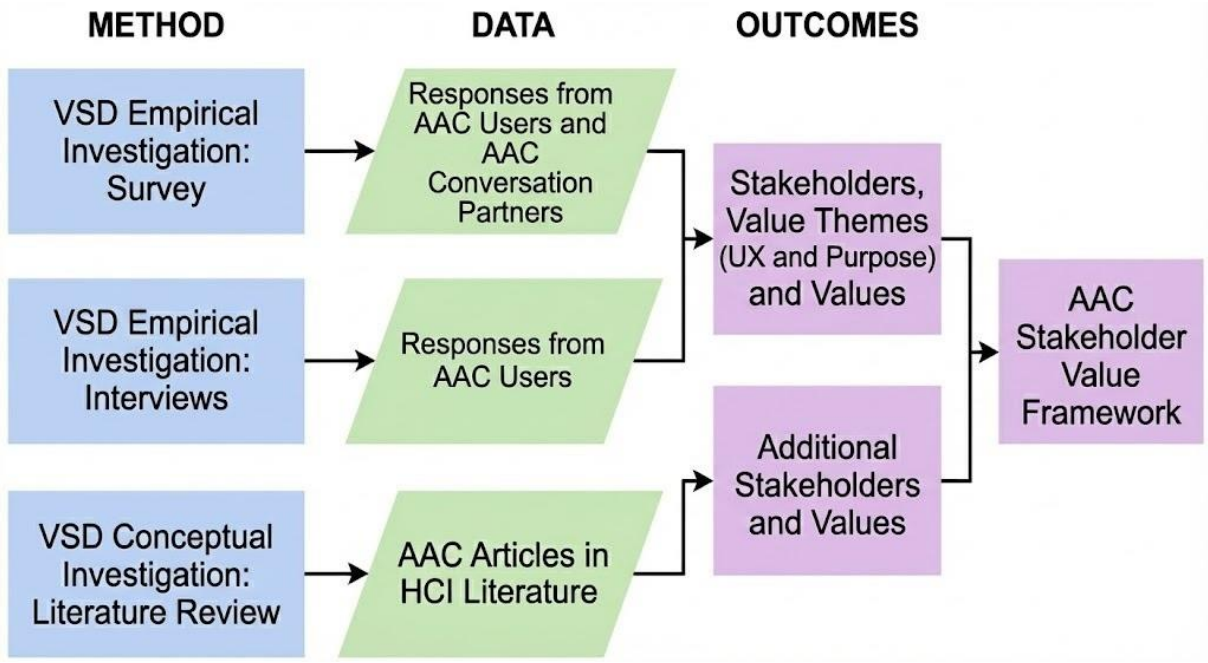


Figure 17: Study Design Flowchart

3.2 Component Characteristics

Robot Hardware: A Cost-Effective of Materials

In order to keep costs down and provide the robot with the greatest possible physical form and functionality, we carefully considered and arranged the hardware components. The finished design, which was made in Fusion 360, has a rounded-square box-shaped head and torso. It is simple to use and child-safe.

Processing & Control:

- Raspberry Pi 4B: The central brain of the robot, handling the main operating system, AI algorithms, and high-level coordination.
- Sensors & Perception: Camera Module: An 8-megapixel app integral for the attention duration recognition detection module.
- Microphone: Captures voice commands for optional speech input.

User Interface (Input/Output)

Dual Touchscreen Displays:

- Upper Display (5-inch): Shows the robot's expressive face to convey non-verbal cues.
- Lower Display (7-inch Touch LCD): The primary user interface for the AAC board and gamified activities.
- Speaker: Provides clear Bangla speech output, amplified by an LM386 Audio Amplifier module.

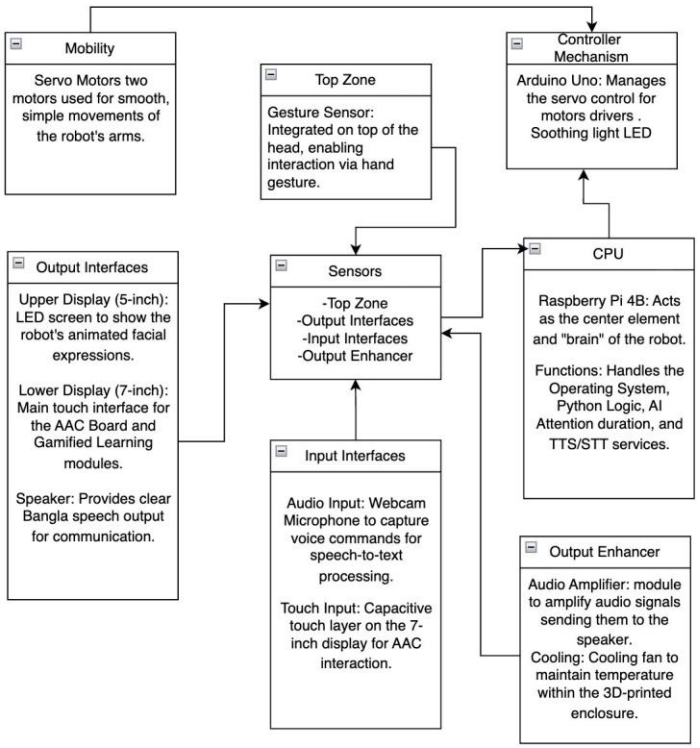


Figure 18: Hardware Block diagram

- Arduino Uno: Manages the servo control for arm movements.

Mobility & Actuation:

- Servo Motors: Used for smooth, simple movements of the robot's arms to enhance expressiveness.
- 3D-Printed Body: The exterior is constructed from lightweight, 3D-printed filament (ABS plastic for internal structure), featuring a soft, soothing exterior and gentle light cues.
- Power Supply: A cable connection electrically powers the entire system.

3.2.1 Software Layers: Integrating AI and AAC

The software architecture is designed to be modular and scalable, ensuring the system can be easily maintained and upgraded.

Operating System: The Raspberry Pi runs a Linux-based OS (e.g., Raspberry Pi OS) for its stability, flexibility, and broad support for the required libraries and hardware.

Middleware & Drivers: This layer includes Python libraries such as OpenCV for computer vision, PyAudio for audio processing, and drivers for the touchscreen and Arduino communication.

Application Layer: This is the core custom software, a Python application encompassing: The main AAC interface and logic.

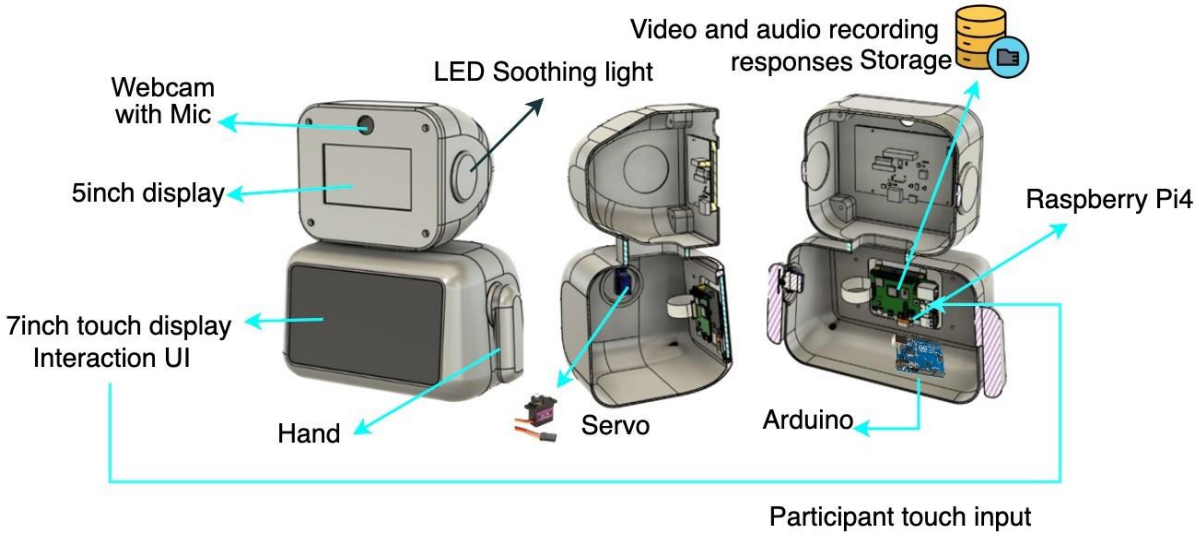


Figure 19: 3D Model Block Diagram

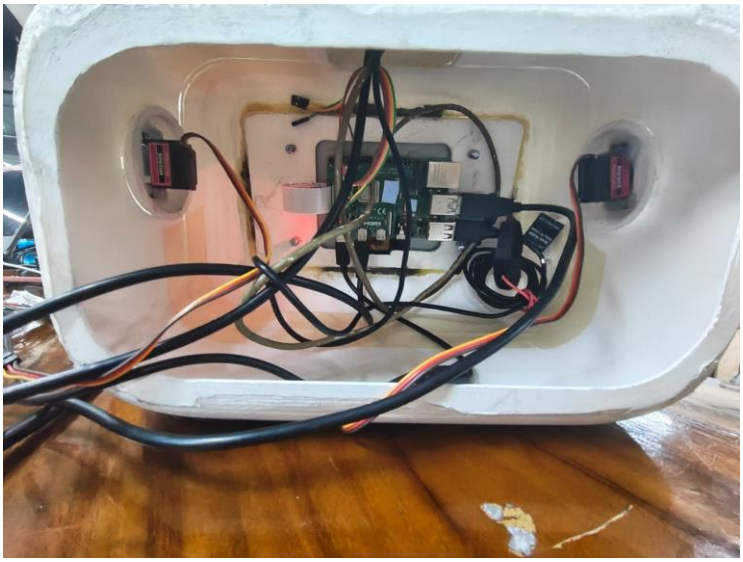


Figure 20: Kiki Version 1

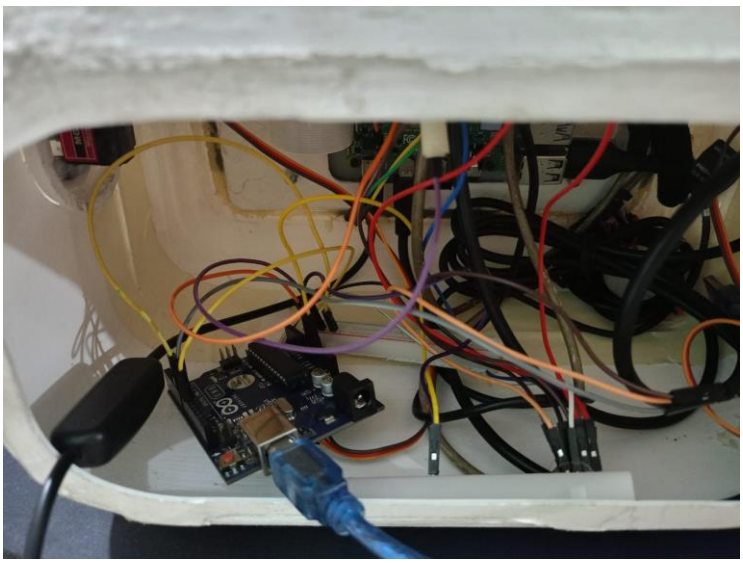


Figure 21: Kiki Version 2



Figure 22: Kiki Version v3



Figure 23: Kiki Final Version3



Figure 24: Picture Exchange Communication System (PECS) cards and Therapy Activity Equipment

- The gamified learning and daily quiz modules.
- The OpenCV for the kiki robot facial emotion express system.
- The progress tracking and data logging system.
- Integration with Google's Text-to-Speech (TTS) and Speech-to-Text (STT) services for Bangla.

3.2.2 Internal and External Communication Interfaces

Internal Communication: The Raspberry Pi communicates with the Arduino Uno via serial communication (UART). The Arduinos handle low-level sensor polling and actuator control, sending processed data back to the Pi for decision-making.

External Communication: The robot uses Wi-Fi connectivity to access Google's cloud-based TTS and STT services when an internet connection is available for high-quality Bangla speech synthesis.

3.3 Subsystem Design

3.3.1 The Bangla AAC and PECS-Inspired Module

This subsystem is the primary therapeutic one. This digital PECS program was developed with the assistance of local Bangladeshi therapists to guarantee that the symbols are suitable for the local culture.

Function: Displays a grid of symbols on the 7-inch touchscreen. When a child taps a symbol, the system triggers a high-quality Bangla speech output of the corresponding word or sentence.

Workflow: Touch Input → Symbol Identification → Bangla Text Generation → TTS Service Call → Audio Output via Speaker.

Data: The symbol database and their corresponding Bangla text are stored locally for reliability.

3.3.2 User Interaction and Personalization Subsystem

This subsystem encompasses the features that make Kiki an adaptive and engaging partner.

Attention Duration: OpenCV identifies the presence of the child with the use of the camera feed. ahead of the Kiki robot, and a personalized categorizes Kiki's emotion expression (e.g. happy, sad, neutral). This enables Kiki to individualize its responses, such as giving encouraging words, should depression be noticed.

Game Base Quiz Learning: A "Daily Quiz" module presents simple, enjoyable vocabulary and sentence-building exercises, turning practice into a game to encourage sustained engagement.

Progress Tracking: The system records the data on the interaction, including the information about the symbols that are used most of the time and quiz performance, stores performance locally. This data can be reviewed by therapists through a simplified interface to keep track of the progress of a child.

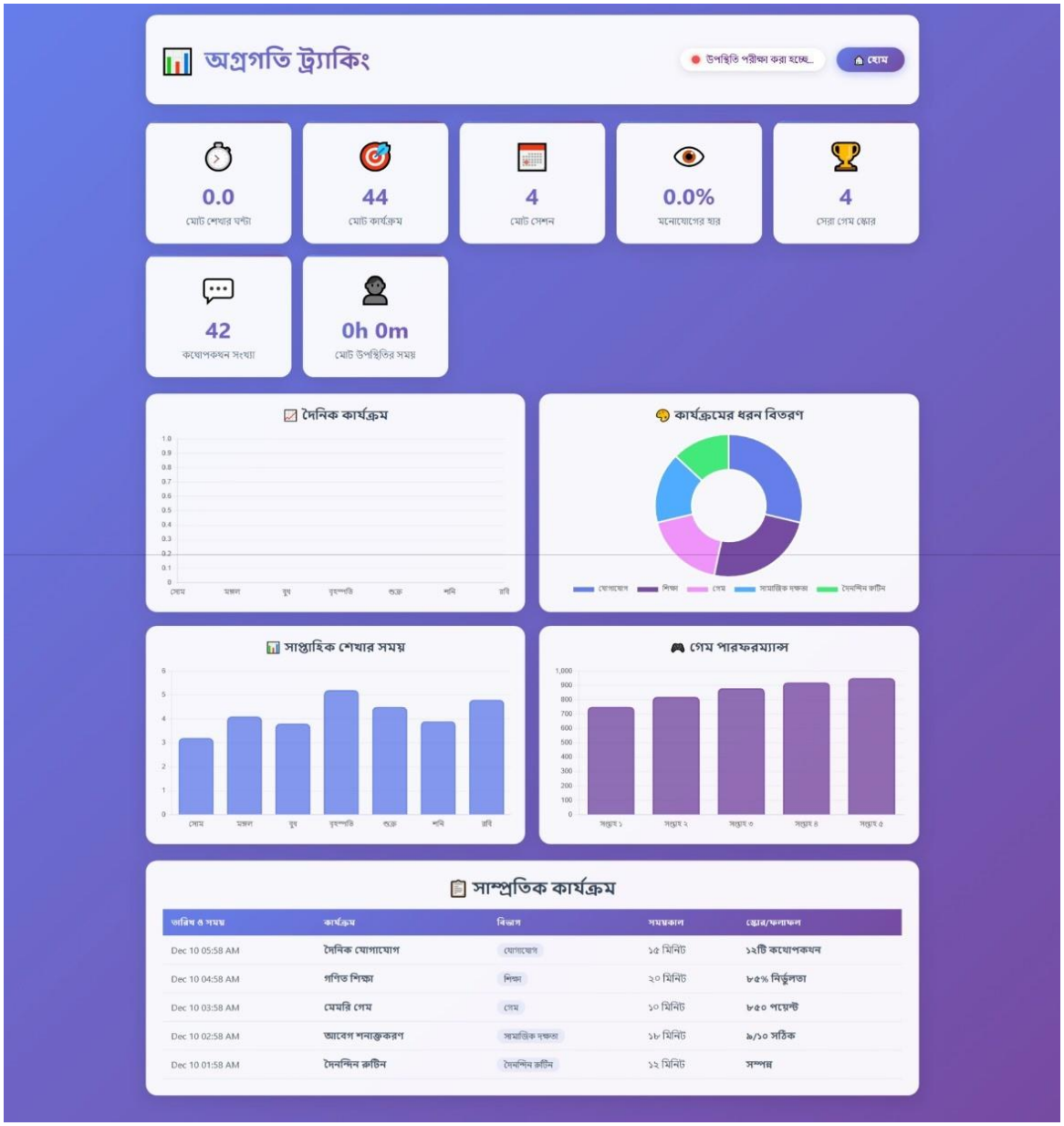


Figure 25: Progress tracking

3.4 Interaction Design

The interaction design is carefully designed to be easy-going, and user-friendly for non-verbal children.

