Enhancing Piano Learning Experience in Young Children with Robotics Assistance

Baran Shajari
McMaster University
Hamilton, Canada
shajarib@mcmaster.ca

Leonard Chen
McMaster University
Hamilton, Canada
chenl299@mcmaster.ca

ABSTRACT

This study analyzes the use of semi-humanoid robots in a piano classroom setting, where the robot interacts with students, providing real-time feedback and pointing out mistakes. Children were observed practicing one piece with the robot's assistance and a similar piece without it. They were assessed based on three criteria: improvement in learning through fewer mistakes, motivation and engagement during practice, and learning speed. The findings expected to show that students made fewer mistakes and completed their pieces faster with the robot. Additionally, it's expected that most students prefer practicing with the robot, describing the experience as more enjoyable and engaging. These results would suggest that humanoid or semi-humanoid robots can be an effective and valuable tool for enhancing young children's music education.

CCS CONCEPTS

• **Human-centered computing → Field studies**.

KEYWORDS

Robotics, Piano Education, Young Children, Learning, Semi-Humanoid Robot

ACM Reference Format:
Baran Shajari and Leonard Chen. 2024. Enhancing Piano Learning Experience in Young Children with Robotics Assistance. In *Proceedings of (CAS 723 Human-Robot Interaction)*. ACM, New York, NY, USA, 9 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

Practicing piano is very important in learning musical skills like Piano. Practicing is found to be the strongest factor in learning musical skills. However, younger children often have difficulties in finding motivations to practice every day, and it's a very self-directed activity which makes it difficult for younger learners [5]. If children have parents around who encourage them to practice, they will get motivated. However, parents do not have the time to listen and sit with their children daily to practice piano [5]. Also, younger learners attending piano classes struggle to practice correctly at home, frequently forgetting what they learned in class.

This research will be focused on understanding how robots can assist young children in learning piano and interacting with them, specifically for teaching young children how to practice piano at home when there are no adults present. We need an approach to address the common challenges of piano education for young children, such as limited retention of material learned in class and the need for personalized learning experiences.

Humanoid robots are designed to interact with humans and usually are equipped with sensors capable of recognizing objects, voices, and faces, enhancing the interactive learning experience [2]. Furthermore, an article [16] has highlighted that robots can be used to achieve a dynamic and expressive piano-playing experience, making them highly suitable for engaging young children.

In this research, the robotics solution is tailored to the needs of young learners. Specifically, the use of semi-humanoid robots is researched in children's musical education, focusing on helping and motivating them in their personal practice sessions. The focus is to observe if the robots can help guide children when adult supervision is not available so they can improve faster and if it will increase their motivation to practice piano.

The methodology for this study centers on comparing two piano practice conditions with a group of students. In the first condition, students practice a piece with the robot as an assistant and the in the second condition, they practice a similar piece alone. In the robot assistant condition, the robot is expected to help by identifying and pointing out mistakes, providing real-time feedback while also motivating children through interactive engagement and encouragement. The goal of this paper is to determine if robot assistants can enhance students' practice sessions by engaging them, reduce errors in their playing and make piano practice more efficient. In order to collect data, participants are interviewed and observed in each practice condition. The data collected from the students will be analyzed to assess whether using robots as an assistant to help with piano practice enhances children's independent music learning.

The research questions guiding this inquiry are as follows:

(1) Will the use of robots improve children's performance and reduce errors in their practice?
(2) Do children get more engaged when robots are involved?
(3) Do children's motivation to practice piano increase when practicing with a robot?
(4) Do children learn faster when practicing with a robot than practicing alone?

By exploring these research questions, this paper will analyze if robots can be effective in teaching piano to young children, as well as identifying methods to foster engagement and inspire continued learning. Gaining insight into these questions will be essential to

CAS 723 Human-Robot Interaction, 2024 Fall, McMaster University

ACM ISBN 978-1-4503-XXXX-X/18/06
https://doi.org/XXXXXXX.XXXXXXX

see if robots can support young children's piano practice at home, ultimately promoting their music education in a fun and interactive Way.

2 HYPOTHESIS

There are three main hypothesis for this study:

(1) Using robotics will improve children's performance by reducing errors in their practice pieces as opposed to solo practice.
(2) Children will interact with the robot and get engaged in learning how to play piano with the robot assistant as opposed to practicing alone.
(3) Children will get motivated to practice piano due to robot's real-time feedback and interaction as opposed to practicing alone.
(4) Children will learn to read and play piano notes faster with the presence of a robot helper as opposed to solo practice.

