Convolutional neural network modelling for autistic individualized education chatbot

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ABSTRACT

The traditional education system for autistic kids needs integration with computer technology that embraces artificial intelligence to help school instructors and management. An application that enables the teacher to retrieve information from a trusted source is essential since the information is only sometimes available on time. Thus, developing a chatbot application that utilizes natural language processing can enhance the management of autistic schools and will help individualized education for autistic students. This research uses a deep learning model that utilizes a convolutional neural network to develop a chatbot as a teaching assist tool for teachers. The results show that the chatbot has achieved ˜0.03% loss when trained with different epoch numbers. In terms of usability, the chatbot achieves mean system usability scores of 80.48 ± 13.03. This may open opportunities for more effective individualized education for students with special needs and increase the potential to improve inclusive education for disabled students. It is useful to include future actions that enable the simplification of the use of this chatbot tool in a wide range of contexts. To close the education gap for children with disabilities, chatbots could help people with communication disabilities and could also significantly enhance the rate of communication.

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1. INTRODUCTION

Autism, often known as an autism spectrum disorder (ASD), is a severe condition characterized by significant social interaction and communication difficulties. There is a broad spectrum of signs and abilities that can range from mild inconvenience to severe disability requiring round-the-clock care in a specialized facility [1]. Instructors usually have a hard time dealing with autistic students due to their lack of experience in teaching and skills. Some schools may not have enough funding to hire professionals to overcome the inexperience issues among instructors [2]. Most educators need more experience in teaching unique needs students. Hence, the problem can be solved by having an application that enables the teacher to gain information from a trusted source thus improving the individualized education system for autistic students. The artificial intelligence (AI) field is a technology that constantly improves assisting daily human tasks. A chatbot is a type of AI technology that can carry natural-sounding conversations for a variety of purposes, thanks to its enormous vocabulary and wide range of conversational topics. Most internet banking applications [3], government officials [4], hospitals [5], universities [6], and other websites [7] are using chatbots nowadays. However, autistic education sectors still implement conventional methods such as manual books, materials, and physical interactions and communications. Currently, autistic education teaching tools to assist teachers are still lacking. The current chatbots designed for autistic education mainly focus on children's usage. A chatbot for autistic kids' usage was designed by [8]. Participants interacted with the chatbots for 20 rounds of trials in their experiment to complete the evaluation. The results showed that the chatbot can successfully attract students' attention to understand it. The chatbot also showed how it could be used in a conversation-based solution for Chinese kids with ASD. Another chatbot was developed by [9] which is designed to diagnose achluophobia and autism using natural language processing (NLP) that implements decision tree algorithms for disease severity detection. Not only can they save the time of an expert diagnosis system, but they also ensure effectiveness. Similar research can be found in [10] where the authors have developed a "Hear to help Chatbot" as an assistance tool for autistic kids to seek help. The specific algorithm used in their AI chatbot has not been mentioned.

A chatbot based on forum data used by the autism online community was proposed in [11]. It embedded a random forest algorithm for the classification task and concluded that the developed chatbot could guess and reply correctly to the queries. It helps many users in finding information about autistics, at least for the basic information. A shift from chatbot to robot was presented in [12]. The robot was introduced to help the children complete their daily tasks and assist the teacher with educational activities. The kids and teachers worked together to create the robot's actions and how it fits into the school. The goal was to improve the kids' well-being. They used a mix of methods to look at how the robot was used throughout the study and how its presence affected the kids' well-being and the school's environment. It can be observed that the robot worked well in the school. It boosted the happiness of a select set of kids by encouraging and maintaining regular contact with them. It also sparked a sophisticated discussion among students and faculty on the benefits and drawbacks of this kind of social technology in the classroom.