3.4.1 User Interface (UI) Design for Non-Verbal Children

The UI is written in HTML, CSS, and JavaScript and presented on the 7-inch touchscreen, is characterized by:

- **Simplicity and Clarity:** Large high contrast buttons with recognizable, culturally modified. symbols.

- **Primary Interface:** Has core activity feature cards such as the main AAC Board, Daily Quiz and Progress Tracker.
- **Navigation:** Easy navigation because of the presence of simple back buttons and a refresh button. between different screens.

3.4.2 Multi-Modal Voice and Touch Interaction Design

Kiki accommodates various channels of interaction to meet the diverse tastes and capacities.

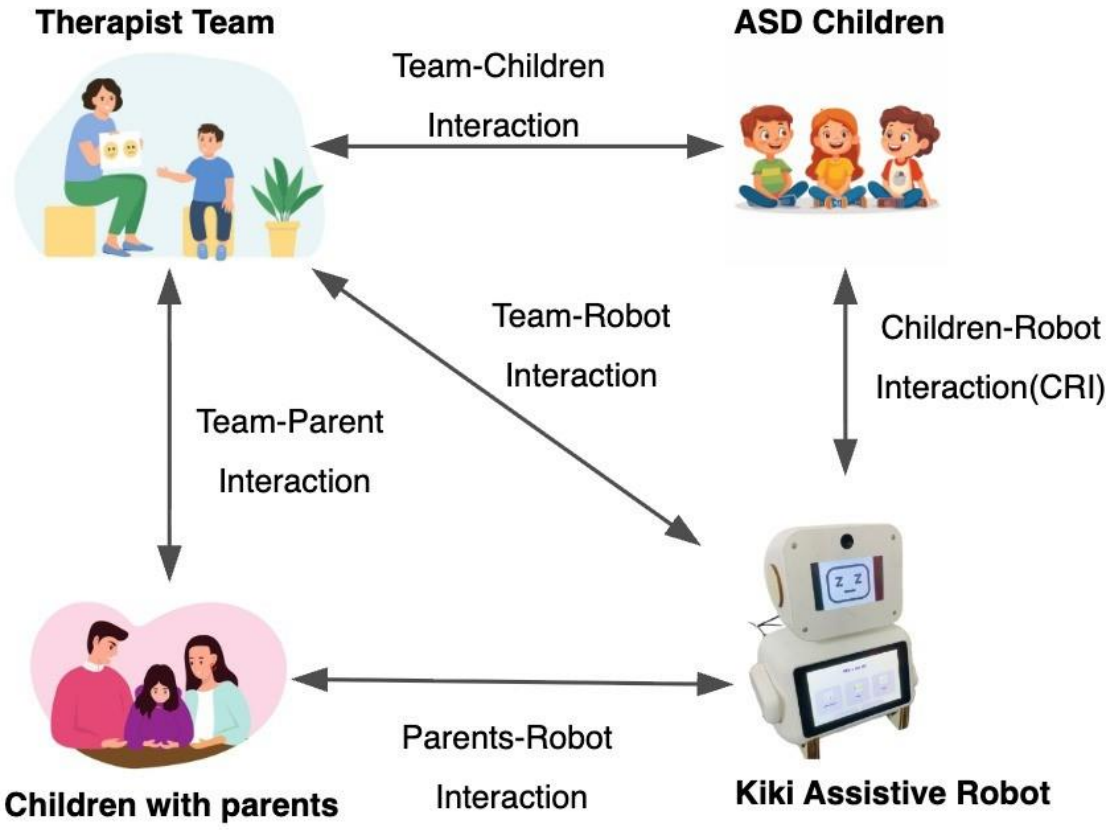


Figure 26: Interaction System Design with Parents/Therapist and ASD children

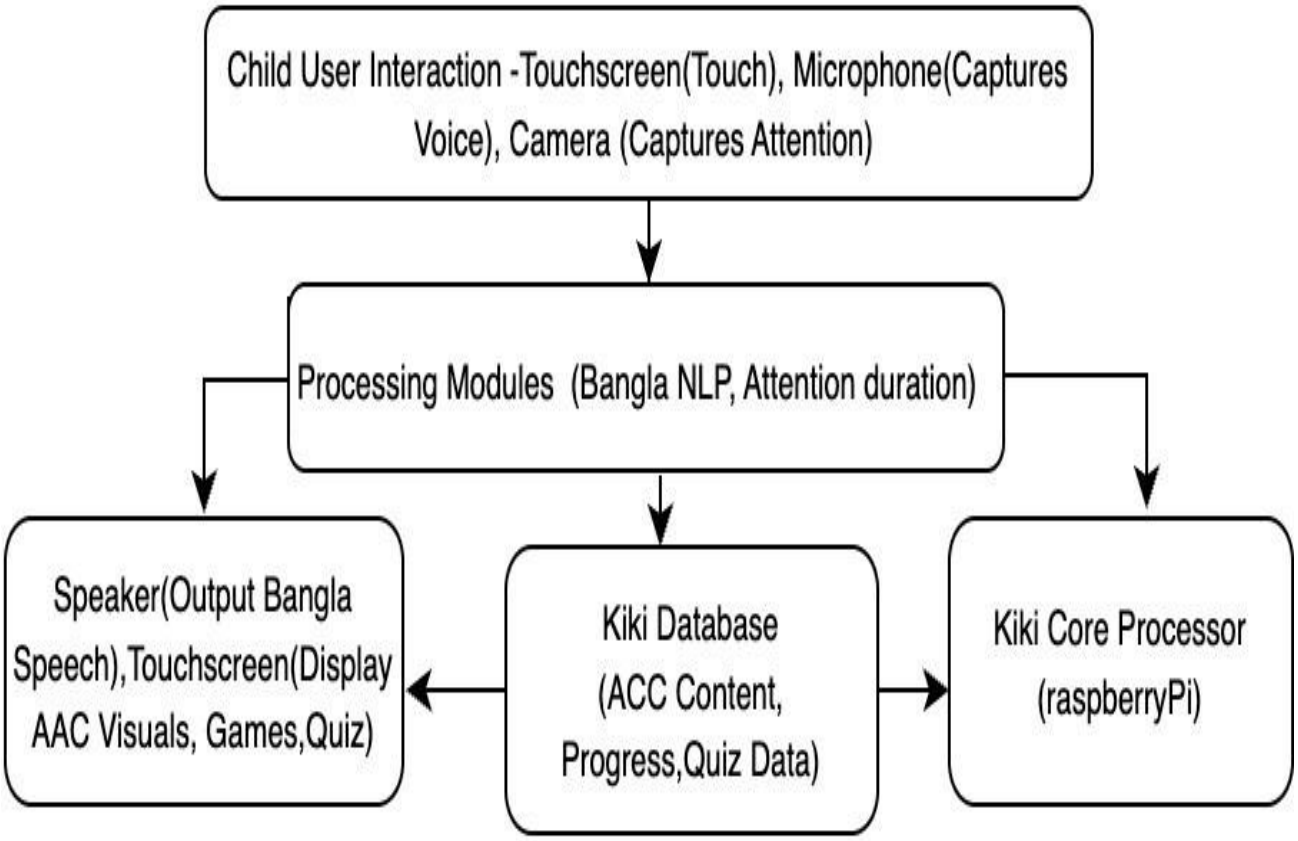


Figure 27: Interaction Design

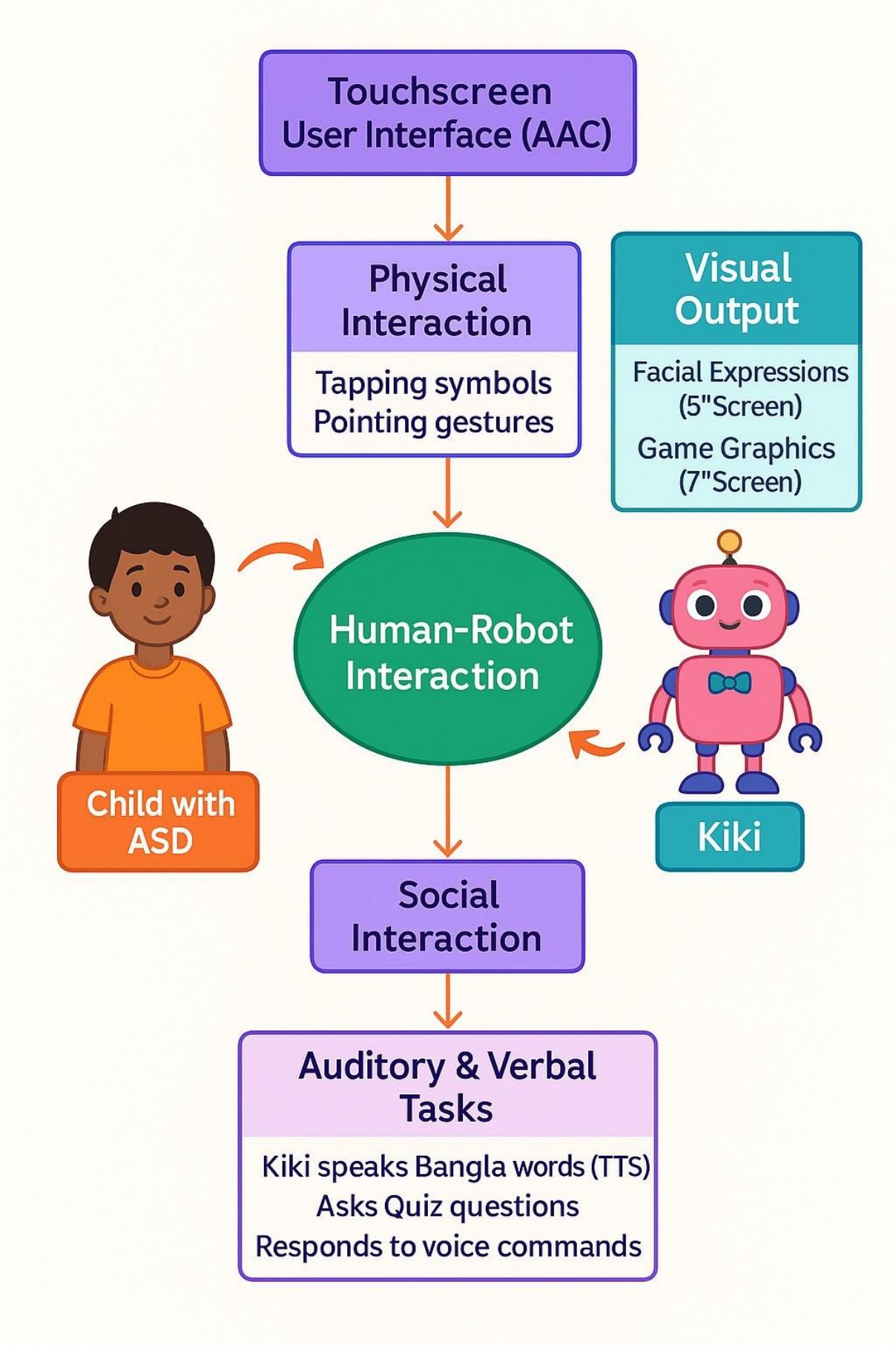


Figure 28: Interaction Design with Kiki and ASD children

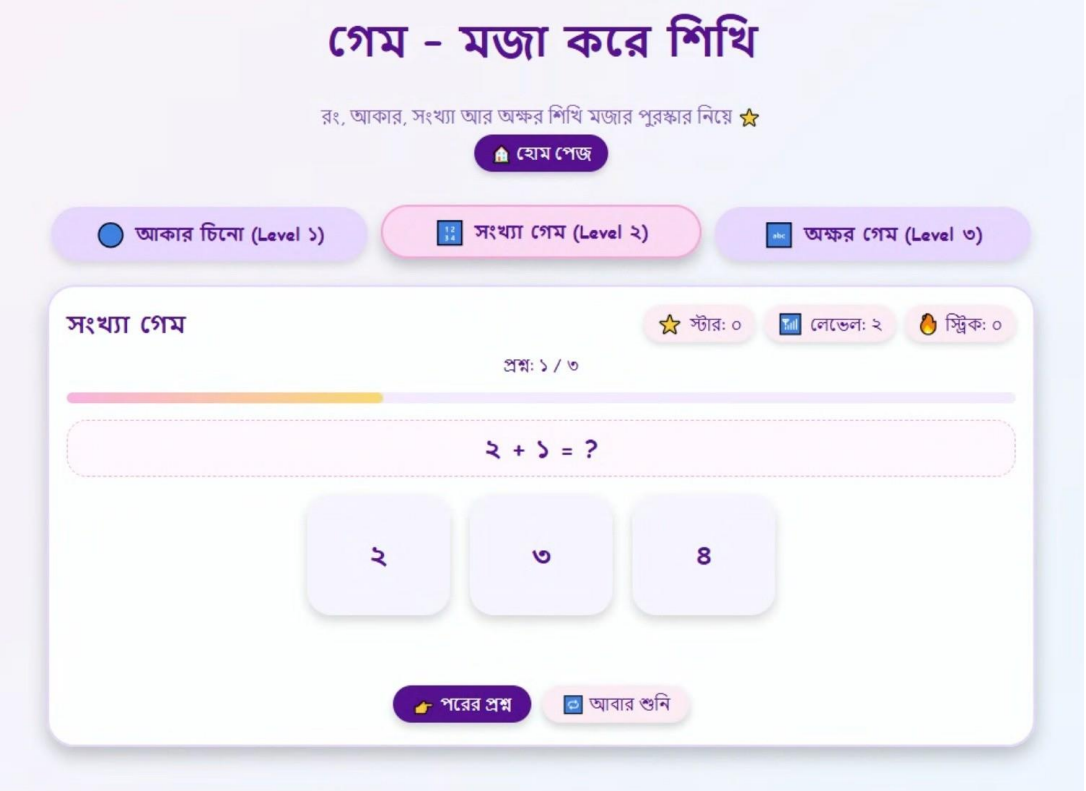


Figure 29: Learning through quiz game feature

- **Touch Interaction:** The major mode. Direct interaction of the children with the symbols and buttons on the touchscreen.
- **Voice Interaction:** children can use the microphone and Speech-to-Text, which is provided by Google and is capable of giving simple voice commands in Bangali. The robot offers articulate auditory feedback by way of its speaker.

3.4.3 End-to-End Therapeutic Interaction Flow

In a normal session with Kiki, there is a logical and facilitating process: Initiation: The child goes up to Kiki with her easy-going visage and lazy movements.

- **Selection:** The child chooses one of the options the AAC board or Daily Quiz through the touchscreen.

Interaction:

- **AAC Mode:** The child taps a symbol (e.g., “water”). Kiki speaks (“pani”) clearly in Bangla.
- **Quiz Mode:** Kiki asks a question; the child responds by tapping the correct symbol.
- **Personalization:** During the same time, the attention duration module analyzes the child’s facial expression. If frustration is detected, Kiki might offer help or encouragement.
- **Conclusion & Logging:** This is the end of the session, and all the communication is recorded to the. local progress tracker to be reviewed later on by the therapist.