3 RELATED WORK

3.1 Foundation and Challenges in Children's Musical Growth

3.1.1 Musical Skill Development. Musical skill development in young children is very complex and includes many emotional and social factors and contributes to the overall emotional and social well being of children. It fosters confidence and enhances children's reading and even vocabulary techniques [13]. Furthermore, music is one of the most effective methods for children's growth and development and offers opportunities for children to develop imagination, creativity, emotion, sensitivity and insight [1]. Thus, it is really important for parents to consider musical education like piano for their children from a young age.

3.1.2 Challenges in Young Children Learning. Although learning musical instruments is beneficial for young children, learning instruments like piano can be a very complex process. One of the main challenges in learning piano at a young age is the lack of motivation. Younger children often need external incentives to practice and engage in learning musical instruments [12]. If children don't get a sense of enjoyment and accomplishment, they will not be motivated to practice. Children also tend to get frustrated very easily and discouraged if they don't see immediate response in their practice [7].

The second major challenge in young children is the retention of learned material in class such as the learned notes and concepts during lessons. Specifically, piano education is very complex for young children because it has the widest sound capacity among all other instruments [4]. It has a range of seven octaves and contains two different staffs and clefs for both hands which makes it very difficult for younger children to remember and memorize [4]. There is a need to work on innovative ways to help younger children with note reading skills to ensure they can play a piece accurately [4].

3.1.3 Parental Support In Musical Education. One of the key factors that help children learn instruments like the piano at a young age is practicing at home with parental guidance. Parents can motivate their children, engage them by pointing out mistakes, and provide constructive feedback. Research indicates that children whose parents encourage them to practice are more motivated and tend to show faster improvement [5]. However, parents often lack the time to sit with their children for daily piano practice [5]. This highlights the need for innovative tools that can help motivate and engage young children at home.

3.2 Tutoring Robot

Tutoring robots are becoming a valuable tool in education, offering personalized feedback and engaging students through interactive learning experiences. These robots, such as NAO and Pepper, are capable of adapting their teaching methods to suit individual learners. This adaptability makes robots an effective addition to traditional and digital teaching environments, particularly for children who benefit from interactive and tailored instruction.

3.2.1 Personalized Feedback and Adaptability. A key strength of tutoring robots lies in their ability to deliver feedback that responds directly to a learner's actions. Research shows that students perform better when robots provide immediate, constructive feedback, correcting mistakes while maintaining a positive tone. For instance, robots programmed to give encouraging comments when learners make progress can motivate continued effort, while corrective feedback helps learners improve their skills over time. The balance between these types of feedback is critical; overly critical robots may discourage students, while excessive praise can reduce the focus on learning [10].

Adaptability is another important feature of tutoring robots. These robots can adjust their behavior based on the student's progress, tailoring their teaching approach to fit the learner's needs. For example, robots capable of modifying their tone, gestures, and pace have been shown to sustain engagement over extended periods [17]. This adaptability ensures the robot's teaching remains relevant and effective, creating a personalized experience that feels supportive rather than standardized.

3.2.2 Social Interaction and Engagement. The social capabilities of robots significantly enhance their effectiveness as tutors. Features such as facial expressions, gestures, and verbal interactions make robots more relatable and engaging for students. In particular, eye contact, smiles, and verbal encouragement have been shown to make learners feel more comfortable and motivated [14]. These social behaviors allow robots to foster a sense of connection with learners, creating a positive and interactive learning environment.

However, social interaction must be carefully calibrated. While robots that exhibit friendly and engaging behaviors are beneficial, excessive social activity can become distracting. For instance, robots that focus too much on social behaviors might divert attention from the learning task, reducing overall efficiency [8]. To maximize their effectiveness, tutoring robots need to strike a balance, ensuring that their social interactions complement rather than interfere with educational objectives.

3.2.3 Physical Presence and Embodiment. The physical presence of robots adds an important dimension to their role as tutors. Unlike virtual or audio-only teaching tools, physical robots can use gestures, point to objects, and provide visual cues, making their teaching more interactive and effective. Studies have shown that students are more engaged and responsive when interacting with physically present robots compared to virtual ones [6]. Physical embodiment enhances the learning experience, particularly in tasks that require hands-on guidance, such as playing musical instruments.