Chatbots can be developed using several methods such as rule-based, retrieval-based, generative, AI-assistant, social media, and hybrid. Rule-based chatbots follow a predefined set of rules and patterns to respond. They typically use if-then statements or decision trees to determine the appropriate reply based on specific keywords or patterns in the user's input [13]. Retrieval-based chatbots store and retrieve predefined responses from a database based on user inputs [14]. These responses are often prewritten and selected based on the closest match to the user's query. Generative chatbots employ more advanced techniques, such as NLP and machine learning, to generate responses in real time. They learn from vast amounts of training data and can generate contextually relevant and coherent responses [15]-[17]. AI-assistant chatbots, also known as virtual assistants, integrate various AI technologies, including natural language understanding, speech recognition, and machine learning. They aim to provide more comprehensive assistance by understanding user intent, retrieving information from databases or application programming interface (APIs), and performing tasks such as setting reminders, making reservations, or providing recommendations [18]. Social media chatbots are designed specifically for interacting with users on social media platforms. They can handle customer inquiries, provide information, deliver personalized content, and even facilitate transactions, all within the social media messaging interface [19]. Hybrid chatbots combine different approaches, such as rule-based systems, retrieval-based methods, and generative models, to leverage the strengths of each technique. This allows for more flexible and robust conversations by switching between predefined responses and dynamically generated ones [20]. The application of deep learning in chatbot development within the corporate sector has shown a notable increase in recent times [21]. The effectiveness of chatbots is continuously enhanced by their exposure to new discussions and user interactions, which the deep learning models learn from [22], [23]. It is not debatable that AI and machine learning play a leading role in autistic education. Apart from assisting the children and medical experts, there is plenty of improvement needed for teachers and instructors to help grow the autistic children's future. Therefore, this research will optimize AI in the autistic education system in the hope that it will help all instructors and school management in their daily tasks.

2. METHODOLOGY

Figure 1 shows this research's overall flow, which contains raw data collection, data pre-processing, chatbot development, and functionality testing. Overall, the research divides the phases into three phases: system design, front-end development, and back-end development. The design process was facilitated by developing design diagrams as shown in the following subsections. The system design includes the system flowchart and use case diagram. The flowchart, as depicted in Figure 2, illustrates the overall flow of how the chatbot operates and the system architecture in further depth.

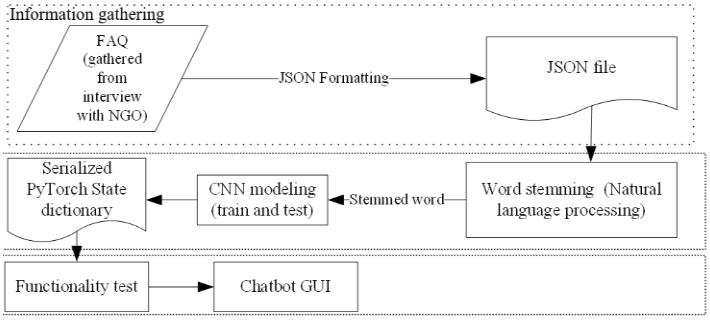


Figure 1. Research flow

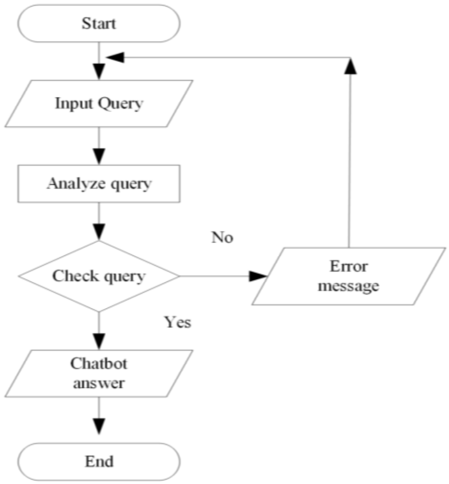


Figure 2. Chatbot flowchart

2.1. System design

One crucial aspect in the system design phase of chatbot development is to guarantee the efficient transition between user queries and the chatbot's responses. In this research, the chatbot will ask the user if they are satisfied with the response once they select the type of inquiry. If the user approves of the response, the chatbot will offer three choices: rephrase the question, email headquarters, wait for a reply, or end the conversation. Upon receiving an appropriate response, the user can decide whether to proceed with further inquiries or conclude the session. Figure 3 displays the use-case diagram, a component of the system design and development process, illustrating how a user interacts with the system. The use case diagram provides a concise overview of the connections among the use cases, user, and system. Two cases originate from the user, while one is generated by the system. The user will enter a query and then click the "Send" button. The system will execute the algorithm to comprehend the user's intention and select the most dependable answer from the trained dataset. Upon completion, the system will present the outcome in the chat. The user can query the chatbot multiple times.

2.2. Front and back-end development

The backend development involves dataset design, convolutional neural network (CNN) model development, and functionality testing. The development in the back end aims to facilitate the front-end development with underlying data. Flask, a lightweight Python web framework with useful tools for building Python online applications, will be used to develop the chatbot. Since it lets developers build a web program in one Python file, it’s more flexible and easier for beginners. Flask may be expanded without a directory structure or boilerplate code.