Figure 30: Interface Home Page



Figure 31: Daily Communication Learning

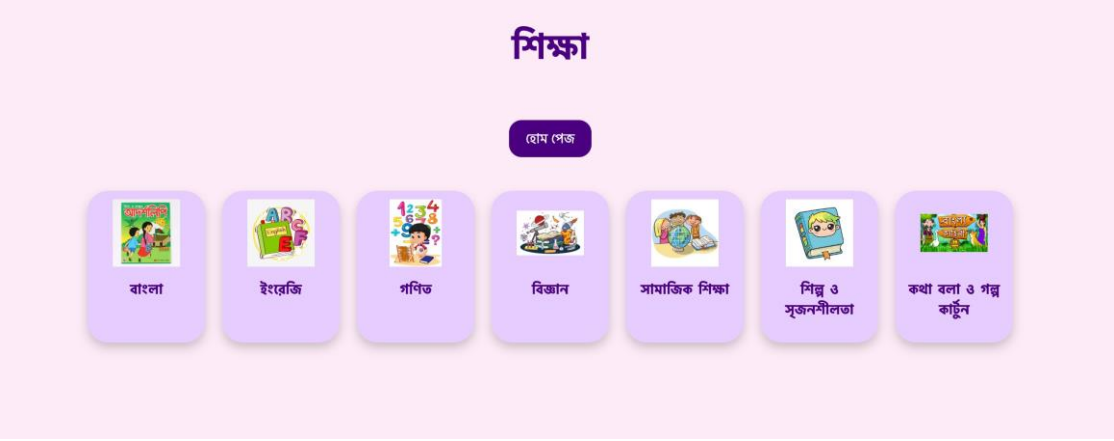


Figure 32: Daily Educational Learning Options

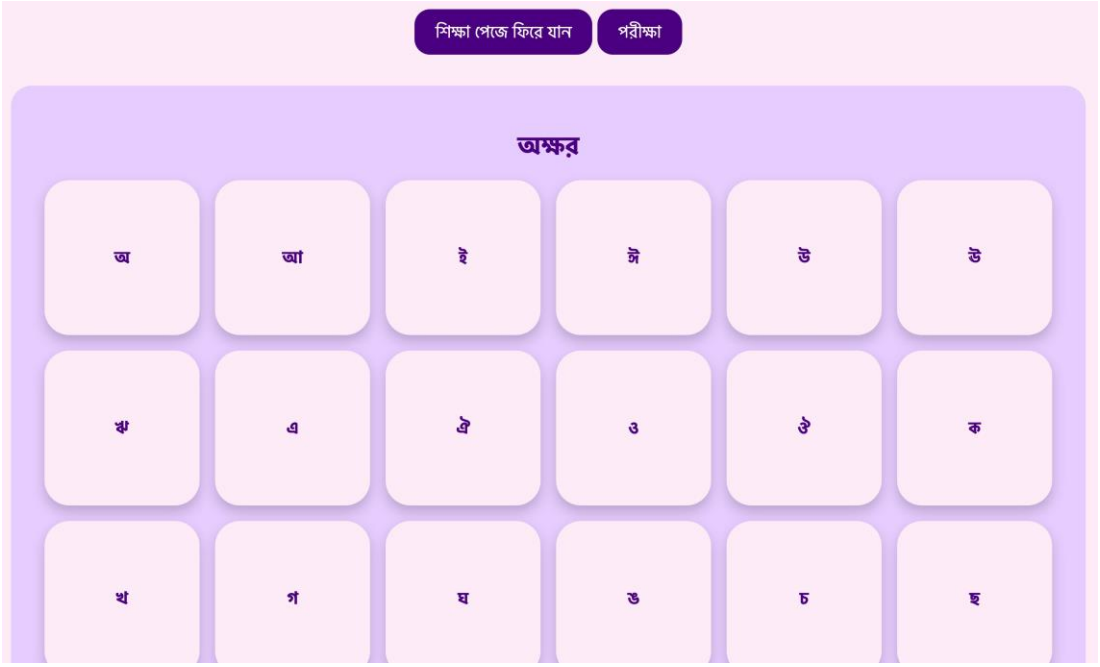


Figure 33: Bangla Letters Learning



Figure 34: Learn How to Express Their Needs

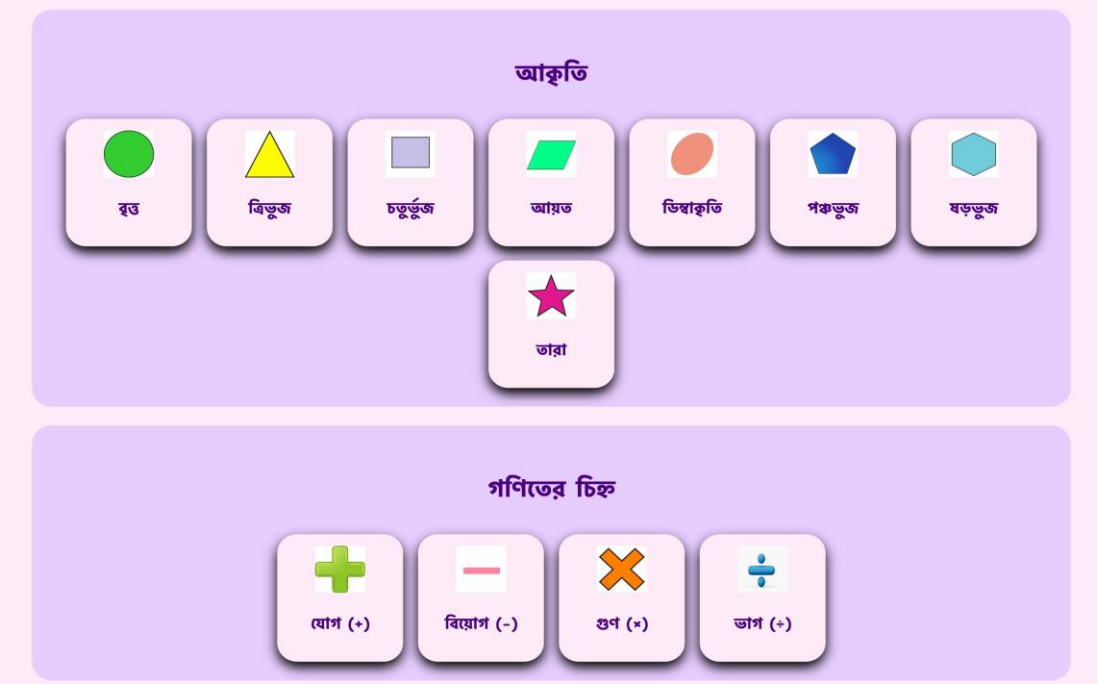


Figure 35: Math learning

3.5 Research and Development Methodology

It was a user-centred and iterative approach to development to make sure Kiki met the real-world.

3.5.1 User-Centred and Design-Based Research (DBR) Approach

We based our process on the direct engagement with the stakeholders. It began with a background research on the current ASD robots, and then development and implementation of questionnaires. and conduct surveys among parents and therapists in Dhaka to determine particular needs of users. This feedback was used directly to guide the original 3D model and UI prototype.

3.5.2 Mood Tracker Survey Form

Mood tracker survey we want to know and take a document manually of ASD chilrdren. behavior. It started with background research of development and administration of questionnaires. and parent and therapist survey in Dhaka to define particular children with ASD mentality. As well, this feedback directly influenced the original 3D model and UI prototype.

3.5.3 Participant Recruitment and Ethical Considerations

The study target group consisted of caregivers, therapists, and ASD children. We conducted a 3-week user study in six special ASD centers in Dhaka. The study participated in the study n=36 children with ASD and n=15 educators and therapists. Informed consent was received as a result of all adult participants and parents of the child participants. All the

centers obtained ethical approval as recorded in the given consent forms.

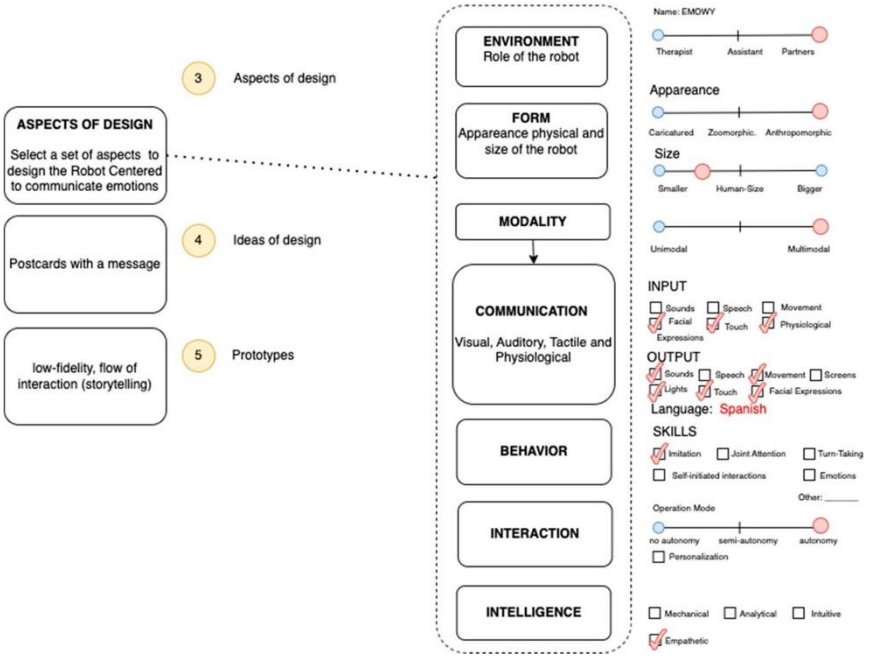


Figure 36: Mapping from User Data to Design Specifications[43]

3.5.4 Procedures: Pre-Survey, Prototyping, and User Study

The methodology was structured in two key cycles:

First Iteration - Theoretical Design and Evaluation: Primary tests through user expectations were determined by pre-surveys. Evaluation was carried out by creating a theoretical design. before physical prototyping, therapists cause refinements.

Second Iteration - Prototype Development and Real-World Testing: A physical prototype was developed and it went through trial and error testing in a laboratory. The refined robot Then one was sent to study 3 weeks in the six ASD centers where direct observation was carried out and post-survey interviews gave both qualitative and quantitative information on its effect.

3.5.5 Software Development: Integrating NLP and Computer Vision

The main application was developed using Python. Key integrations included:

- **OpenCV:** Real-time attention period as well as robot facial expression and attention duration.
- **Google Cloud APIs:** To achieve more fidelity Bangali NLP TTS and STT.
- **Front-End (HTML/CSS/JS):** In the case of the responsive touchscreen user interface of AAC board, communication with the Python backend.

Child's Name: _____
Date: _____
Session No.: _____

Before Interaction

Please rate the child's behavior/emotional state (tick one per row):

Behavior/Emotion	None	Mild	Moderate	Severe
Appears anxious or fidgety	☐	☐	☐	☐
Avoids eye contact	☐	☐	☐	☐
Shows repetitive behavior	☐	☐	☐	☐
Appears withdrawn/silent	☐	☐	☐	☐
Needs comfort/stimulation	☐	☐	☐	☐

After Robot Interaction

Behavior/Emotion	Improved	No Change	Worsened
Anxiety level	☐	☐	☐
Verbal engagement	☐	☐	☐
Facial expressions (smiles)	☐	☐	☐
Physical relaxation	☐	☐	☐
Interest in the robot	☐	☐	☐

Additional Comments:

_____

_____

Observer Name: _____
Role: Parent / Teacher / Researcher
Signature: _____

Figure 37: Mood Tracker Survey Form Before and After Interaction

3.5.6 Hardware Development and 3D Printing Process

The structural model was created in Fusion 360, with the help of such tools as Extrude, Revolve, and so on. Fillet, and loft to make a rounded-square, child safe design. The model was then 3D-printed through filament-based printing with emphasis on cost-effectiveness and longevity. The ABS plastic is used as internal structure with strength and exterior employs the lighter one material.

3.5.7 Algorithm Development for Emotion Expression and Progress Tracking

- **Robot Emotion Expression:** OpenCV was created and trained using standard emotion datasets so that faces can be categorized into such categories as, happy, sad, angry and neutral.
- **Progress Tracking:** This is a simple logging algorithm that captures timestamps, symbols used and store answers to questions in a local database file (e.g. CSV or SQLite), which can be represented to the therapist.

3.5.8 Environment Design: Simulating Therapy Center Conditions

In the course of development, the robot was tested in environments that were meant to imitate the calm but possibly distracting environment of a therapeutic facility. For the final user study, Kiki was directly put into their therapy rooms in the six partner centers, and worked with children at their regular sessions under the direction of their habitual therapists and ours researchers.

Chapter-4

Architectural Framework of Kiki

This chapter discusses the overall architectural structure of the Kiki robot, which explains its design philosophy, hardware and software architecture, and AAC interface UI workflow, which enables it to operate as a socially supportive device. It is designed in such a way that the architecture is modular, scalable and robust so that every component works together to provide a therapeutic and interactive user experience.

4.1 Design Overview

The implementation of Kiki is based on the central ideology of accessibility, cultural relevance, and efficacy in therapy. In Bangladesh, therapists, teachers and children with ASD were all involved in designing each aspect of the building, including the appearance of the building, as well as the functionality of the software.

4.1.1 Core Purpose and Therapeutic Functionality

Kiki's primary purpose is to act as a communication coach and emotional support aid for non-verbal and minimally verbal children with ASD. Its core functionalities, which directly stem from this purpose, are:

- Bangla AAC Communication: To provide an intuitive, PECS-inspired digital platform for expressing needs, wants, and emotions in the native Bangla language.
- Daily Quiz Learning: To transform repetitive practice of vocabulary and sentence structure into an enjoyable and motivating activity.
- Emotion-Aware Interaction: Emotion-Aware Interaction aims to recognize the basic emotional states of a child and will alter interactions according to the child's emotional state to maintain engagement and provide adequate support.
- Progress Monitoring: Progress Monitoring gives therapists and parents a "real-time" perspective at how a child's communication skills have changed as time progresses.

4.1.2 User-Centered and Culturally Sensitive Design Principles

The design is informed by the input of local stakeholders in a fundamental way as they operated and communicate pre-surveys.

- Approachability: The robot's design and friendly, friendly look were based on the perception that 80% users preferred a like a child look over an elderly one.
- Inclusivity: 87% of respondents said they preferred the robot to be gender neutral that which meant that all children could relate to it.

Component	Specification	Function	Price (BDT)	Price (USD)
Raspberry Pi 4	4GB Model	Central Processing Unit	11,960	$97.50
Raspberry Pi 7" Display	Official 800x480 Touch	Visual Interface & UI Input	7,450	$60.90
5-inch Display	Waveshare 5" HDMI	Facial Expression Output	4,500	$36.79
Arduino Uno	R3 (ATmega328P Clone)	Motor/Sensor Controller	532	$4.30
Webcam with Mic	USB 1080p	Visual & Audio Input	2,600	$21.25
MG90s Servo	Micro Servo (Metal Gear)	Hand Movement	336	$2.70
Speaker	3W, 4 Ohm	Audio Output (Bangla Speech)	750	$6.10
LED (Pack)	5mm Assorted Colors	Soothing light	280	$2.90
Wires	Wires Connectors	Connectivity	504	$4.10
3D Printed Body	Custom Enclosure	Protective Enclosure	1,900	$15.21
Memory card	Storage(128GB)	Store Data and the operating system	2500	20.45
Total			**33,312**	**$272.20**

Figure 38: Component Price List of Kiki robot

- Functionality: A high preference (87%) for having AAC content and emotions displayed on a screen led to the dual display approach becoming the one.
- Expressiveness: Integration of arms (80% preference), a simple and expressive face is possible (non-verbal communication, expression, gesture, animation).

4.1.3 Modular System Architecture

Kiki breaks down its architecture into three main physical and logical modules and this makes it easy to develop, test, and maintain. This low-cost and scalability is directly caused by this modularity.

- The Head Module (Interaction Perception) contains the major user interface and the inputs of the senses.
- The Body Module (Core Processing & Storage): The Body Module is the one that does the core processing and storage. Carries the primary computing units and, in certain designs, a physical PECS card or other therapeutic equipment.
- The Base Module (Mobility & Power): Sits on the system, supports the stability of the structure, accommodates the power system, and, in mobile models, it accommodates the navigation drivers.

4.2 Hardware Framework

The hardware framework is a testament to a cost-effective yet capable design, integrating off-the-shelf components with custom 3D-printed structures.

4.2.1 Functional Description of Core Components

Raspberry Pi 4B: Serves as the central computational unit. It runs the main operating system, hosts the custom Python application OpenCV attention time duration , manages the touchscreen interfaces, and handles all network communication (e.g., for cloud-based TTS).

Dual Display System:

Upper Display (5-inch): Dedicated to displaying Kiki's animated face, providing non-verbal social cues and emotional expressions to make the robot more lifelike and engaging.

Lower Display (7-inch TFT Touch LCD): Serves as the primary interactive surface for the AAC board, game base daily quiz learning modules, and system navigation.

Camera Module: This is placed in such a way that it captures the face of a child during an interaction. It supplies visual data to OpenCV to get the real-time face attention period.

Microphone: Speech output, voice input. Sound quality. The mini portable Bluetooth speaker that is premium has the advantage of enjoying the voice training experience.