Robot design also plays a critical role in their effectiveness. Humanoid features, such as expressive faces and articulated limbs, can make robots more engaging and relatable. At the same time, overly complex designs might overwhelm learners, particularly young children. Simpler, approachable designs are often more suitable for educational contexts, where the goal is to support and guide learners in a non-intimidating way [9].

3.3 Technology in Education

Over the past few decades, the integration of advanced technology into educational environments has revolutionized how learning is delivered and received, especially in early childhood and primary education. Technologies like e-learning platforms, interactive software, and more recently, social robots, have significantly enhanced student engagement and learning outcomes by adopting an interactive and personalized approach to education. According to this conference paper [15], social robots such as NAO, Pepper, and Skusie have been successfully implemented across various educational domains, including language learning, STEM education, and special needs education, where they play a crucial role in improving student motivation and engagement. These technologies create interactive environments that encourage children to actively participate in lessons, leading to improved retention and deeper comprehension of the material.

Figure 1: Two NAO robots. Photograph by Paco Arjonilla [Public domain], via Wikimedia Commons. (https://commons.wikimedia.org/wiki/File:Pareja_de_robots_NAO.jpg).

Research has shown that these technologies not only stimulate cognitive engagement but also offer emotional support, which is critical for young learners [11]. In their study, they emphasized how social robots in early childhood education can serve as empathetic companions, helping to reduce stress and anxiety while simultaneously promoting learning. This aligns with the broader trend towards technology-enhanced personalized learning, which aims to tailor educational experiences to individual students' needs and learning paces. The application of robots in education is a natural progression from this trend, offering a dynamic tool to further enhance student motivation and engagement.

3.4 Technology and Robotics in Music Education

Music education, like many other areas of learning, has been positively impacted by the integration of technology, particularly social robots. Music learning, which often requires repetitive practice, real-time feedback, and motivation, is a perfect context for the introduction of robotics and AI-driven systems. Studies have shown that using robots in music education can provide both technical guidance and emotional encouragement to students, especially young learners. For instance, this article [18] explored the use of virtual reality robots to teach music to children with high-functioning autism. Their findings demonstrated that the virtual music education program not only improved the children's music skills but also contributed positively to their cognitive and social development. The success of such programs suggests that technology-enhanced music education can offer significant benefits to learners, particularly those with special needs.

Furthermore, research from this article [19] shows that robots can play a crucial role in improving children's performance during music practice. Their study focused on how robots can assist children in learning musical instruments, such as the piano, by providing real-time feedback on rhythm, pitch, and general performance. The presence of robots during practice sessions not only improves children's technical skills but also enhances their motivation to continue practicing, an essential component of successful music learning. The use of robots as companions during music practice, especially when no human instructor is available, can provide the much-needed encouragement and guidance that young learners often require to stay engaged with their musical education.

3.5 Robot-Assisted Piano Tutoring for Children

Teaching musical instruments like the piano to young children presents unique challenges, particularly in sustaining motivation and ensuring effective practice between lessons. Research has indicated that regular practice is essential for developing musical skills, but maintaining a child's motivation to practice consistently is often difficult [5]. Social robots offer a promising solution by acting as consistent, interactive tutors that can provide personalized feedback and encouragement during practice sessions, which is especially valuable in the absence of adult supervision.

This study [3] compared two social robot models NAO and Zenbo and examined their effectiveness in teaching children how to tune a guitar and practice musical performances. The study found that children preferred robots with more expressive features, such as facial expressions and gestures, which helped to keep them engaged during the learning process. Similarly, [19] explored the impact of social robots on children's piano practice and found that the robot's role (evaluative vs. non-evaluative) significantly influenced the children's performance and motivation. Children performed better when the robot adopted a non-evaluative role, acting as a supportive companion rather than a critical evaluator. This highlights the importance of designing robots that not only provide technical assistance but also emotional support during learning activities.

3.6 Conclusion and Contribution

The works reviewed show the importance of music education for young children and the potential of robots as learning tools. While music education helps children grow emotionally, socially, and mentally, challenges like lack of motivation, difficulty remembering lessons, and limited parental guidance often make learning hard for young learners. At the same time, tutoring robots have shown great promise in providing personalized support, real-time feedback, and engaging interactions.