Dataset design is how the data is stored and used. Table 1 shows some examples of the raw dataset. The data were collected manually by conducting interviews with the non-government organization (NGO) representatives such as teachers and physiotherapists. The data were divided into two sections which are educational and administrative.

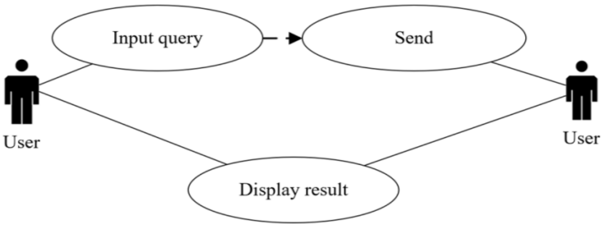


Figure 3. Chatbot use case diagram

Table 1. Data distribution

Types	Examples	Quantity
Educational	1. The child has poor gross motor skill	120 sentences
	2. Is there a lesson plan for circle time?	840 words
	3. How about toilet training?	40 repeated words
Administrative	1. How about teaching material?	150 sentences
	2. How do I know about my staff profile?	955 words
	3. Can you explain about staff leave?	138 repeated words

In addition to face-to-face meetings, internet meetings with the representatives were also used to collect data. Before the interviewing sessions, ethical approval was sought and received. Observations on the kids at the National Autistics Center were conducted to form a dataset that contains the frequently asked questions (FAQ). The raw data that were used in this research went through a pre-processing stage such as tokenization, stemming, and lemmatization. In the tokenization, the sentences were chunked into words. Then, all the unnecessary marks such as punctuation marks, stop words, and fillers were filtered. Word normalization was executed on the filtered tokenized word by using an NLP approach of stemming and lemmatization. In stemming, the string was divided into substrings by utilizing specific rules. Stemming was done to remove word affixes and suffixes thus reducing inflection in words to their root forms, hence assisting in text, word, and document preparation for text normalization. On the other hand, lemmatization is removing only inflectional endings and returning the lemma, which is the basic or dictionary form of a word such as tense, case, voice, aspect, person, number, gender, and mood. Reducing inflectional words can avoid redundancy in the NLP process. Although lemmatization is quite complex compared to stemming, it provides the lexical and morphological of the words, which finally produces the dictionary form of the words.

The raw data, as shown in information gathering, were converted into a JavaScript object notation (JSON) file, a form the algorithm can read. JSON is a lightweight format for storing and transporting data. Figure 4 shows a snapshot of the JSON used for the chatbot. JSON is a standard data interchange format that JSON file dictionary including tags, patterns, and responses [24], [25]. Traditionally, machine learning modeling needs to go through a complex task such as data preparation and feature extraction before going through different suitable modeling processes of training, testing, and validation. By using JSON, all the hustles can be skipped. In the JSON dictionary, there will be one unique response for each tag, and there may be multiple questions based on the tags. The tags were separated into two sections, each containing a single answer with numerous intended user inputs. The tags also include keywords such as acquaintance and greeting. The JSON file was trained using a CNN that is explained in the next sections.

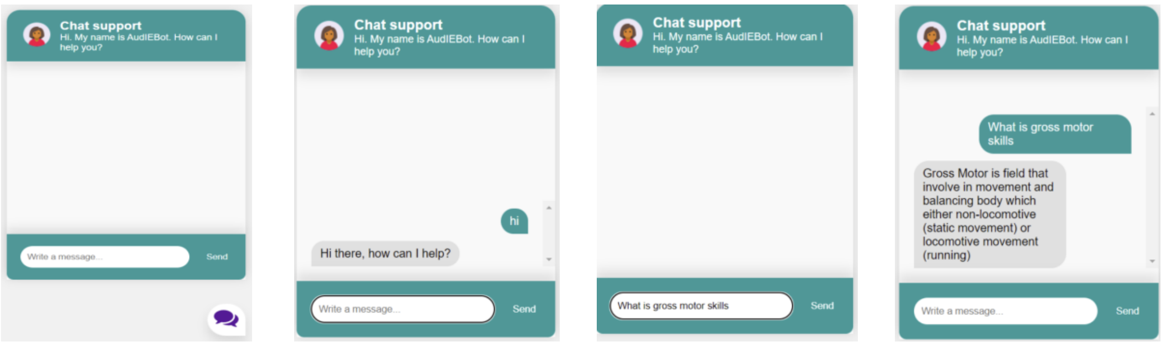
```
intents": [
  {"tag": "greeting",
   "patterns": ["Hi", "How are you", "Is anyone there?", "Hello", "Good day"],
   "responses": ["Hello, thanks for visiting", "Good to see you again", "Hi there, how can I help?"],
   "context_set": ""
  },
  {"tag": "goodbye",
   "patterns": ["Bye", "See you later", "Goodbye"],
   "responses": ["See you later, thanks for visiting", "Have a nice day", "Bye! Come back again soon."]
  },
  {"tag": "thanks",
   "patterns": ["Thanks", "Thank you", "That's helpful"],
   "responses": ["Happy to help!", "Any time!", "My pleasure"]
```