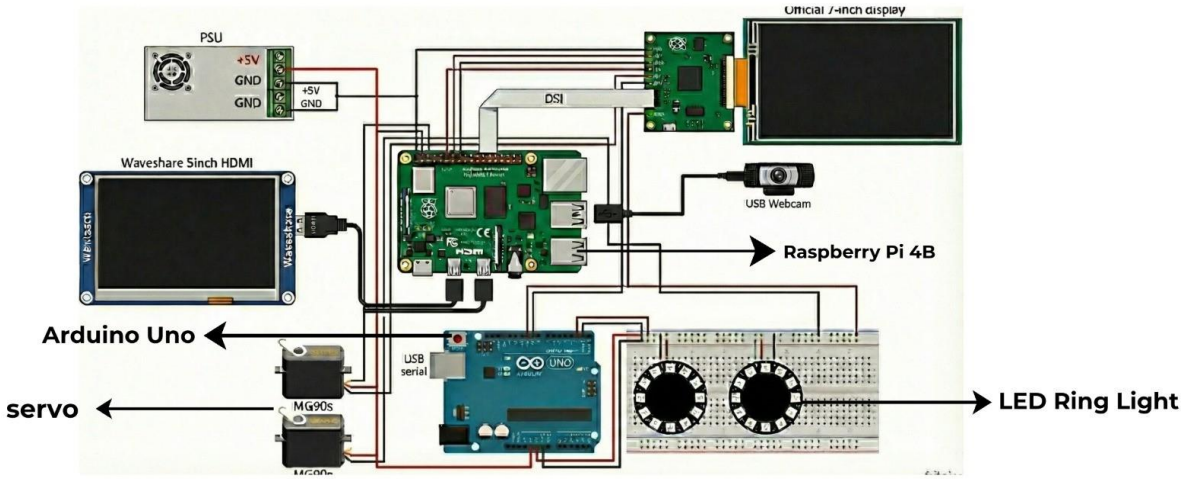


Figure 39: Hardware Architecture

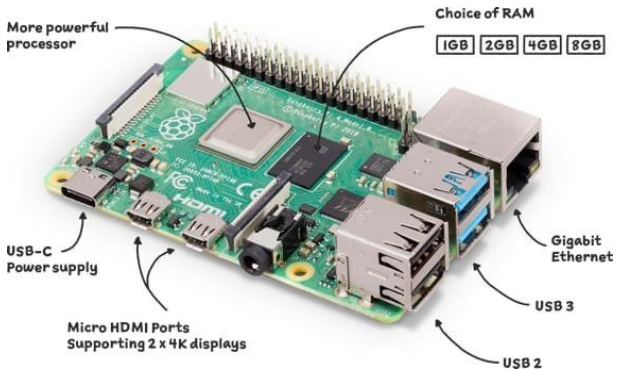


Figure 40: Raspberry Pi 4B [71]



Figure 41: Waveshare 5 inch HDMI TFT-LCD (G) Display[71]



Figure 42: 7 inch 1024 x 600 HDMI TN LCD Display with Capacitive Touch [71]



Figure 43: Logitech C505 HD Webcam with Long Range Microphone [71]



Figure 44: Elegant JBL M3 Mini Portable Bluetooth Speaker [71]



Figure 45: Micro Servo MG90S [71]



Figure 46: Arduino UNO R3 met ATmega 328P-PU chip USB [71]

Audio Subsystem: It consists of a microphone which can record any optional spoken command as well as a speaker with LM386 amplifier which gives Bangla speech a clear and audible sound.

Servo Motors & Arduino Uno: The arm can move safely and easily by the servos which are governed by an Arduino Uno, to look more expressive by waving or pointing.

Wires: Use wires to connect all the parts and make sure that power and data flow correctly. High-quality wires maintain a neat and functional internal layout, minimizing the risk of disconnections or faults.

LED lamp plate: LED soothing light in the robot head on both sides to enhance the environment and maintain a calming feeling



Figure 47: Connecting Wires

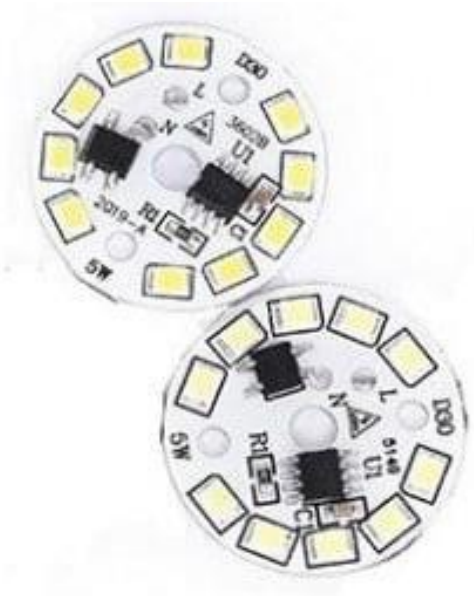


Figure 48: AC230V LED lamp plate 5W 29MM Robotics

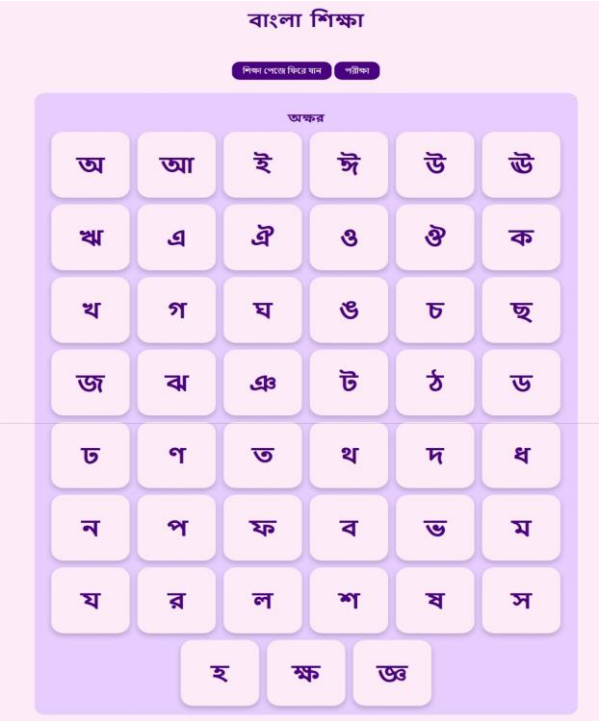


Figure 49: Bangla Letters Learning Making Words for Communication

4.2.2 Comprehensive System Integration

It is a whole system that is formed by the integration of these components. The central component Raspberry Pi 4B, is used as the main processor. The camera and microphone provide the input regarding perceptions. The touchscreen is used as the main input/output interface. Pi then processes this data with AAC logic, game states and AI models ran against it. It in turn produces outputs, which are a speech through the amplifier and speaker, graphics on the displays, and, where needed, commands sent to the Arduino Uno through the serial channel, to cause the servos to move. Every component is supplied by a centralized battery pack that can be located in the base module, and a cooling fan provides thermal regulation of the Raspberry Pi in long-term use.

4.3 Software Architecture

The software architecture is the ”brain” of Kiki, designed for clarity, modularity, and ease of future enhancement.

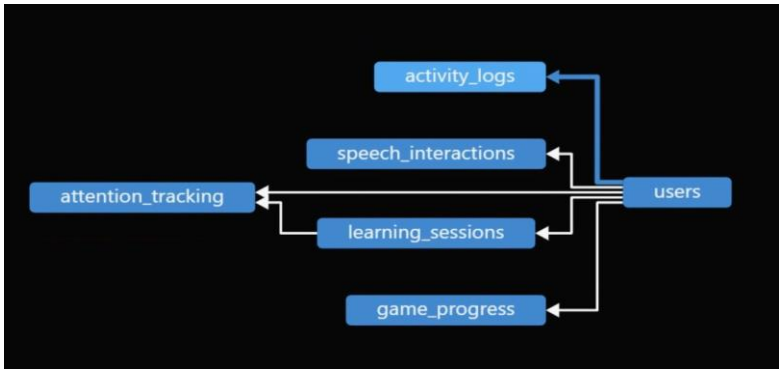


Figure 50: Software architecture

For Kiki, the software architecture is likened to the ‘brain’ it was designed with enormous attention paid in every area making sure that lines correctly reflect real data flow. In developed regions, Kiki” S architectural philosophy was basically characterized by high reliability and affordable. While the established platforms like Kaspar follow a complex deliberative-reactive (Sense-Think-Act) architecture to achieve semi-autonomous operation [63], the architecture used in Kiki is thought by more unifying lines, conical in the sense of making the minimum integration cost a priority. We prioritise dependable execution of core therapeutic tasks such as AAC tab based communication and varieties of emotions expression robot responses over full autonomy, which results in the slick software stack described.

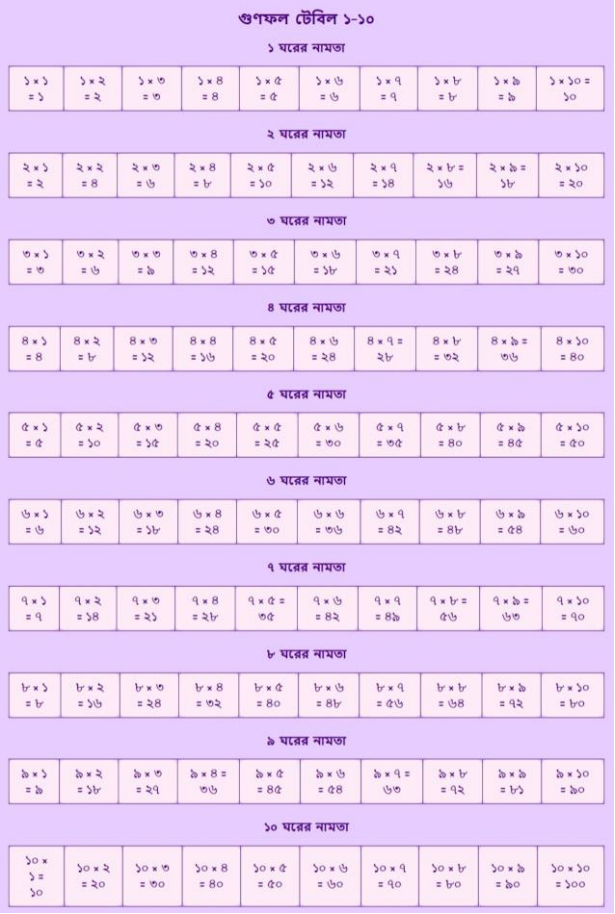


Figure 51: Math Learning

4.4 Design Principles: Accessibility, Engagement, and Scalability

The software was built with three main principles:

Accessibility: The UI needs to be easy for children with diverse cognitive and motor abilities to use.

Engagement: The flow between AAC, games, and adaptive responses must be seamless and rewarding.

Scalability: The codebase must be structured to allow for new features (e.g., new game types, more complex AI) to be added without a major rewrite.

4.4.1 Development Stack and Deployment on Raspberry Pi

The core application was developed as a custom Python program. Key libraries and technologies include:

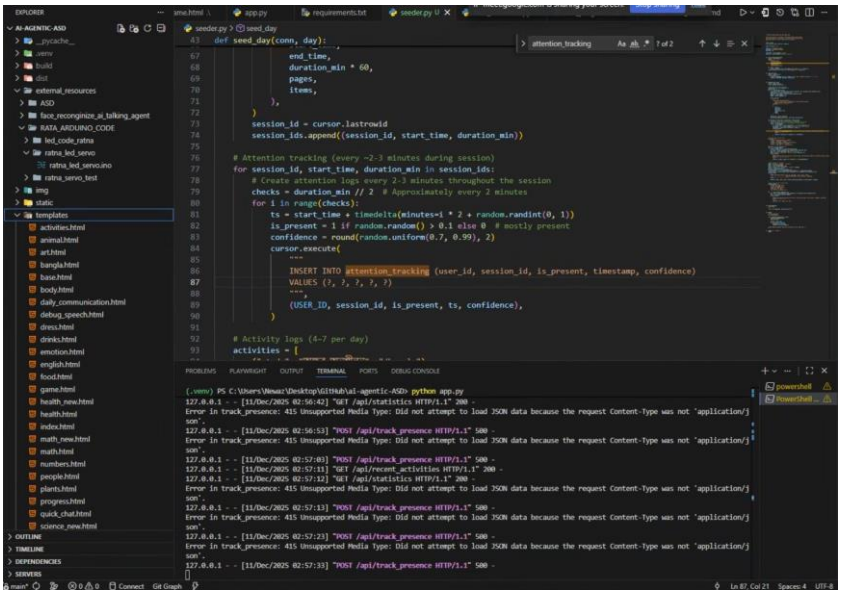


Figure 52: Software Coding of Kiki Robot

Frontend: HTML, CSS, and JavaScript for the touchscreen UI, rendered in a lightweight browser or kiosk mode.

Backend Logic: Python with frameworks like Flask or a simple HTTP server to communicate between the UI and core logic.

AI & Vision: OpenCV for Kiki robot facial expression like excitement, happy, sad to give children appreciation.

Speech Services: Google Cloud Text-to-Speech and Speech-to-Text APIs for high-quality Bangla audio.

Deployment: The entire system is configured to auto-start on the Raspberry Pi boot, launching directly into the main Kiki interface without requiring technical intervention from the therapist.

4.4.2 Main AAC Interface: Symbol Grid, Navigation, and Bangla TTS

The main interface is a grid-based layout of culturally adapted symbols. The software workflow is:

Touch Event: A touch event on the screen is captured by the JavaScript frontend.

Symbol Identification: The frontend sends the symbol ID to the Python backend.

Text-to-Speech: The Python backend retrieves the corresponding Bangla text and uses the Google TTS API to generate an audio file.

Audio Playback: The Python backend plays the generated audio file through the speaker system.

This process creates an immediate and clear cause-and-effect interaction for the child.

4.4.3 Secondary Interfaces: Game Base Learning Module and Daily Quiz

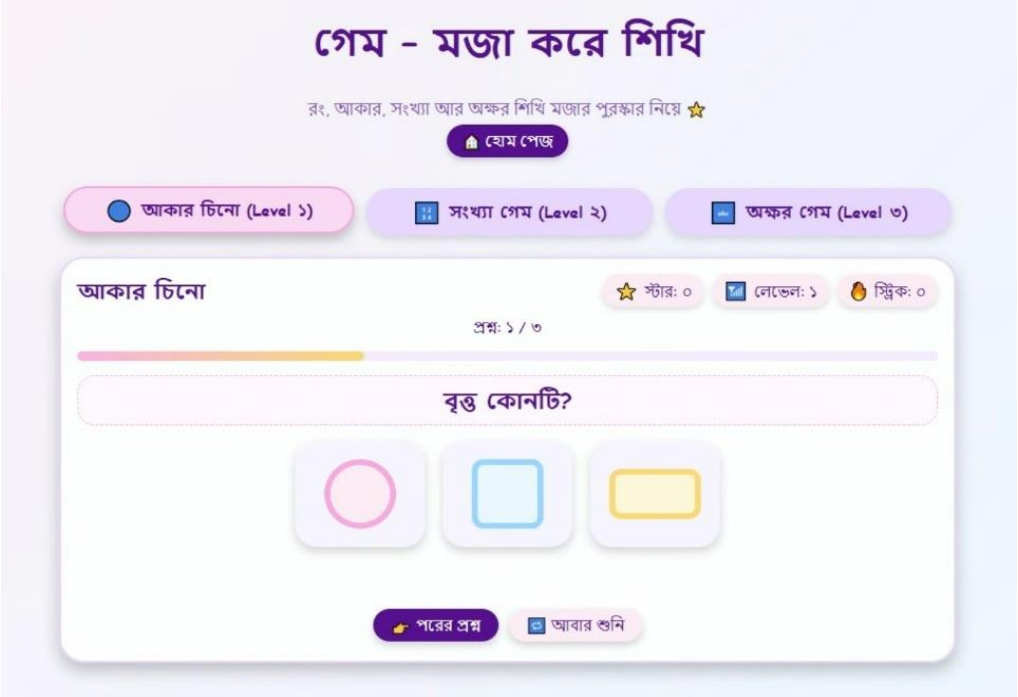


Figure 53: Daily Quiz Shape learning

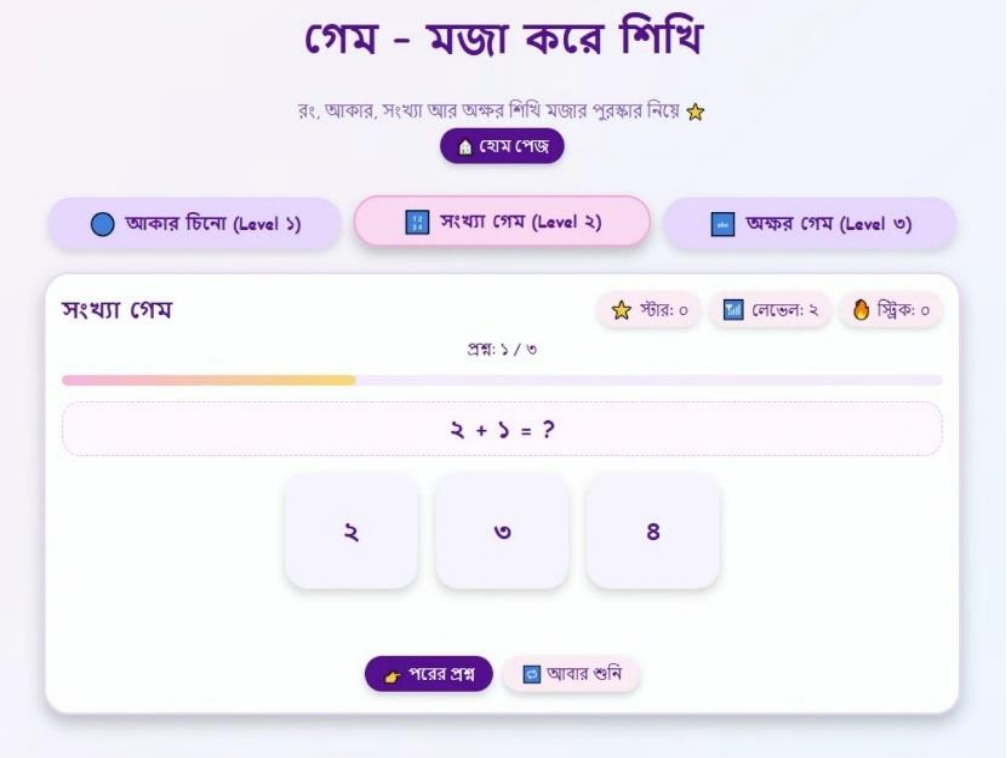


Figure 54: Daily Quiz Math learning

This module operates as a separate state within the main application. It presents multiple-choice questions or matching activities using the AAC symbols. The logic tracks correct and incorrect answers, providing positive auditory and visual feedback. Its state is man- aged independently from the main AAC board but shares the same symbol database and TTS engine.