However, many studies focus on academic learning or general music education without examining how robots can specifically support piano practice. Current research also pays less attention to whether robots can help sustain children's motivation and engagement over time, which are very important for mastering an instrument. Additionally, while robots are known to assist with learning, their role in creative and skill-based tasks like piano practice needs more exploration.

This study focuses on how robots can address the challenges of piano practice for young children, a topic not yet widely studied. By looking at whether robots can improve learning speed, engagement, and motivation during practice sessions, this work adds to our understanding of how robots can play a unique role in helping children learn and enjoy music.

4 INTERACTION DESIGN

The interaction design focuses on three main aspects: Passive Initialization, Real-Time Feedback, and Error Correction with Physical Guidance. These elements are designed to make the robot a helpful and engaging tutor for young children practicing piano. Below, each interaction is explained in detail.

4.1 Passive Initialization

The robot starts the interaction when it detects a child sitting at the piano. It gently initiates by asking, "Would you like to practice today?" This approach makes the robot proactive, reducing the child's hesitation to begin. If the child agrees, the robot scans the music sheet to prepare for the session. This step is critical as it creates a welcoming environment and ensures the robot is ready to assist based on the piece the child is about to play. Studies like Zhao's work on adaptive interaction highlight the effectiveness of proactive robot behavior in maintaining engagement by initiating interaction naturally [14].

4.2 Real-Time Feedback

While the child practices, the robot listens to the performance and provides immediate feedback.

- Correct Notes: When the child plays correctly, the robot responds with positive reinforcement, such as "Great job!" or "That sounds wonderful!"
- Incorrect Notes: If the child makes a mistake, the robot gently points it out, saying, "Oops, let's try that again."

Real-time feedback ensures that children understand their errors and feel encouraged to improve. Research by Kumar and Zhang shows that such feedback keeps learners motivated and helps them progress more effectively [10].

4.3 Error Correction with Physical Guidance

When the child struggles with a note repeatedly, the robot steps in with physical guidance. Using its hand, the robot points directly to the correct note on the piano, providing clear and actionable feedback. This feature bridges the gap between verbal instruction and practical correction, making the learning experience more intuitive. Studies like Wilson and Scott's emphasize the importance of physical embodiment in tutoring robots, where gestures and physical cues significantly enhance understanding [6].

5 PROTOTYPE

5.1 Prototype Goal

The main goal of the prototype is to see if the robot can help children stay engaged while practicing piano. We want to check how children react to the robot's features, like starting the session on its own and giving feedback as they play. This will help us understand if the robot can keep children motivated and focused during practice.

Another goal is to test how well the robot's feedback works. The robot gives suggestions using words and actions, like pointing to the correct note when the child makes a mistake. The prototype lets us see if these methods help children play better and correct their mistakes more easily.

We also want to know if it feels natural for children to interact with the robot. If the robot is easy and comfortable to use, children will enjoy practicing more. This is important because the robot needs to feel like a friendly helper, not something that makes practicing harder.

Finally, the prototype is used to check the robot's size and design. We made the robot to fit next to a piano, so we need to make sure its height, appearance, and position are right for young children. These tests will give us ideas on how to improve the robot in the future.

5.2 Strategy

We developed the prototype step by step, keeping in mind the limitations of a low-fidelity cardboard robot. To overcome these challenges, we combined the physical design with an iPad app to simulate some key functionalities, such as note recognition and feedback.

First, we designed the robot in Autodesk Fusion to determine its size and overall structure. The height was carefully chosen to match the piano's music stand so that it could "see" the music sheet and interact effectively with a child. The cardboard construction allowed us to create a simple, humanoid form, including a head and torso. Features like eyes and a mouth were added to make the robot look friendly and approachable for young learners. However, due to the low-fidelity nature of the prototype, certain features were not possible to fully implement.

The Passive Initialization feature, where the robot detects when a child sits at the piano, was particularly challenging to implement.

Table 1: Interaction Design and Goals

Interaction Element	Goal
Passive Initialization	Encourage the child to begin practicing without hesitation and create a welcoming atmosphere.
Real-Time Feedback	Keep the child motivated, help them understand their errors, and support consistent improvement.
Error Correction	Provide clear, actionable guidance to help children correct mistakes efficiently

Without sensors or hardware for detection, this feature was instead simulated during testing to demonstrate how it would work in a real scenario.