Figure 4. JSON file for dataset design

Traditionally, machine learning modeling needs to go through a complex task such as data preparation and feature extraction before going through different suitable modeling processes of training, testing, and validation. By using JSON, all the hustles can be skipped. In the JSON dictionary, there will be one unique response for each tag, and there may be multiple questions based on the tags. The tags are separated into two sections, each containing a single answer with numerous intended user inputs. The tags also include keywords such as acquaintance and greeting. The JSON file is trained using a CNN that is explained in the next sections.

2.2.1. User interface design

The user interface (UI) design is one of the most important aspects of a system's design to make it appealing and user-friendly. Having a user interface design early in the project development process might assist in avoiding mistakes and demonstrate how the system operates from the user's perspective. The user interface design is part of the front-end process that will have choices of buttons for the user to interact with the chatbot. Figure 5 depicts a graphical user interface (GUI) that is offered for aesthetic purposes and to make the dialogue more user-friendly. Based on Figure 5, when the user inputs a query and clicks the send button the chatbot is connected to the trained dataset and able to post the response. The test was a success since the chatbot sent a reply. Figure 5(a) lets you start the chatbot, Figure 5(b) lets you use a simple motion, Figure 5(c) lets the user send a query, and Figure 5(d) lets the chatbot answer.



(a) (b) (c) (d)

Figure 5. Graphical user interface of AudiEBOT: (a) starting the chatbot, (b) a simple gesture, (c) sending a query, and (d) Chatbot replies

2.2.2. Chatbot modelling using convolutional neural network algorithms

The CNN model was chosen to develop the chatbot because of its performance in predicting user input compared to other conventional machine learning algorithms. The CNN is a widely recognized architecture in the field of deep learning. It has been extensively employed in several domains, including image processing and network intrusion detection [26]. One of the key advantages of CNNs is their ability to facilitate deeper neural networks with significantly fewer parameters. Compared to other classification methods, CNN requires substantially less pre-processing and can significantly learn all filters and features. CNNs are multilayer perceptron (MLP) variants with convolutional layers. The convolutional layer minimizes network complexity by applying a convolution function to the input and forwarding the result to the next layer, analyzing a sentence/image at a time. CNN reduces complexity, allowing deeper networks to handle more complicated input. In chatbot development, CNN takes a text as input and assigns important parameters of learnable weights (w) and biases (b) to various features and objects in the text, allowing it to differentiate between them. The CNN model that was used in this research consists of 3 hidden layers, each with 10 neurons as shown in Figure 6. The batch size used in the CNN modeling is 10 with 0.001 learning rate. The hidden neuron in each hidden layer acts the same as our brain which is influenced by the organization of the visual cortex. The input size is related to the hidden size, and the hidden size is connected to the number of classes, based on the relationship between the layers.

When the user provides input, the model initially tokenizes the information by dividing it into tokens, which are smaller pieces of text. The tokens in this context consist of characters, words, and sub-words. The tokens are subsequently serialized into a stream of 0 s and 1 s, a process known as serialization. Then, it compares the input with the data from which the bot was trained and estimates the probability of that input being associated with each tag. The pattern with the highest probability tag is considered and compared with a predetermined confidence threshold. If this tag's probability exceeds the threshold, a random function is used to display one of its responses on the user interface. The process is shown in Figure 7.

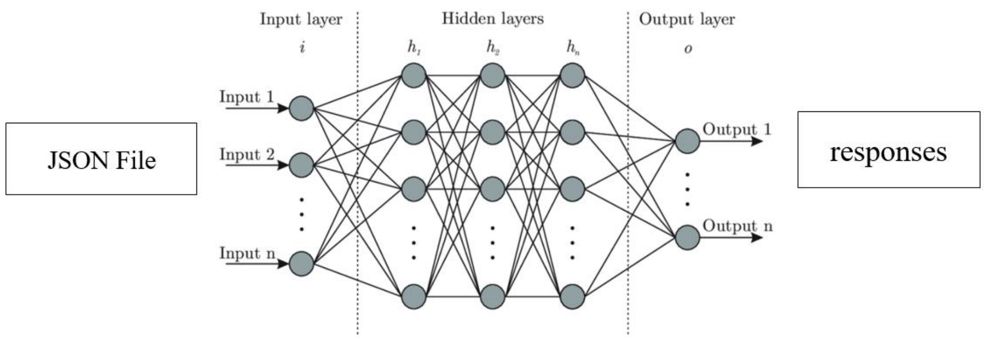


Figure 6. CNN with 3 hidden layers, I input layer, h_n: hidden layers and *o* is the output layer