Figure 55: Daily Activities learning

4.4.4 AI-Driven Modules: Attention Duration and Adaptive Response

This is a parallel processing thread within the Python application:

Frame Capture: The Camera continuously captures video frames.

Face Detection & Emotion Classification: OpenCV robot faces expression in each frame.

Adaptive Response: The resulting emotion label (e.g., 'happy', 'sad') is fed into the main application logic. If 'sadness' is detected with high confidence, the robot might proactively say an encouraging phrase or suggest a favorite activity from the AAC board.

4.4.5 Data Handling: Progress Tracking and Local Storage

In Figure 56, all child interactions are logged anonymously to a local database (e.g., SQLite).

Logged Data: Timestamp, symbol pressed, quiz question and answer, and optionally, the dominant emotion during the interaction.

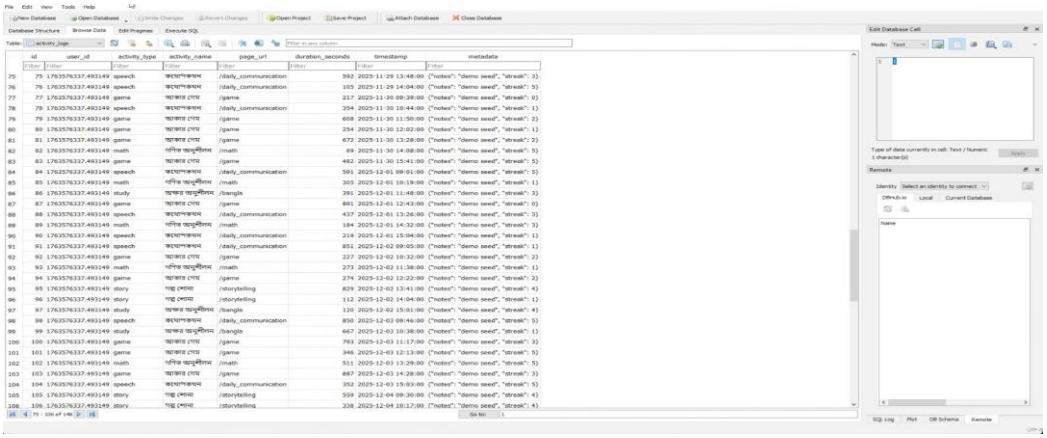


Figure 56: Database Store Activity Data

Data Access: A simple, password-protected interface allows therapists to view aggregated data and progress charts, turning qualitative observations into quantitative insights.

4.4.6 Planned Upgrades and Future Software Developments

The architecture is designed to accommodate future expansions, including:

Offline TTS Engine: Integrating a local, offline Bangla TTS engine to eliminate dependency on internet connectivity.

Advanced NLP: Implementing a more sophisticated Bangla NLP model for better understanding of spoken commands.

Therapist Portal: Developing a web-based dashboard for therapists to review progress data from multiple children and sessions remotely.

4.5 End-to-End System Workflow

The following workflow illustrates how a typical therapeutic session is executed by the integrated system.

4.5.1 User Interaction Initiation

A child taps the symbol for "water" on the 7-inch touchscreen. The touch event is registered by the UI.

4.5.2 Command and Attention Duration Interpretation

The UI sends the symbol ID to the main Python application. Simultaneously, in a separate thread, the attention duration module analyzes the most recent camera frame and classifies the child's expression as "neutral."

4.5.3 Sensor and Camera Data Acquisition

The main application has now received two key data points: 1) the intent to communicate "water," and 2) the child's emotional state is neutral.

4.5.4 Task Execution and Therapeutic Activity Delivery

The main application executes the task: It retrieves the Bangla word ("pani") from its local database. It calls the Google TTS API with this text and receives an audio file. It initiates playback of the audio file through the speaker system.

4.5.5 Multi-Modal Output Delivery

The system delivers a coordinated, multi-modal response:

Auditory: The speaker clearly outputs the synthesized Bangla speech: " ".

Visual: The robot's face on the upper display may show a smiling animation to reinforce the interaction.

Data Logging: The Python application logs the event: [Timestamp], Symbol_ ID: "water", Emotion: "neutral" to the local database.

This seamless workflow, from intention to multi-modal feedback, encapsulates the therapeutic cycle that Kiki is designed to facilitate, providing a consistent, engaging, and supportive communication partner for the child.

Chapter-5

Data Collection and Analysis

Kiki was developed using the user-centered design Ideology and was customized to the Bangladeshi context. This chapter describes the methods used by us to gather and ex- amine data to get to know about the needs and preferences and challenges of therapists, teachers and children with ASD in Bangladesh. The insights from this process were instrumental in defining Kiki's design, functionality, and therapeutic role, ensuring the final product was culturally resonant and practically useful for autism support.

5.1 Pre-Study Data and Foundation

Kiki was designed as an user-centered design and was developed on this basis designed specifically to the context of Bangladesh. This chapter outlines the detailed in-depth methodology of data collection and analysis used to know the needs, preferences, and complications of therapists, educators, and children with ASD in Bangladesh. The learn- ings of this process played a critical role in determining the design, functionality, and therapeutic role, so that the end product would be culturally relevant and useful for autism support.

Within this section, the reader learns about the nature of the pre-study data and foundation. Prior to any prototyping, data grounded on the local stakeholders was obtained set the level of expectations and to base the design on the particular socio-cultural context of Bangladesh.

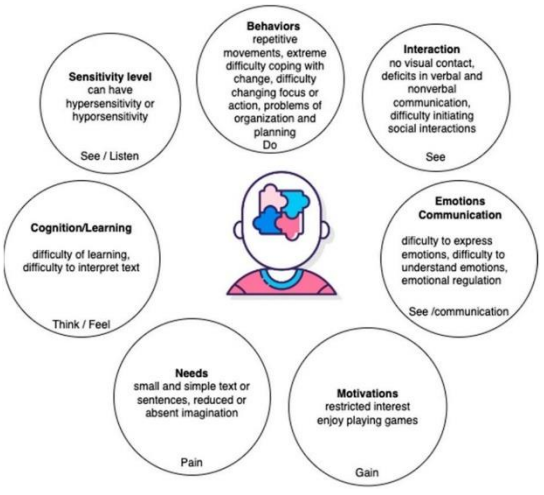


Figure 57: Empathy map for children with autism.[28]

To compose the rich qualitative data of our first interactions with therapists. and caregivers, we have created an empathy map (Figure 61). This tool allowed us to holistically comprehend the experiences, sufferings, and benefits of a non-verbal child with ASD within. Bangladesh. These learnings of this map played a crucial role in the definition of the problem space. and informed directly the shape of the following pre-survey, and the main functionalities. of Kiki, we ensured our solution was pegged on real- world needs of our end-users.

5.1.1 Significance of Pre-Surveys for Design

The pre-survey findings offered important quantitative proofs on important design choices. The data were collected through the feedback of both caregivers and therapists in Bangladesh and constituted a direct connection between the end-users and the development team. The most significant findings that directly influenced Kiki's architecture included:

Appearance and Character: (80 %) of users favored child-like design rather than an adult-like one, since it was understood to be more comfortable and friendly to children with ASD. This was directly translated into the warm, curvy, and comfortable style of the final. robot.

Gender and Inclusivity: A high majority (87%) supported a gender-neutral design, which implies that neutrality is more inclusive and comfortable to the users. This principle informed the visual design of the robot and the voice of the robot.

Form and Function: Participants heavily preferred a humanoid (87 %) and short (73 %) robot with a face/screen to display emotions and AAC content (87 %). This justified the dual-screen approach and the humanoid morphology.

Expressiveness and Interaction: The robot should have arms (80%) validated the necessity of non-verbal communication means, which results in the incorporation of servo-driven weaponry and a speaking face.

Core Role Definition: Most of the respondents found the major function of Kiki as a communication coach and emotional support help, pulling the focus together Bangla AAC and attention duration modules as a prerequisite in the involvement of both the functional and emotional sections in cognitive functioning of ASD children.

5.2 Process of Surveying and Interviewing Stakeholders

The qualitative approach was employed in order to collect detailed data on the needs, Challenges, and promises of a Socially Assistive Robot (SAR) with children with ASD in Bangladesh.

The objectives of the interview and surveys include: The main aim was to receive an in-depth insight into the difficulties to be experienced in Treatment of ASD in Bangladesh and stipulate certain conditions of a socially assistive robot which would not only be culturally acceptable, but therapeutic as well.

5.2.1 Interview and Survey Objectives

The primary objective was to capture detailed understanding of the challenges faced in ASD therapy in Bangladesh and define specific requirements for a socially assistive robot that would be both culturally appropriate and therapeutically effective.

5.2.2 Participant Selection and Data Collection

Data were collected through semi-structured interviews and direct observations at six specialized ASD centers in Dhaka. The target participants included caregivers, therapists, and children with ASD. The study included n= 36 children with ASD and n=15 educators and therapists. We obtained informed consent from all adult participants and the parents of the child participants, and we received ethical approval from all participating centers.

5.2.3 Survey and Interview Design

The interview and survey questions were well formulated to address various dimensions of stakeholder needs:

Respondents were questioned on their preferences as far as the physical design of Kiki was concerned- such as size, color, face expressions, and general figure. Children who have ASD are likely to react these questions measured comfort in a positive and predictable, non-threatening visual stimuli levels and visual appeal. Examples of guiding questions were:

- What characteristics do you prefer that a robot should have in order to be friendly, calming, or interesting to ASD children?

- What colors or facial expressions do you think are most comfortable to children in the time of therapy sessions?"

Therapeutic Context: The comprehension of the existing communication issues and therapy methods.

Design Preferences: Visual and structural preferences on how the robot should look like.

Functional Expectations: Therapeutic functions and roles that are anticipated of the robot.

5.2.4 Key Steps in the Conduct of Survey and Interviews

The process followed these key steps:

Preparation & Literature Review: Relying on the initial literature review (on), the following preparation was made. AAC in ASD, SARS, cultural adaptation) and preliminary situational analysis in local ASD.

A draft questionnaire and interview guide was developed.

Expert Review: Senior therapists and special educators reviewed the draft instruments dealing with ASD children to test the appropriateness of culture, clarity, and relevance. Feedback was also used to enhance wording, less ambiguity and ensure sensitivity.

Pilot Testing: A pilot exercise was done using a small sample (e.g., 2 therapists + 2) understandability, flow, duration, and to identify potentially distressing (caregivers) to test or confusing items. According to the pilot feedback, certain questions were rephrased; response options narrowed down; and placement ordered to increased comfort of respondents.

Ethical and Informed Consent Process: Informed consent of adults and parental informed consent (and assent in case of children) was taken. The purpose of the study, The voluntary use of the data, the anonymity, and the use of the data were described.

Recruitment of Participants were recruited purposely (therapists, caregivers), and, where feasible, children of a diverse age, level of verbal ability, and histories of therapy actual use - to make sure that a variety of information is collected and thus can be relevant to a wider scope.

Data Collection — Interviews, Surveys & Observations: Semi-structured interviews and surveys were conducted face-to-face within the therapy centers, in familiar environments to the children. The body language, the interaction between the child and the therapist, and the spontaneous reactions regarding the use of the robot were also observed and noted during the therapy sessions. This was done with consent.

Data Recording and Documentation: All responses (verbal, non-verbal, observational) were recorded systematically. Interviews were audio-recorded (where consent provided) and complemented by written notes. Observations were documented using structured observation sheets. Demographic and contextual data were logged in participant sheets.

Transcription, Coding & Thematic Organization: Interviews were recorded and then transcribed and thematically organized. Observation notes were typed. Answers were

coded as thematic (e.g., communication challenge, preference of appearance, robot, therapy, constraint, expected robot functions, concerns/risks). This coding was the basis on which qualitative analysis was developed.

Preliminary Analysis & Feedback Loop: Findings were presented with some employing therapists who will be involved to member check and to make sure that the emerging themes were based on actual therapeutic situation. Minor adjustments in coding definitions were made in accordance.

Data Consolidation and Preparation for Design Integration: Following Analysis, insight was turned into design requirements, feature prioritization and possible features constraints. These in turn told the next phase of the design of the robot of the Kiki- the Kiki-robot- design such as hardware, software, interaction design and planning of therapy sessions.

5.2.5 Importance of the Survey and Interviews

It is a qualitative method which helped us to obtain rich and contextual insights that were fundamental to come up with a robot that will really be beneficial in the real world settings in Bangladesh.

Participant and Context Details: Participants, including therapists, special educators, and caregivers, first provided demographic information and details about their professional experience with ASD children. This contextual information helped interpret their responses based on their therapeutic background, familiarity with AAC systems, and prior exposure to assistive technologies. It also provided insight into how their daily challenges and experience levels shaped their expectations from a social robot like Kiki.

Preferences for Kiki's Appearance and Child-Friendly Characteristics: The people were questioned on what they liked about the appearance of Kiki, such as size, color, smile, and shape. Autistic children tend to prefer unthreatening and clear images, thus these questions examined the level of comfort and the attractiveness of the design. Some example questions were:

- "What features make a robot appearance friendly, calming, or engaging for ASD children?"
- "Which colors or facial expressions do you feel are most comforting for children during therapy sessions?"

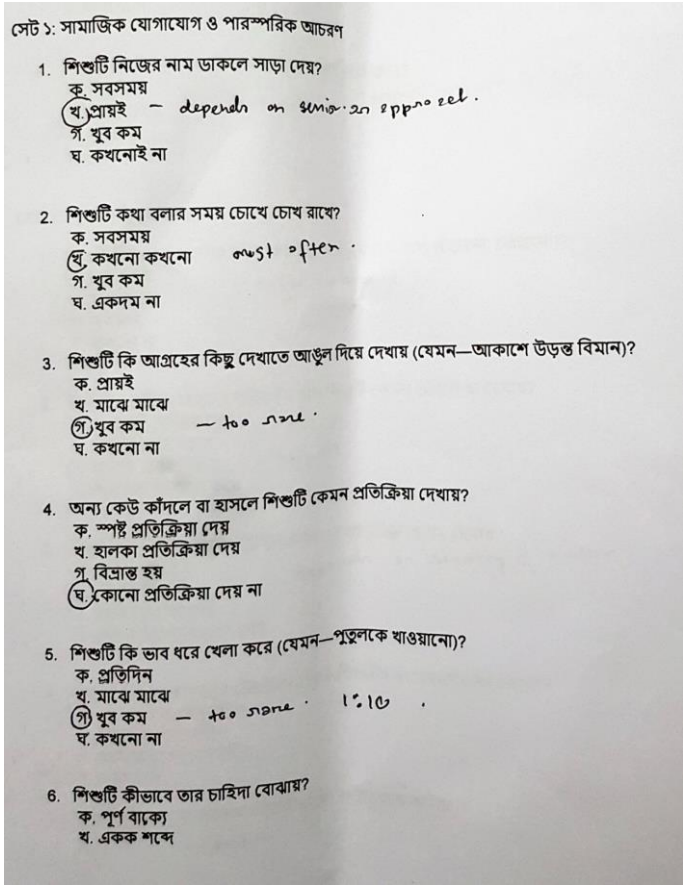
These responses helped refine Kiki's expressive face, choice of colors, and body pro proportions to ensure a non-intimidating, playful, and emotionally readable design.