Music note recognition was another difficult aspect to implement directly on the robot. To address this, we developed an iPad app that simulates the robot's ability to analyze notes. The app is preloaded with the music sheet and can recognize notes played on the piano, providing real-time feedback such as whether a note is correct or incorrect. This approach allows us to test the interaction design without requiring advanced robotics hardware.

The physical pointing feature, where the robot points to the correct note on the piano, was also impossible to achieve with the cardboard prototype. Instead, we focused on demonstrating this through verbal guidance and simulated gestures, leaving the physical pointing feature for future iterations when a high-fidelity robot can be used.

By combining the low-fidelity robot with the iPad app, we were able to showcase the key elements of the interaction design while acknowledging the prototype's limitations.

5.3 Prototype

The prototype is a combination of a low-fidelity cardboard robot and a supporting iPad app developed in Swift, designed to simulate the key functionalities of the envisioned piano tutor robot. The design focuses on both physical presence and software features to create an engaging and interactive learning experience.

The physical prototype was built to represent the robot's form and presence in a real piano setting. Its design was first modeled in Autodesk Fusion, as shown in Figure 2, to determine the dimensions and proportions suitable for use alongside a standard piano. The robot's height was specifically chosen to align with the music sheet stand, allowing it to maintain eye-level interaction with seated children. Constructed from cardboard, the robot features a simple humanoid form with a head and torso, complemented by basic facial features such as eyes and a mouth to make it look friendly and approachable. Although the prototype lacks mechanical functionality, it visually demonstrates how the robot would integrate into the practice environment, as illustrated in Figure 3.

The software component, an iPad app developed in Swift, focuses on simulating two critical functionalities: real-time musical note detection and feedback. The app uses the iPad's microphone to analyze the audio of the notes played by the child. This process involves the following steps:

5.3.1 Audio Signal Capture. The app records the sound of the piano using the iPad's built-in microphone. The audio signal is represented as a time-domain function

$$x(t)$$

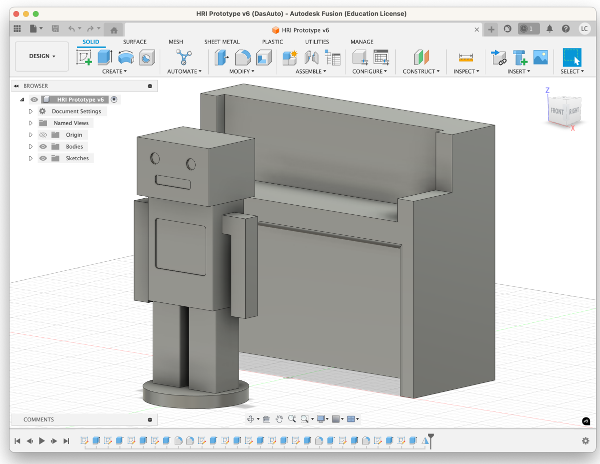

Figure 2: The 3D modeling prototype in Autodesk Fusion.

where t denotes time.

5.3.2 Frequency Analysis. To identify the frequencies in the audio signal, the app converts the recorded sound from the time domain to the frequency domain using the Discrete Fourier Transform (DFT). The DFT is defined as:

$$X(f) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j2\pi f n/N}$$

Here:

$X(f)$ is the magnitude of frequency f,
$x(n)$ is the discrete audio signal sampled at time intervals,
N is the total number of samples in the signal.
n is the index of each sample .

The DFT is implemented using the Fast Fourier Transform (FFT) algorithm for efficiency. The output $X(f)$ provides the strength of each frequency component in the signal.

5.3.3 Peak Frequency Detection. The app identifies the dominant frequency f_{peak} by finding the frequency with the highest magnitude in $X(f)$. This frequency corresponds to the note played by the child.

5.3.4 Note Matching. Each musical note has a standard frequency. For example:

$$\text{A4} = 440\,\text{Hz},$$
$$\text{C4} = 261.63\,\text{Hz}.$$

Figure 3: The cardboard prototype robot Ray.