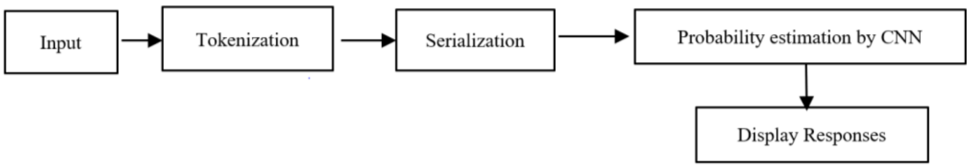


Figure 7. The system architecture

Multiple tests were set up for the modeling of CNN by testing a range of 500 to 4,500 epochs to achieve minimal loss. The epochs were initially set at 500. However, the outcome appeared less than promising. The number of epochs increased by 500 until it reached 4,500. It was discovered that epochs of 4,000 are optimal because they produced the lowest error rate. A predetermined confidence threshold between 0.50 and 0.85 was established to compare the input with the data that was trained in the model. It was discovered that when 0.7 was selected, too many inappropriate responses were displayed, and when 0.85 was selected, the CNN prediction was too strict. Consequently, the value of 0.75 was chosen. To measure the accuracy of the chatbot, the accuracy of the chatbot was calculated using (1).

$$accuracy = \frac{Correct\ classification\ of\ instances}{all\ instances} \quad (1)$$

3. RESULT AND DISCUSSIONS

The results present training and testing of the CNN model using specific pre-defined hyperparameters and thresholds. The correctness of the chatbot is also evaluated numerous times to select the most dependable number of cycles of the dataset that must be trained to achieve the lowest error. Several test intents and their ground truth confidence percentages were prepared.

3.1. Modelling training result

Table 2 shows the training result of CNN modeling during the chatbot development that was done in four folds. The results are also arranged according to the NLP threshold setting. Each epoch represents one cycle of training, while loss is the proportion of train errors. The number of epochs is altered to determine and minimize the number of errors. As described in the preceding section, multiple epochs were utilized to train CNN. On average, four folds of training were done. The second fold denoted the lowest loss of 0.031.

3.2. Chatbot testing

To see the performance of the chatbot, two types of testing were done. The first was by using threshold and the next one was using usability questionnaires gathered from [26]. A test case was constructed to confirm that the system produced the intended result. The chatbot was tested for all potential flaws to guarantee that the application could handle the problem.

Table 2. Training result of CNN modeling

Fold 1		Fold 2		Fold 3		Fold 4	
Number of epoch	Loss	Number of epoch	Loss	Number of epoch	Loss	Number of epoch	Loss
500	0.0069	500	0.0069	500	0.0069	500	0.0069
1,000	0.1744	1,000	0.1	1,000	0.2	1,000	0.1901
1,500	0.0002	1,500	0.0002	1,500	0.0002	1,500	0.0002
2,000	0	2,000	0	2,000	0	2,000	0
2,500	0.0876	2,500	0	2,500	0.0876	2,500	0.0876
3,000	0	3,000	0	3,000	0	3,000	0
3,500	0	3,500	0	3,500	0	3,500	0
4,000	0	4,000	0	4,000	0	4,000	0
4,500	0.1733	4500	0.1702	4,500	0.1715	4,500	0.1801
Average loss	0.0491		0.0308		0.0518		0.0516

3.2.1. Testing based on threshold

The chatbot considered a response valid if its confidence score is equal to or greater than 0.75. The confidence score represents the model's estimation of how confident it is in generating the response. Based on the testing, when the 0.75 threshold was chosen, most test intent scored a confidence of more than 90%. To find the optimum threshold value for the chatbot, we fed the bot with the test that has been annotated with its correct responses or its correct ground truth value. Then the output was inspected based on the confidence threshold at different levels of 0.50, 0.75, 0.80, and 0.85. There were about 150 intents tested for each of the confidence thresholds. Results for the average accuracy against confidence thresholds are presented in Table 3. It can be observed that the highest accuracy is at a confidence threshold of 0.80 which is about 85%.