Expected Therapeutic Functions, Roles, and Interaction Style of Kiki: Participants were asked to articulate what functions they believed would be most beneficial for ASD interventions. These questions explored expectations related to communication support, behavior prompting, attention engagement, and learning assistance. Examples of targeted questions included:

- “What specific tasks do you expect Kiki to support during therapy sessions?”
- “Which AAC functions would improve communication for non-verbal or minimally verbal children?”
- “What kind of personality—playful, calm, motivating—would help children engage more effectively?”

Participants frequently highlighted the need for Kiki to:

- provide Bangla AAC communication assistance,
- help children practice attention duration,
- give simple task prompts,
- encourage participation through interactive games,
- maintain a supportive, patient, and friendly personality.



সেট ১: সামাজিক যোগাযোগ ও পারস্পরিক আচরণ

1. শিশুটি নিজের নাম ডাকলে সাড়া দেয়?
   ক. সবসময়
   (খ.) প্রায়ই — depends on seniors approach.
   গ. খুব কম
   ঘ. কখনোই না

2. শিশুটি কথা বলার সময় চোখে চোখ রাখে?
   ক. সবসময়
   (খ.) কখনো কখনো — most often.
   গ. খুব কম
   ঘ. একদম না

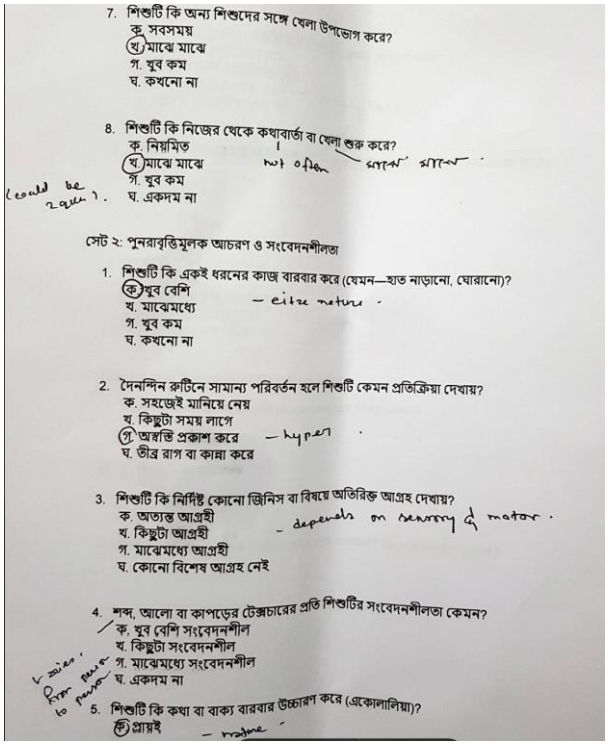
3. শিশুটি কি আগ্রহের কিছু দেখাতে আঙুল দিয়ে দেখায় (যেমন—আকাশে উড়ন্ত বিমান)?
   ক. প্রায়ই
   খ. মাঝে মাঝে
   (গ.) খুব কম — too rare.
   ঘ. কখনো না

4. অন্য কেউ কাঁদলে বা হাসলে শিশুটি কেমন প্রতিক্রিয়া দেখায়?
   ক. স্পষ্ট প্রতিক্রিয়া দেয়
   খ. হালকা প্রতিক্রিয়া দেয়
   গ. বিভ্রান্ত হয়
   (ঘ.) কোনো প্রতিক্রিয়া দেয় না

5. শিশুটি কি ভাব ধরে খেলা করে (যেমন—পুতুলকে খাওয়ানো)?
   ক. প্রতিদিন
   খ. মাঝে মাঝে
   (গ) খুব কম — too rare. 1:10
   ঘ. কখনো না

6. শিশুটি কীভাবে তার চাহিদা বোঝায়?
   ক. পূর্ণ বাক্যে
   খ. একক শব্দে

Figure 58



7. শিশুটি কি অন্য শিশুদের সঙ্গে খেলা উপভোগ করে?
ক. সবসময়
খ. মাঝে মাঝে
গ. খুব কম
ঘ. কখনো না

8. শিশুটি কি নিজের থেকে কথাবার্তা বা খেলা শুরু করে?
ক. নিয়মিত
খ. মাঝে মাঝে
গ. খুব কম
ঘ. একদম না

সেট ২: পুনরাবৃত্তিমূলক আচরণ ও সংবেদনশীলতা

1. শিশুটি কি একই ধরনের কাজ বারবার করে (যেমন—হাত নাড়ানো, ঘোরানো)?
ক. খুব বেশি
খ. মাঝেমধ্যে
গ. খুব কম
ঘ. কখনো না

2. দৈনন্দিন রুটিনে সামান্য পরিবর্তন হলে শিশুটি কেমন প্রতিক্রিয়া দেখায়?
ক. সহজেই মানিয়ে নেয়
খ. কিছুটা সময় লাগে
গ. অস্বস্তি প্রকাশ করে
ঘ. তীব্র রাগ বা কান্না করে

3. শিশুটি কি নির্দিষ্ট কোনো জিনিস বা বিষয়ে অতিরিক্ত আগ্রহ দেখায়?
ক. অত্যন্ত আগ্রহী
খ. কিছুটা আগ্রহী
গ. মাঝেমধ্যে আগ্রহী
ঘ. কোনো বিশেষ আগ্রহ নেই

4. শব্দ, আলো বা কাপড়ের টেক্সচারের প্রতি শিশুটির সংবেদনশীলতা কেমন?
ক. খুব বেশি সংবেদনশীল
খ. কিছুটা সংবেদনশীল
গ. মাঝেমধ্যে সংবেদনশীল
ঘ. একদম না

5. শিশুটি কি কথা বা বাক্য বারবার উচ্চারণ করে (একোলালিয়া)?
ক. প্রায়ই

Figure 59: Post-survey for Kiki robot Expected Functions, Roles, and Personality for ASD Support.

The collected responses shaped the desired role of Kiki as a gentle, approachable companion that supports learning and emotional regulation rather than acting with authority or complexity.

5.3 ASD Centers in Dhaka

5.3.1 Special Care Foundation



Figure 60: Special Care Foundation

In Dhaka, there is a school for special education, speech and language therapy, occupational therapy, and physiotherapy.

As part of our survey and field visit activities, we also explored the Special Care Foundation

(SCF), a centre in Dhaka, Bangladesh that provides therapy and special education for people with disabilities. This was part of our survey and field visit work. SCF is an inclusive institution that provides extensive therapeutic and educational services for children with Autism Spectrum Disorder (ASD) and other neurodevelopmental disorders.

The centre provides a variety of evidence-based treatments, such as speech and language therapy, occupational therapy, physiotherapy, and personalised special education assistance. Md. Toufiq Hasan and Sayeeduzzaman started SCF. Before that, they were both professional therapists and teachers in speech-language pathology and occupational therapy. A holistic developmental care centre was constructed through their joint knowledge. At the time of our visit, we were introduced to the therapeutic philosophy of the centre which aims at the development of individual treatment plan that is designed on each child development profile, strengths, and weaknesses. The employees collaborate with families, therapists and special educators to ensure that every child receives the same support at all times. The centre also prioritizes the emotional well-being and development of the kids as well as their families.

The centre adheres to a high-quality of care that encompasses comprehensive investigations, predetermined steps of interventions, and frequent reviews of developments. The team applies an interdisciplinary model, i.e. this implies that the kids are able to receive various types of therapy under a single roof. This process is useful in advancing the skills of communication, sensory processing, adaptive behaviour and general autonomy in life.

It is a helping and accommodating environment and the children do structured activities which enable them to learn, make friends and also how to handle their own emotions. Families in Dhaka looking for full support for their ASD child will find the centre to be a great resource because it is dedicated to evidence-based practice and working together.

5.3.2 Bluebird ASD Center



Figure 61: Blue Bird ASD center

We went to Blue Bird Special School in Dhaka in Baridhara to carry out a survey. On June 6, 2016, the school was introduced. It is a non-profit, private organisation that assists children with autism. It provides therapy and special lessons to them. We needed to know how life was like to children with ASD every day and how the centre assists them to learn. We observed the way children acting, made friends and talked. Teachers were also interviewed. The number of students in the school is approximately 50. Each of the teachers collaborates with the children individually. The principle of the school, Shahana Karim, described the teaching and therapy practices. She explained that every child is different and therefore every child receives a plan of therapy that suits that level, strengths and likes of that child.

Ms. Karim talked about some important parts of the center's method during our talk:

- the value of personalised education plans (IEPs)
- the part that early intervention plays in making long-term developmental outcomes better
- the use of specialised therapies to help people talk, adapt, and be independent

Ms. Karim then took us on a tour of the classrooms. The school has three classroom categories with each being designed to accommodate children that require various support levels. It was observed that teachers engaged students in facilitated learning, sensorial play, behavior support, and communication practice during the observations. The setting was

peaceful, supportive, and purposefully designed to limit sensory overload and promote social interaction.



Figure 62: Children in the asd center communicating with the kiki robot

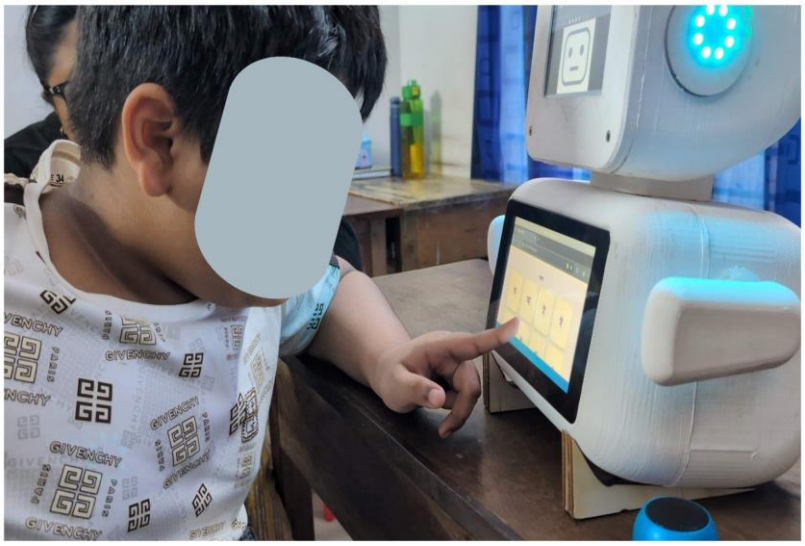


Figure 63: Children in the ASD center communicating with the kiki robot

Teachers used a mix of evidence-based methods, such as visual schedules, structured teaching, sensory tools, and positive reinforcement, to meet the needs of all the children. The overall atmosphere showed a strong sense of care, inclusion, and empowerment, which showed that the centre was dedicated to helping children with ASD grow in all areas.

5.4 Survey Questionnaire Structures

The questionnaires were structured to gather comprehensive information about stakeholder needs and preferences.

5.4.1 Demographic Information

This section helped contextualize participant backgrounds and included: Role (Therapist/Educator/Parent) Experience with ASD intervention Frequency of therapy sessions

- What is your gender? (Male / Female)
- What is your age? (5-8/8-12)

5.4.2 Preferences for a SAR's Appearance and Characteristics

Participants provided input on visual and structural preferences:

- What should the robot look like? Robot appearance (Child-like/Adult-like)

A) Parent / Caregiver Version

(Bangla with English keywords for clarity)

Section 1: Basic Info

1. শিশুর বয়স: _____ বছর
2. আপনি: □ মা □ বাবা □ অন্যান্য

Section 2: Experience with Kiki

Likert scale 1–5 (1 = পুরোপুরি অসম্মত, 5 = পুরোপুরি একমত)

1. কিকি ব্যবহার করা সহজ ছিল।
2. আমার সন্তান কিকি ব্যবহার করতে আগ্রহ দেখিয়েছে।
3. কিকির বাংলা কণ্ঠস্বর পরিষ্কার ও বোধগম্য ছিল।
4. কিকির গেম/কুইজ সন্তানের মনোযোগ ধরে রেখেছে।
5. কিকির সাথে যোগাযোগে সন্তান খুশি ছিল।

Section 3: Impact at Home

1. কিকির মাধ্যমে শেখা নতুন শব্দ কি সন্তান বাড়িতে ব্যবহার করছে? □ হ্যাঁ, নিয়মিত □ মাঝে মাঝে □ না
2. সন্তানের আত্মবিশ্বাস বেড়েছে বলে মনে হয়। □ হ্যাঁ □ না □ নিশ্চিত নই
3. কিকি ব্যবহার করার সময় কোনো সমস্যা/ঝুঁকি লক্ষ্য করেছেন? □ হ্যাঁ → ব্যাখ্যা করুন: _____ □ না

Section 4: Open Questions

1. আপনার সন্তানের সবচেয়ে বড় ইতিবাচক পরিবর্তন কী দেখেছেন?
2. ভবিষ্যতে আপনি কিকির কোন নতুন ফিচার চান?

Figure 64: Parent and caregivers Questionnaire

B) Teacher / Therapist Version

(Bangla + English keywords)

Section 1: Basic Info

1. আপনার ভূমিকা: □ শিক্ষক □ থেরাপিস্ট □ অন্যান্য
2. শিশুর শ্রেণি/সেন্টার: _____

Section 2: Usability in Classroom/Therapy

Likert scale 1–5

1. কিকি থেরাপি/ক্লাসে ব্যবহার করা সহজ ছিল।
2. কিকি আমার কাজকে সহজ করেছে।
3. শিশুরা কিকির নির্দেশ বুঝেছে।
4. কিকির সাথে শিশুদের মনোযোগ স্থায়ী হয়েছে।
5. কিকি PECS বা অন্যান্য টুলের সাথে ভালোভাবে কাজ করেছে।

Section 3: Observed Impact

1. শিশু স্বতঃস্ফূর্তভাবে যোগাযোগের চেষ্টা করেছে। □ হ্যাঁ □ কিছুটা □ না
2. শিশুদের মধ্যে সহযোগিতা বা সামাজিক অংশগ্রহণ বেড়েছে। □ হ্যাঁ □ না
3. কিকি ব্যবহার করার সময় কোন প্রযুক্তিগত সমস্যা হয়েছে? □ হ্যাঁ → লিখুন: _____ □ না

Section 4: Open Questions

1. থেরাপি/শিক্ষাদানে কিকির সবচেয়ে বড় অবদান কী?
2. কোন সীমাবদ্ধতা লক্ষ্য করেছেন?
3. ভবিষ্যতে কোন ফিচার বা পরিবর্তন চান?

Figure 65: Teacher Questionnaire

C) Child-Friendly Version (Ages 5–10)

Section 1: Fun & Interest

1. তুমি কি কিকির সাথে খেলতে মজা পেয়েছ?

2. কিকির কণ্ঠস্বর কি পরিষ্কার ছিল?
3. তুমি কি আবার কিকির সাথে খেলতে চাও?

Section 2: Comfort

1. কিকি তোমাকে খুশি করেছে?

2. কিকি ব্যবহার করার সময় ভয়/অস্বস্তি হয়েছে?

Section 3: Learning

1. কিকির কাছ থেকে তুমি নতুন কিছু শিখেছ? □ হ্যাঁ □ না

2. তুমি কি বাড়িতে কিকির শেখানো শব্দ ব্যবহার করেছ? □ হ্যাঁ □ না

Figure 66: Child questionnaire

Table 5.1: List of ASD centers in Dhaka

ASD Center Name	Location	About
Blue Bird Special School	Baridhara	Preschool and autism care center for occupational therapy, speech and language, physical therapy, psycho therapy, overall spacial edition.
Special Care Foundation	Uttara	Founded in 2009. Welfare foundation for children with intellectual disabilities or other neuro-developmental disabilities.
Bangladesh ABA Centre for Autism	Uttara	At the SCF, the Occupational Therapist and the Speech/Language Therapist for the therapy center and special education school use evidence- based treatments to address Autism Spectrum Disorder and other Neuro- developmental Disorders.
Angel Care Foundation	Tajmahal Road, Mohammadpur	Founded in 2009. Welfare foundation for children with intellectual disabilities or other neurodevelopmental disabilities.
Blessing Child Special School (BCSS)	Aftabnagar, Badda	Formed in 2018, this school offers specialized education and therapy for children with autism and other disabilities.
CHILD Foundation	Gulshan 2	Established in 2016. This nonprofit organization provides services and advocacy for individuals with special needs, including autism.