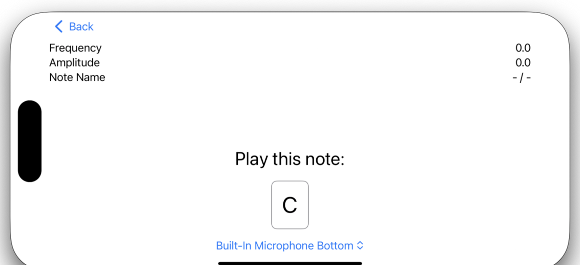

Figure 4: The screenshot of the iPad App.

The app matches f_{peak} to the closest note N_i using a predefined mapping of notes and their frequencies. This is achieved by minimizing the absolute difference:

$$N_i = \arg\min_i \left| f_{\text{peak}} - f_i \right|$$

where f_i represents the standard frequency of the i-th note.

5.3.5 Feedback Generation. The app compares the detected frequency f_{peak} with the expected frequency f_{expected} from the preloaded music sheet:

- If $\left| f_{\text{peak}} - f_{\text{expected}} \right| \leq \Delta f$ (e.g., $\Delta f = 2\,\text{Hz}$), the app provides positive feedback such as "Great job!"
- If $\left| f_{\text{peak}} - f_{\text{expected}} \right| > \Delta f$, the app highlights the error and provides corrective feedback, such as "Try again".

6 STUDY DESIGN

This study used the prototype of a semi-humanoid robot in a piano classroom setting to investigate its effectiveness in enhancing young children's piano practice. The goal was to allow students to practice piano with an accompanying robot and assess their performance, engagement, motivation and efficiency compared to practicing alone.

6.1 Participants and Setting

The study involves a group of students enrolled in the same piano class at a beginner level. They are around the same age from a diverse group of students. Each student is given two similar notes to practice while being observed in a piano classroom setting. Initially, they practice the first piece alone on their own. Next, they play the second piece with the robot present as a helper interacting with them during their practice session. Students' engagement and motivation, speed of learning and mistakes were documented each time.

6.2 Evaluation process

A quantitative approach was used to analyze research questions one and four by calculating the average number of student mistakes and the average time to complete each piece. For research questions two and three, a qualitative method is employed through interviews and observations to assess student engagement and motivation during practice.

6.3 Data Analysis

During each session, students were given two music sheets of equal difficulty and length. To address the hypothesis, we observed and ranked four parameters.

6.3.1 Piano Learning Enhancement. We observed each student as they practiced both pieces and recorded the number of mistakes made after completing the piece. The statistic of mistakes across all students for each method was calculated and compared to determine which approach results in fewer mistakes shown in Table 2. As shown in Table 2, the number of mistakes decreased by 60% when children practiced with the robot.

6.3.2 Student Engagement. We video-recorded the sessions and analyzed the recording by categorizing and identifying students' behavioural patterns towards the robot to observe student engagement. It was shown that children tried to engage with the robot by talking with it and trying to hold the robot's hand. They also listened to the robot while it made suggestions. They often looked at the robot for validation after playing a note, and if the note was a mistake, they would try multiple times to fix it and spend more time trying to learn from their mistakes. This behavioural pattern is

Table 2: Students Performance Result

Number of Mistakes	Student 1	Student 2	Average Mistake
Without Robot	6	4	5
With Robot	3	1	2

Figure 5: Evaluation setting with a female student. The student practices piano while the cardboard robot, "Ray," provides a supportive presence next to her. An instructor observes the interaction.

Figure 6: Evaluation setting with a male student. The student practices piano while the robot, "Ray," engages beside him. An instructor monitors the session.

fascinating in young children as they tend to get tired of practicing quickly and often get distracted when practicing alone.

6.3.3 Student Motivation. At the end of the class, we interviewed each student briefly, asking them three simple questions illustrated in Table 3. The result illustrated that both students enjoyed practicing more with the robot and preferred to have one at home for their practice. Once, asking the students if they would try a more difficult piece with the robot's assistant; one student said yes, and another said they were unsure. We believe one possible reason could be that participants were aware of being video-recorded and may have been reluctant to make mistakes in front of the camera.

6.3.4 Time Efficiency. We recorded the time each student took to learn the first piece and then compared it with the time taken to learn the second piece using the robot. After gathering data from all students, the average learning time for both methods will be compared, with the faster method indicating more efficient learning. As shown in Table 4, our result indicates that students took slightly more time when practicing alone than with the robot. On average, their efficiency increased by 32% while practicing with the robot.