Table 3. Test cases of confidence thresholds

Confidence threshold	Average confidence score (%)
0.50	47
0.60	66
0.70	75
0.75	88
0.80	85
0.85	80

3.2.2. Chatbot usability questionnaires

A chatbot usability questionnaire is a set of questions designed to assess the user experience and usability of a chatbot. It helps gather feedback from users to understand their satisfaction, ease of use, and overall impression of interacting with the chatbot. The elements that are included in a chatbot usability questionnaire as shown in Table 4. The questionnaires were ranked from strongly disagree to strongly agree, with intermediate choices in between.

Table 4. Chatbot usability questionnaire

Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Q1 The chatbot's personality was realistic and engaging					
Q2 The chatbot seemed too robotic					
Q3 The chatbot was welcoming during the initial setup					
Q4 The chatbot seemed very unfriendly					
Q5 The chatbot explained its scope and purpose well					
Q6 The chatbot gave no indication as to its purpose					
Q7 The chatbot was easy to navigate					
Q8 It would be easy to get confused when using the chatbot					
Q9 The chatbot understood me well					
Q10 The chatbot failed to recognize a lot of my input					
Q11 Chatbot responses were useful, appropriate, and informative					
Q12 Chatbot responses were not relevant					
Q13 The chatbot coped well with any errors or mistakes					
Q14 The chatbot seemed unable to handle any errors					
Q15 The chatbot was very easy to use					
Q16 The chatbot was very complex					

The data collected from the surveys in Table 4 were analyzed using the system usability score (SUS) following (2) as mentioned by [27].

$$\overline{SUS} = \frac{1}{n}\sum_{i=1}^{n} norm.\sum_{j=1}^{m}\begin{cases} qi,j-1, qi,jmod2>0 \\ 5-qi,j, otherwise \end{cases} \quad (2)$$

where m=10 is the number of questions, n=total number of subjects (questionnaires), $q_{i,j}$=individual score per question for each participant and norm=2.5. The results of the SUS can be categorized into percentile ranges as shown in Table 5.

Table 5. Description of SUS grades

SUS grade	Description of result
0-25	Worst Imaginable
>84.1	Best Imaginable

A group of 50 people who satisfied the requirements for being healthy adults were recruited as volunteers to assess the usefulness of the chatbot. Figure 8 illustrates a boxplot that portrays the SUS outcomes acquired from the assessment of the chatbot. The chatbot has achieved a mean SUS score of 80.48 ± 13.03 with a median score of 85.95. The highest achieved score was 100.0, and the lowest recorded score was 50. The chatbot's average score places it inside the top 93rd to 100th percentile range. Hence, it can be inferred that the chatbot has a commendable degree of usability as determined by the conventional SUS values.

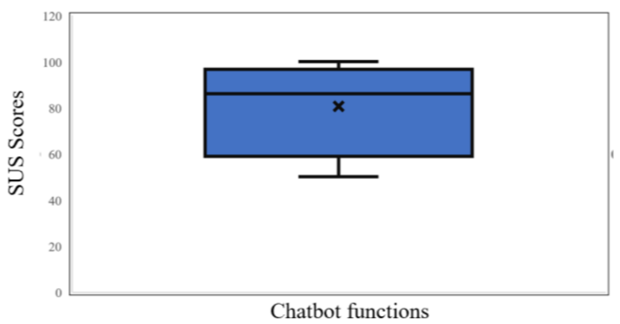


Figure 8. Chatbot usability questionnaire scores

4. CONCLUSION

In this study, a chatbot is proposed as a solution to the problem of educational system management for autistic children. The research focuses on how to assist teachers in managing their everyday responsibilities while working with autistic students. It is an interactive system that provides pre-programmed responses in response to questions posed by users. It frees customers from the constraints of time limits and makes it possible for them to obtain responses quickly, making it an excellent substitute for conventional live chat. The Python programming language will be utilized throughout the construction of the chatbot, which will take place in the system gateway of the school. Users will have the ability to have a more natural dialogue with the chatbot thanks to the implementation of deep learning, which has also been demonstrated to have a greater level of accuracy when replying to user inquiries. In the not-too-distant future, the chatbot will be incorporated into Telegram, an instant messaging service, and users can speak with one another regarding autistic school management via Telegram. Users may also benefit from the chatbot system, notably reducing the time necessary to conduct a physical consultation between teachers, physiotherapists, and the upper management team.

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