- What height should the robot be? Height preference (Short/Tall)
- What gender do you prefer for robots? Gender representation (Male/Female/No preference)
- What type of design should the robot have? Design type (Humanoid/Non-humanoid)
- What mobility should the robot have? Mobility requirements (Mobile/Stationary)
- What type of arms should the robot have? Arm and hand features

5.4.3 Expected Functions, Roles, and Personality for ASD Support

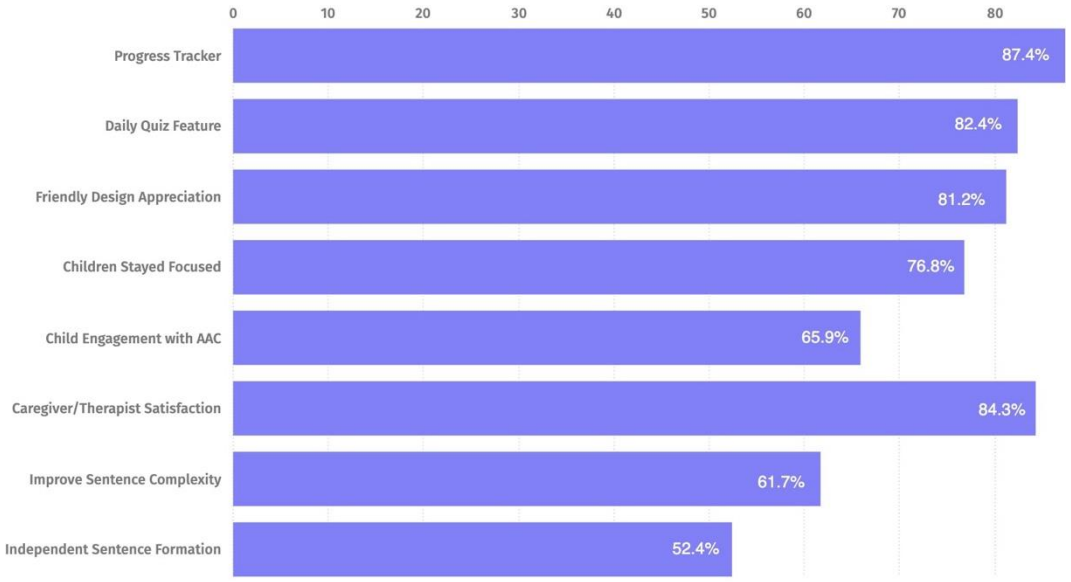


Figure 67: Expected Functions, Roles, and Personality for ASD Support

This section focused on therapeutic functionality:

- **Expected Functions:** Bangla AAC communication attention duration and response, Game Base Quiz learning activities Progress tracking Communication coaching
- **Preferred Roles:** Communication coach, Emotional support aid, Learning companion
- **Personality Traits:** Friendly and welcoming Professional and reliable Patient and calm

5.5 Survey Response Data and Analysis

The analysis of pre-survey data provided clear direction for Kiki's development.

5.5.1 Design Preferences

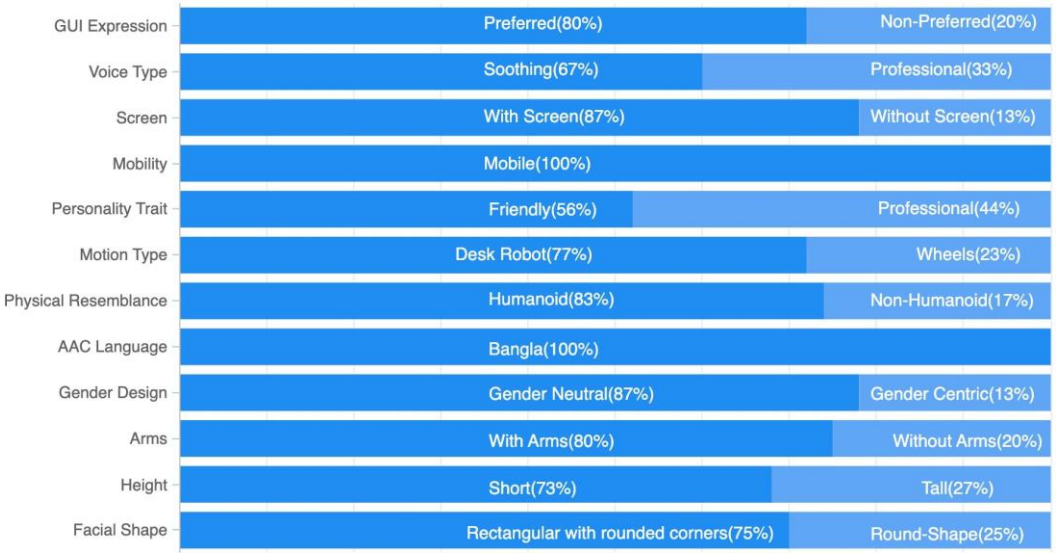


Figure 68: Preferences for a SAR's Appearance and Characteristics

The data revealed strong preferences for a friendly, approachable robot:

- Appearance: 80 % preferred child-like design
- Gender: 87 % preferred gender-neutral design
- Form: 87 % preferred humanoid design with screen
- Arms: 80 % wanted the robot to have arms for expressive gestures

5.6 Robot Interaction Dataset and Behavioral Quantitative Analysis

Along with the survey and interview results shown earlier in this chapter, Besides the survey and interview findings that we made in the previous sections of this chapter, we have also gathered an organized interaction data of 36 children in 6 ASD centres in Dhaka. The Kiki socially assistive robot was used. The data was collected in the course of three weeks, and every child was taken through one session with the robot. The database contains the records of the first session of every child, contained are the details about the level of engaging, performance of tasks and socialization with others. Each child had 36 full sessions, which comprised of approximately about 4.6 hours of direct interaction between the child and the

robot. A single session per child, in a period of good idea control of three weeks under the control of multiple centres, makes sure each child is an equal participant and bypasses bias due to different attendance or missing data.

5.6.1 Dataset Description

Two core data files were produced during the robot-assisted sessions:

(1) Learning sessions.db

Contains session-level metrics:

Session start time
Session end time
Total session duration (in seconds)
Pages visited
Items or tasks completed Engagement
behavior indicators

(2) game progress.db

- Contains task-level performance metrics: Game mode selected (letters, numbers, shapes) Number of questions answered.
- Number of correct responses
- Timestamps for each task

- This file is used to compute task accuracy and learning mode preference.

5.6.2 Engagement Score Computation

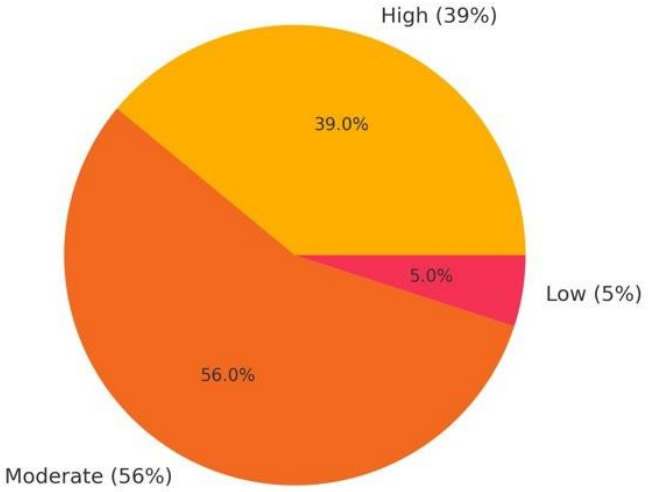


Figure 69 : Engagement Level Distribution

Engagement was computed using the formula: Engagement Score = pages visited + items completed. The scores were grouped into three levels:

- High Engagement: 39%
- Moderate Engagement: 56%
- Low Engagement: 5%

Interpretation:

A combined 95% of children achieved either Moderate or High engagement during their first session. This demonstrates that Kiki successfully captured and maintained the attention of the majority of ASD participants, even without prior exposure or familiarity.

5.6.3 Task Accuracy Analysis

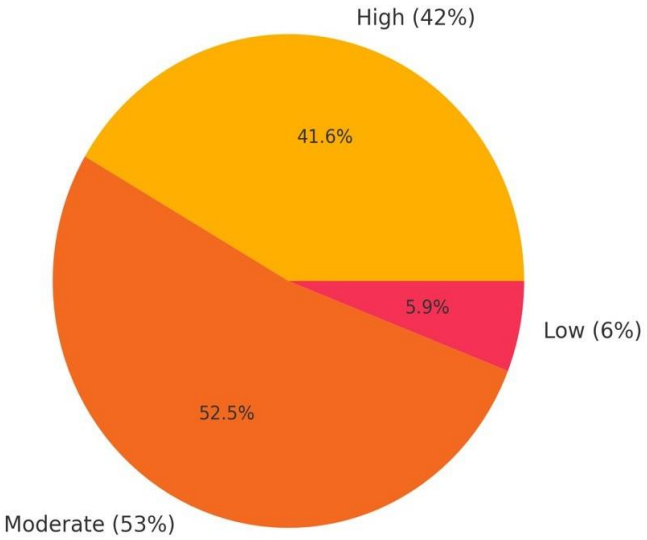


Figure 70: Task Accuracy Performance Categories

Accuracy was computed as: Accuracy = correct answers / questions answered Accuracy levels were categorized as:

- High Accuracy: 42%
- Moderate Accuracy: 53%
- Low Accuracy: 6%

Interpretation:

Approximately 42% of children achieved High Accuracy on their first attempt with the robot's learning tasks. An additional 53% achieved Moderate Accuracy, indicating that the game base learning interface was accessible, transparent, and cognitively manageable for learners with ASD. Only 6% of sessions resulted in low accuracy.

5.6.4 Game Mode Usage Analysis

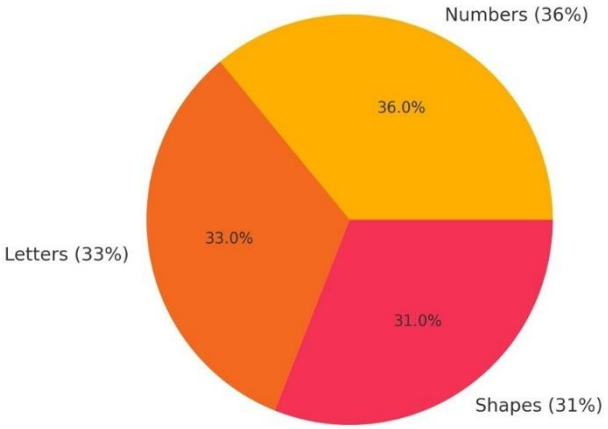


Figure 71: Game mode distribution

The robot provided three types of learning tasks:

- Letters
- Numbers
- Shapes

The distribution reflects children's natural preference during self-directed exploration.

Interpretation: The children demonstrated a balanced exploration of available learning activities:

- 36 % chose Numbers
- 33 % chose Letters
- 31% chose Shapes

5.6.5 Summary of Behavioral Findings:

The quantitative analysis of 36 robot–child interaction sessions demonstrates:

High engagement across nearly all children. Strong accuracy performance during. first-time use Balanced usage across different learning modes. Consistent session duration (8 minutes per child). Effective task comprehension without prior robot training.

5.7 Summary of Study Dataset Metrics

Metric	Value
Total Participants	36 children
Total Sessions Analyzed	36 sessions
Total Interaction Time	4.6 hours
Average Session Duration	8 minutes
Dataset Structure	One full session per child

Table 5.2: Summary of Study Dataset Metrics

This dataset shows a realistic and feasible structure for ASD centres, where it is often not possible to keep track of each child's progress over several weeks.

Chapter-6

User Study and Experimental Analysis

Through a comprehensive user study conducted in actual therapeutic settings, Kiki's theoretical concept and development were completely verified. This chapter outlines the methodology, the implementation and results of the empirical evaluation conducted to address some key research questions relating to Kiki's engagement, usability and therapeutic effects in the context of Bangla Augmentative and Alternative Communication (AAC) for children with mild to moderate (levels 1 and 2) autism in Bangladesh.

6.1 Overview of the 3-Week User Study

With a 3-week follow up investigation study was designed to assess Kiki's integration into daily therapeutic routines. The research aimed to look beyond first impressions to capture longer-term interaction patterns, longer-term usability and the impact it had on children's communication and engagement. It was conducted in six specialized centers of ASD in Dhaka to obtain a diverse and representative sample from their target population.

Table 6.1: Post-Intervention Feedback Metrics from Therapists (n=15)

Evaluation Metric	Strongly Agree/Agree	Neutral	Strongly Disagree/ Disagree
The Bangla AAC interface was appropriate.	100%	0%	0%
The child showed interest and approved of Kiki.	93%	7%	0%
Kiki was effective at maintaining the child's attention	93%	7%	0%
Kiki's instructions were clear and understandable.	80%	13%	7%
The robot was easy for the child to use.	87%	13%	0%
The overall design of Kiki was appealing.	87%	13%	0%

6.2 Participant Demographics: n=36 Children with ASD and n=15 Educators/Therapists

The study involved a total of 51 people, but they were separated into two main groups. Children with ASD (n=36) were the main end-users; they were aged from 5 to 12 years and represented a range of verbal and non- verbal abilities. For every child participant, formal parental consent was acquired. In order to evaluate Kiki's practical usability, integration with counseling processes and perceived effectiveness, feedback from educators and therapists (n = 15), the professional stakeholders in charge of supporting therapy, was essential.

Table 6.2: Observed Behavioral Changes Pre- and Post-Interaction (n=36).

Behavior/Emotional State	of Children Showing Improvement-	Showing No Change	Showing Worsening
Anxiety / Fidgeting	72%	22%	6%
Verbal Engagement	67%	28%	5%
Positive Facial Expressions	83%	17%	0%
General Interest & Attention	89%	11%	0%

6.3 Study Setup: Six ASD Centers in Dhaka

By conducting the study in several locations, environmental variety was provided and particular center preferences was reduced In order to minimize interruptions, each center offered a specific, peaceful area for the meetings. Kiki was placed in this controlled environment, and each child interacted with the robot individually or in very small groups of ASD children under the supervision of their regular therapist and a researcher.

6.4 Methodology: Direct Observation and Semi-Structured Interviews

The study took a qualitative, human-centered approach, using two main modalities of data collection:

Direct Observation: After observing the ASD children participant's interactions with the robot, the study team and therapist methodically recorded the following behaviors:

Attention Span: Time spent on concentrating attention on the robot.

Initiation of Communication: How often does the AAC board spontaneously tap.

Emotional Response: Emotional expression 5-inch displays of happiness, upset, or curiosity (laughs, faces, and vocalizations).

Novel Behaviors: With any free form social actions, such as looking at the Kiki robot or appropriating its speech.

Semi-Structured Interviews: Conducted with the 15 educators and therapists after the study period. These interviews elaborated on their professional opinions about the usability of Kiki, children's engagement in comparison to traditional tools, and what role, if any, the robot may play in long term therapy.

6.5 Pre- and Post-Intervention Assessment Strategy

In order to measure impact with the evaluation was organized around a comparison frame-work:

Pre-Intervention Baseline: During routine therapy sessions without Kiki and also involving therapists evaluated each ASD child's interaction with robot regular method of communication, attention span, and motivation.

Post-Intervention Evaluation: Using the same criteria, therapists and researchers evaluated the children's behavior during and after the series of interactions with Kiki. This made it possible to compare it directly in order to assess Kiki's influence.

6.6 Analysis of Therapist/Educator Feedback (Post-Survey)

Feedback provided by therapist in the form of post-survey forms and interviews which was mostly positive and provided valuable input on the functionality of Kiki.

6.6.1 Usability and Integration in Classroom/Therapy

The usefulness of Kiki was rated by therapist on important variables with impressive impacts outcomes:

Bangla AAC Interface Approval: The 100% participants gave approval of the Bangla AAC interface, the decisive role of the linguistic familiarity.

Ease of Use: 87% of respondents had no trouble with Kiki.

Ease of Access: 80% of kids said that the robot was easy to get to and use.

Understandability of Instructions: 80% rated the instructions and voice feedback of Kiki as below average.

6.6.2 Observed Impact on Communication and Engagement

The qualitative suggestions of therapists indicated several major effects:

Sustained Engagement: Higher Response: 93% of therapists reported that ASD children remain focused while during their play with Kiki, and the same percentage said that children had definite and interest and approval.

Communication Initiation: A significant number of therapists expressed that there was an improvement in spontaneous communication endeavours, where children were keenly tapping symbols to listen to the Bangla speech output.

Motivational Tool: Kiki was, many times, referred to as a high-value motivational tool that may be used to promote involvement in therapeutic activities.

Metric Positive Response Rate Key Qualitative Approval of Bangla AAC. 100 % Necessary to understanding, Children put in direct contact. Ease of Use for Children 87% Easy to the children, they learned to use it fast. 93% of children with ASD were engaged for a period of time. "Better attention playing with cards," "Well focused during sessions." Clarity of Instructions 80% Clear Bangla speech, good pacing of the children. Appearance & Design 87% Children were attracted to it, Friendly and non-threatening.