7 RESULTS

Based on our results, humanoid robots will improve children's piano performance, motivation, and engagement and lead to faster improvement in their performance.

These expected outcomes align with the four hypotheses of this paper.

(1) Piano Learning Enhancement: It was shown that the average mistakes made by students decreased by 60% when practicing their second piece with the robot. The robot provides real-time feedback, helping children correct their mistakes more accurately and consistently which leads to an improvement in the children's overall performance.

(2) Student Engagement: Based on observing the video recordings of the student's practice session, students show higher levels of engagement when practicing piano with a robot; they focused more on playing the correct note, and if the robot indicated an error, they would try different notes until they reached accuracy. The

Table 3: Student Motivation Assessment

Interview Questions	Student 1	Student 2
Did you enjoy practicing piano more with the robot or without it?	With the robot	With the robot
Would you like to have one of these robots at home for weekly practice?	Yes	Yes
Do you want to practice a harder piece with the robot present?	Yes	Not sure if I can

Table 4: Students' Time Efficiency

Time to Complete a Piece (minutes)	Student 1	Student 2	Average Time to Complete
Without Robot	10	15	12.5
With Robot	7	10	8.5

robot's real-time feedback played a crucial role in maintaining their engagement in their practice sessions, as they carefully listened and waited for the robot's validation after each note.

(3) Student Motivation: Based on the interview questions, it was shown that practicing with the robot, with its interactive and supportive nature, enhanced students' motivation to fix mistakes and continue learning. They preferred to practice with the robot, and one student also became motivated to try more complex pieces in its presence. They also preferred having a robot in their homes to assist them with their practice and make it more enjoyable.

(4) Time Efficiency: It was shown that students learn piano pieces faster with the robot's assistance. In comparison, the time it takes for students to complete a piece increases by 32% if the robot is present. This is due to the robot's immediate feedback and error correction, leading to more efficient practice sessions.

In summary, integrating semi-humanoid robotics into piano practice offers young students a valuable tool to enhance their music education while making the learning process more engaging and efficient. These results suggest that robotics could play a transformative role in future music education, helping students enjoy the process of learning while improving their Performance.

8 DISCUSSION

In this research, we expected a reduction in mistakes during robot-assisted practice, an increase in student engagement and motivation to practice, and improved efficiency while practicing a piece. Our findings support the four hypotheses that using robots in piano practice sessions can significantly improve young children's performance, engagement, motivation, and learning speed. Robots can enhance music education by offering real-time feedback and interactive support. Feedback and physical cues can help children correct errors more effectively. This demonstrates the potential of using interactive technology to improve performance in skill-based learning.

8.1 Improvements and Future Work

Future versions of the prototype should focus more on helping children feel comfortable and engaged while learning. One improvement could be making the robot interact more naturally, like smiling or nodding when the child does well. These small actions can make the robot feel friendlier and encourage children to stay motivated during practice.

Another important improvement is how the robot gives feedback. Right now, the robot uses simple verbal feedback, but future versions should make it more personalized. For example, the robot could change its tone or words depending on how the child is doing. This would help the child feel more supported and make the practice session more enjoyable.

Finally, the design should stay simple and easy for children to use. The robot should be intuitive so that children can interact with it without any difficulty. By focusing on these changes, future prototypes can make the robot not just a tutor, but also a fun and friendly companion that helps children enjoy practicing piano.

REFERENCES

[1] Adesokan Zacchaeus Adelere. 2021. MUSIC EDUCATION: A PANACEA FOR THE HANDICAPPED CHILDREN. *African Musicology Online* 8, 2 (Nov. 2021). https://doi.org/10.58721/amo.v8i2.8

[2] Aida Amirova, Nazerke Rakhymbayeva, Elmira Yadollahi, Anara Sandygulova, and Wafa Johal. 2021. 10 Years of Human-NAO Interaction Research: A Scoping Review. *Frontiers in robotics and AI* 8 (2021), 744526–744526.

[3] Bruno de Souza Jeronimo, Anna Priscilla de Albuquerque Wheler, JoséPaulo G. de Oliveira, Rodrigo Melo, Carmelo J. A. Bastos-Filho, and Judith Kelner. 2022. Comparing Social Robot Embodiment for Child Musical Education. *Journal of Intelligent & Robotic Systems* 105, 2 (2022), 28. https://doi.org/10.1007/s10846-022-01604-5

[4] Sezen Hatice. 2021. Note reading methods used in piano education of 4 to 6 years old children. *Educational research and reviews* 16, 7 (2021), 310–324.