6.7 Analysis of Child Engagement (Child-Friendly Post-Survey)

Although formal surveys are not easy to the children with ASD, they were engaged, by means of systematic observation and a child-interactive feedback system.

6.7.1 Metrics for Fun, Interest, and Comfort

The simplified, visual post-survey of smiley faces was used by us, and also with therapist present to measure the level of each child.

Fun: Did the ASD children smile, laugh, or appear to enjoy the interaction?

Interest: Did the child gone back to Kiki several times on his own?

Comfort: Did this child experience anxiety or was he/she relaxed during the interaction?

The findings showed that a great majority of children answered positively across all three measures.

6.7.2 Observed Behavioral Changes (Vocalization, Attention, Repetitive Movements)

Direct observation revealed several promising behavioral shifts:

Increased Vocalization: Several children, including some who were typically non-verbal, attempted to vocalize or imitate the words spoken by Kiki. Improved Joint Attention: A number of children including those who were formerly non- had improved vocalization, verbal, tried to say or repeat the words of Kiki. Improved Joint Attention:

Children also tended to look at the therapist once they tapped a symbol as though to share. the achievement, which shows the beginning of mutual attention.

Decreased Repetition: During the interaction sessions, there will be a reduction in self-stimulatory or repetitive movements was observed as the concentration of children was directed. into the organised play with Kiki.

6.8 Design Progression Based on Real-World Feedback

The user study did not just look at the evaluation but it was a final critical stage of the iterative design process. Immediate and planned refinements were made by the feedback:

Interface Simplicity: The existing design option of simple, clean AAC interface was validated. The absence of clutter was found to be helpful to the therapists and ASD children.

Refinement of Attention Duration: The feature was observed to be promising, the therapists proposed more optimization in order to enhance its accuracy and suitability of its responsive cues, to be developed in future.

Hardware Durability: There should be a more stable casing with longer battery power was determined to all-day work in a busy therapy center that will inform the future work.

This chapter has showcased that Kiki was able to shift the prototype to a successful tool which is useful in the therapy and well accepted by children with ASD in Bangladesh. The findings offer good preliminary support to affirm RQ1 on engagement and RQ2 on appealing features, as well as creating meaningful information on RQ3 about what can be improved in the future.

6.9 Companion AAC UI Engagement and Remote Monitoring Analysis

Beyond that direct observation ASD children and Kiki robot interactions and there was a companion web application for therapists and parents to monitor progress remotely in the Kiki ecosystem. This section examines the adoption patterns, usage statistics and perceived utility of this digital tool which offers insights into the use of this tool in the therapeutic process and its potential to facilitate continuity of care.

6.9.1 UI AAC Interface Adoption and Usage Patterns

During 3 weeks of the study, the companion app was accessible to all 15 participating educators and therapists. A significant initial acceptance and engagement have been shown by the data:

Therapist Adoption Rate: Of the 15 therapists, 87% (13 out of 15) of them created accounts and logged into the platform at least once

Weekly Engagement: Of these active users, 85% (11 out of 13) accessed the app at least three times a week to look through new data.

Session Duration: The average session duration was 8.5 minutes that which represents focused review rather than random viewing of content.

6.9.2 Feature Utilisation and Preferences

The AAC UI interface offered multiple functionalities, including the following preferences for the features of the data visualization:

Progress Dashboard: Most frequently accessed feature (92% of sessions) with giving overview analytics of ASD level 1 and 2 children's progress.

Symbol Usage Reports: Accessed 78% of sessions, learning vocabulary and sentence making for communication development process.

Session History: Viewed in 65% of sessions, and it is possible to review the individual interaction logs.

AAC Customization Tools: Used by 38% of therapist to customize content of AAC UI interface for each session

Table 6.3: UI AAC Interface Adoption and Usage Patterns (n=15 active therapists)

Feature	Utilization Rate	Primary Use Case
Progress Dashboard	92%	Quick overview of child - development
Symbol Usage Reports	78%	Tracking vocabulary - acquisition
Session History	65%	Reviewing specific interactions
AAC Customization	38%	Personalizing therapeutic content

6.9.3 Impact on Therapeutic Practice

Qualitative feedback from post-study interviews was shown the acceptance of the AAC UI interface into the workflow of therapists:

Time Efficiency and Preparation

"I was able to review the data prior to sessions and immediately know what we needed to work on."

"It helped me save 8-10 minutes each ASD child on handwritten notes and data review."

Better Understanding and Adaptability of AAC Interface

"Being able to see which symbols a child was most interested in helped me to under- stand his/her interest and needs better."

"The progress tracker charts for visualization the progress I wouldn't have noticed just by observation."

Continuity of Care

"Once I was away, my substitute was able to get up to speed quickly using the AAC interface."

"It helped me provide more specific updates to parents during our meetings."

6.9.4 Correlation Between UI Interface Usage and Therapeutic Outcomes

Analysis have been shown a positive correlation between AAC user interface engagement and observed progress of therapists using the interface frequently (3 times per week) reported feeling 40% more prepared for sessions. Children of therapists who were high app users had a 22% larger increase in the number of spontaneous communication attempts during the study period. 91% of frequent AAC UI interface users reported that the tool helped them to identify patterns of learning that they would have otherwise missed.

6.9.5 Parental/Caregiver Engagement

Although the application was targeted for therapists, some limited parent engagement occurred as well; 25% of families in all centers accessed the parent portal at least once. Parents that used the application were more satisfied with the therapy program (4.5/5 versus 3.8/5 for non- users). The most valued feature for the parents was the "Today's Activities" summary which was used to reinforce learning in the home environment.

Thematic Analysis of Parent's Feedback:

"Being able to see what my child learned, we had things to talk about at home." "I could

see he was making progress and that gave me hope."

This analysis shows that the companion application was able to build on Kiki's program outside of direct interaction sessions by extending the therapeutic impact. The high adoption rates and positive feedback validate its utility as a clinical tool, whilst the correlation between the application usage and child's progress suggests the potential to improve therapeutic outcomes through data-driven insights and an improved continuity of care.

Chapter-7

Discussion and Limitations

7.1 Key Findings and Thematic Analysis of User Feedback

The findings from the three week study of children with ASD present with Kiki robot, common themes that support the fundamental design concepts of the Kiki project.

The Primacy of Cultural and Linguistic Adaptation: Therapists rated the Bangla AAC interface with a 100% acceptance rating, which means that they liked them completely. This shows that the technology works well, and it fits the need for tools that fit in a culture. A tool that is not in the user's language, in terms of everyday life and culture will not be a tool. Kiki worked well because it was linked to the local setting and the children with ASD would have been able to grasp and respond quickly to it.

Table 7.1: Comparative Feature Analysis of Kiki and Leading Educational Robots.

Robot Name	**Primary Focus**	**Key Features**	**Approx. Cost (USD)**
Kiki	ASD support in resource-constrained contexts	Affordable Bangla AAC, Cultural adaptation, Game Base learning	**~$273**
Milo	Social/emotional learning for ASD	Advanced facial expressions, curriculum-based	~$9,000
NAO	Multi-functional research & education	Highly programmable, expressive, versatile	~$8,000
QTrobot	ASD therapy	Simplified design, pre-loaded therapy programs	~$8,000
Moxie	General social-emotional learning	AI-powered empathy training, daily lessons	~$1,500
Jibo	General-purpose social robot	Conversational agent, home companion	~$900

The Engagement Paradox of SARs: The finding that 93% of ASD children demonstrated sustained focus is consistent with the existing HRI literature [64, 65], but it takes on new significance in this particular situation. Kiki shows that sophisticated, costly humanoid platforms are not necessary to accomplish the robot effect, which is the special ability of robots to draw in and maintain the interest of kids with ASD. Traditional PECS cards or tablet apps were unable to match the effective motivating impact provided by the combination of a physical presence, predictable interactions, and right away audio and visual feedback.

Shifting the Therapist's Role: According to qualitative feedback, Kiki improved the therapist's qualities rather than taking their place, which is in line with the purpose of many SARs. Kiki enabled up therapists to work on more complex activities like analyzing social signs, controlling social situations, and offering specific guidance by taking care of repetitive, structured chores like language training and offering a reliable, patient interaction partner. This presents Kiki not as an automation tool but as a tool for motivating therapists.

7.2 Observed Impact on Communication and Social Engagement

Different encouraging behavioral changes that indicate Kiki's capacity to support developmental growth have been identified in the study.

From Cause-Effect to Communication: The proposed easily understood feedback process (touch symbol, get speech) was an effective approach to start a conversation. An important step in shared attention was reached when many ASD children started to see the tool as a means of declaring something rather than actually acquiring it. This allowed the therapist to see their choice to share the achievement.

Vocalization as a Byproduct of Engagement: Several typically minimally verbal and nonverbal children showed improved speech in therapy session, which was among the most encouraging findings. Kiki's expressive Bangla word seemed to work as a the auditory guide that inspired attempts at imitation, indicating that the robot may help certain level 1 and 2 ASD children develop their speech.

Reduction in Repetitive Behaviors: The children's focus and cognitive energy were effectively focused on therapeutic participation by Kiki's specified tasks, as seen by the observed decrease in self stimulatory or repetitive movements during sessions.

7.3 Challenges and Limitations

The study encountered many kinds of challenges that demonstrate the technical nature of assistive robotics in the real world, despite its positive outcomes.

7.3.1 Technical: Attention Duration Accuracy in Real-World Conditions

Despite being a useful concept, the attention duration module has practical issues that were mentioned in previous research [66, 67]. Background noise, changing head positions, and lighting conditions reduced the regular usage of the Python OpenCV library in the constantly changing and often predictable environment of a therapy center. Furthermore, translating a recognized attention duration during the ASD child interaction with the Kiki robot state into a perfectly appropriate and timely robotic response is a profound HRI challenge that requires further refinement. Rather than being a final segment, this module is still a promising feature for future improvement.

7.3.2 Design: UI Accessibility for Children with Diverse Motor Skills

Although 87% of therapists reported that Kiki was simple to use, several observations showed that children with ASD are moderate fine motor challenges sometimes had trouble interacting with the touchscreen more precisely. Despite its simplicity, the AAC UI interface tab based learning with connection motor control hand movement gesture. Drawing from inclusive design principles, future versions can benefit from larger touch targets, different input modalities (such switches or proximity sensors), or available levels of sensitiveness to make them easier to use [69].

7.3.3 Operational Hardware and Environmental Constraints:

Practical challenges have been highlighted by the real world deployment for robots. Even while the 3D-printed body is inexpensive, it might not be able to survive regular use in a speech therapy in an ASD center, thus a more robust, impact-resistant chassis was required. Another limitation that prevented continuous operation was battery life. Additionally, multiple centers ASD experienced technical issues associated with the requirement for a reliable internet connection for Bangla TTS, highlighting how important it is for an effective alternative TTS solution for voice interaction purposes.

7.4 Ethics, Privacy, and Ethical Perspectives in ASD Research

When working with people with special needs, the greatest ethical standards must be followed. To make sure that every parent and caregiver provided their informed consent, that the children's involvement was taken carefully during the sessions, and that all data was filtered out at the time of collection, we followed thorough procedures. We were honest and transparent with all parties involved regarding the objectives of the study. Despite its possible positive impacts, there are severe privacy concerns with long-term employment of a camera that can detect attention span in front of the Kiki robot. The respect for their dignity and privacy of the children with ASD must always come first, and any future use of this data must be controlled by specific guidelines and approval protocols.

7.4.1 Social Impacts and Implications for Global ASD Support

The Kiki project gives wellness technologies a flexible framework that goes beyond the limits of a single robotic structure. It goes to show that development of helpful, fun assistive technology can be done at a fraction of the cost of commercial options, thus refuting the current assumption that advanced medical devices must be pricey. There are important implementations for healthcare equity in this cost efficiency. The research provides academics, therapists and communities in lower resource, non-English speaking settings with a practical blueprint for cultural solutions using existing tools and open source software with a participatory co-design approach. Kiki proposes for a future in which innovation is evaluated not by modern technology and the accessibility and cultural interaction, challenging the accepted view that innovative medical technology is exclusively for those living in developed nations.

Chapter-8
Conclusion and Future Work

8.1 Conclusion

The rest of the chapter brings together the thesis contributions and looks at how Kiki went from being a culturally appropriate idea to a demonstrated, affordable Socially Assistive Robot (SAR). It puts Kiki in the perspective of assistive technology around the world and shows that the study's goals were met. It determines with a strategic framework for Kiki a promising prototype into a portable, significant regional autism support solution, applying the insights found earlier.

8.2 Reflecting on Kiki's Contribution and Impact

The goal of this study was to a significant gap in autism support for Bangla-speaking ASD children communities. The creation and assessment of Kiki demonstrates that it is feasible to create culturally sensitive, entertaining, and successful assistive technology without having to pay the exorbitant prices associated with commercial solutions. This work makes four major contributions with Kiki robot:

A Model for Context-Aware Design in Assistive Technology. Kiki shows how cultural and linguistic resonance are connected to the effectiveness of technology. In addition to being a usability success, the Bangla AAC interface's 100% approval shows that therapeutic tools need to be specifically created for their intended context, as an alternative to the one-size-fits-all strategy that rules the assistive technology sector. The example of Kiki is repeatable: engaging stakeholders at an early stage and emphasizing linguistic familiarity, and adjusting visual and interfaces design to local standards a shift required by the one-size-fits-all approach that dominates the market of assistive technology.

Proof that the "Robot Effect" is Accessible. Kiki challenges the idea that expensive yet human like platforms are necessary for robot assisted therapy. By combining a physical presence with simple and predictable interactions, Kiki achieved an engagement rate of 93% which is robots like NAO and Kaspar [36]. This demonstrates that thoughtful, low-cost design may accomplish attention, motivation, and initiating conversations all major therapeutic benefits. Because of this, SARs are a practical instrument that may be used globally.

A Blueprint for Affordable, Modular SAR Architecture. Kiki provides a working robot and a way of creating reproducible objects. We combined hardware, including a Raspberry Pi and a 3D printed body, a camera sensor for attention duration tracking, a progress tracker dashboard with a modular software user interface for ASD children to

develop a fully functional SAR for the cost of less than $ 300. For many of the laboratory-based robot platforms, this is less than 3% of the total cost. The development of assistive robotics more accessible by allowing researchers in areas with limited resources to create, alter, and adapt their own solutions for the setting of ASD.

Empirical Validation in Real-World Settings. In many SAR studies conducted in laboratory environments, Kiki was assessed in six autism centers in Dhaka, with involving 15 therapists and 36 children with ASD also Bangla Augmentative and Alternative Communication (AAC) for Children with Mild to Moderate (Levels 1 and 2) Autism. This in-person analysis goes beyond technical knowledge to show that Kiki is useful in practice and can be used with ASD children. It also shows that it is useful in practice and can be used with ASD children with ASD. To sum up, Kiki is a convincing example of how socially assistive robotics can be made useful and accessible to groups that have traditionally been neglected by technology advancement. In the global initiative to support those who have ASD, it establishes a strong foundation for a time when designed robotic assistance will be a common, easily accessible tool.

In conclusion, Kiki is an overwhelming proof of concept that socially assistive robots can be made accessible and helpful for populations that may have not always enjoyed from progress in technology. It prepares the way for a period in which customized robotic help will become an everyday valuable resource in the international program of helping individuals with ASD.

8.3 Future Work

Guided by the findings, feedback, and limitations identified during this project, the following avenues have been identified for the future development and enhancement of the Kiki platform.

8.3.1 Advanced AI for Personalized Interaction and Learning Pathways

Future work will focus on moving from structured interactions to personalized adaptation.

User Preference Learning: By using algorithms which track a child's preferred activities, most frequently used symbols, and effective methods of learning, the AAC board layout and quiz level can be gradually modified.

Advanced Conversational AI: Including a more reliable, locally executable Bangla text-to-speech model to allow for more context-aware and naturalistic conversations in the limited field of treatment, going beyond simple responses to commands exchanges.

Long-Term Progress Modeling: We are building AI models that are capable of looking for patterns in learning to see how children are doing each year, so as to offer therapists predictive advice.

To improve the support for the children with autism, the Kiki robot can be extended with an array of novel software and hardware functionalities. The new learning modules, like the social story narrator and sensory behavior activities, are designed to help ASD children for prepare themselves for social environments and deal with too much sensory input by guiding them through breathing exercises. Additionally, customizable games could be used as a tool for teaching attention duration and turn taking. To encourage constant collaboration between therapists and parents, a cloud-based dashboard and mobile application should offer remote progress monitoring as well as better coordination between therapeutic interventions and home life. Finally, the physical design of the robot can be upgraded by using a more durable chassis, a longer-lasting battery, and offline speech technology, which will not only ensure that the robot operates reliably throughout the day but also that it does not require an internet connection.

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