[5] J A E Hughes, P Maiolino, and F Iida. 2018. An anthropomorphic soft skeleton hand exploiting conditional models for piano playing. *Science robotics* 3, 25 (2018).

[6] Junko Kanero, Elif Tutku Tunalı, Cansu Oranç, Tilbe Göksun, and Aylin C. Küntay. 2021. When Even a Robot Tutor Zooms: A Study of Embodiment, Attitudes, and Impressions. *Frontiers in robotics and AI* 8 (2021), 679893–679893.

[7] Satoshi Kawase, Jun'ichi Ogawa, Satoshi Obata, and Takeshi Hirano. 2018. An Investigation Into the Relationship Between Onset Age of Musical Lessons and Levels of Sociability in Childhood. *Frontiers in psychology* 9 (2018), 2244–2244.

[8] James Kennedy, Paul Baxter, and Tony Belpaeme. 2015. The Robot Who Tried Too Hard: Social Behaviour of a Robot Tutor Can Negatively Affect Child Learning. In *2015 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. ACM, New York, NY, USA, 67–74.

[9] Elly A. Konijn and Johan F. Hoorn. 2020. Robot tutor and pupils' educational ability: Teaching the times tables. *Computers and education* 157 (2020), 103970–.

[10] Xin Lei and Pei-Luen Patrick Rau. 2021. Effect of Robot Tutor's Feedback Valence and Attributional Style on Learners. *International journal of social robotics* 13, 7 (2021), 1579–1597.

[11] Michelle M. Neumann, Imogene Calteaux, David Reilly, and David L. Neumann. 2023. Exploring teachers' perspectives on the benefits and barriers of using social robots in early childhood education. *Early child development and care* 193, 13-14 (2023), 1503–1516.

[12] Rachana Nitin, Daniel E. Gustavson, Allison S. Aaron, Olivia A. Boorom, Catherine T. Bush, Natalie Wiens, Chloe Vaughan, Valentina Persici, Scott D. Blain, Uma Soman, David Z. Hambrick, Stephen M. Camarata, J. Devin McAuley, and Reyna L. Gordon. 2023. Exploring individual differences in musical rhythm and grammar skills in school-aged children with typically developing language. *Scientific reports* 13, 1 (2023), 2201–14.

[13] Joseph M. Piro and Camilo Ortiz. 2009. The effect of piano lessons on the vocabulary and verbal sequencing skills of primary grade students. *Psychology of music* 37, 3 (2009), 325–347.

[14] Raquel Ros, Ilaria Baroni, and Yiannis Demiris. 2014. Adaptive human–robot interaction in sensorimotor task instruction: From human to robot dance tutors. *Robotics and autonomous systems* 62, 6 (2014), 707–720.

[15] Ivana Ružić and Igor Balaban. 2023. The use of social robots as teaching assistants in education: literature review. In *Central European Conference on Information and Intelligent Systems*. Faculty of Organization and Informatics Varazdin, Varazdin, 205–212.

[16] Luca Scimeca, Cheryn Ng, and Fumiya Iida. 2020. Gaussian process inference modelling of dynamic robot control for expressive piano playing. *PloS one* 15, 8 (2020), e0237826–e0237826.

[17] Sofia Serholt and Wolmet Barendregt. 2016. Robots Tutoring Children: Longitudinal Evaluation of Social Engagement in Child-Robot Interaction. In *Proceedings of NordiCHI 2016*. ACM, New York, NY, USA, 1–10.

[18] Mojtaba Shahab, Alireza Taheri, Mohammad Mokhtari, Azadeh Shariati, Rozita Heidari, Ali Meghdari, and Minoo Alemi. 2022. Utilizing social virtual reality robot (V2R) for music education to children with high-functioning autism. *Education and information technologies* 27, 1 (2022), 819–843.

[19] Heqiu Song, Emilia I. Barakova, Jaap Ham, and Panos Markopoulos. 2024. The impact of social robots' presence and roles on children's performance in musical instrument practice. *British journal of educational technology* 55, 3 (2024), 1041–1059.