

A Robotics-Based Approach to Mathematics Education

A Prototype and Its Evaluation
with Children

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ABSTRACT

Mathematics is an integral component of the curriculum in all stages of education and it is important that children master basic mathematical concepts and operations from a young age. The underlying project aims to investigate how we can increase the interest of young children towards this subject with the help of a humanoid robot. The public library in Wildau (Germany), which integrated the reading robot called "ReadingNAO" [3] developed by our team at the RoboticLab of the TH Wildau (UAS), won an innovation award for libraries in Berlin and Brandenburg, leading to the launch of a project that lasted for one year from 2018 to 2019. Today, the ReadingNAO has been in use in several public libraries in Germany. This achievement has further inspired continuous research and development in the field of robotics especially in the areas of education and hospitality services. As part of the author's internship project during her second semester, she programmed a NAO robot¹ that was designed to teach elementary school children a few basic mathematical concepts, namely basic multiplication from 1 to 10 as well as geometry. This article discusses the idea, concept, implementation, and a basic evaluation conducted through a practical experiment with a group of elementary school children.

KEYWORDS

Humanoid Robotics, Math, Learning

1. INTRODUCTION

The focus of this project is to design an enjoyable and engaging learning experience in the subject of mathematics using a humanoid robot. In the field of education, several studies and experiments have proven that the use of humanoid robots in teaching have led to increased levels of interest and concentration displayed by children towards a certain topic [1]. It also has been shown that children display genuine feelings of empathy and friendship towards robots. Additionally, it is widely recognised that many students experience boredom during mathematics lessons. The project attempted to evaluate whether a humanoid

robot is indeed capable of introducing more fun into the traditional classroom setting for a mathematics lesson and help children grasp mathematical concepts better. For this, a practical experiment was carried out with children from a local school in Wildau (Germany) and their feedback on the experience was collected and assessed.

2. CONCEPT AND IMPLEMENTATION

For this project, a NAO robot (version 6) was used for the implementation. It is a programmable humanoid robot developed by Aldebaran (also formerly known as Softbank Robotics Europe) [2], and is widely used in the field of STEM education, hospitality services and healthcare. It offers a wide range of programming possibilities and supports many commonly used programming languages including Python and C++, as well as drag-and-drop block-based programming. The robot is equipped with head- and mouth-mounted cameras, microphones and speakers, as well as seven touch sensors located throughout its body. It can also perform speech recognition, converting the speech it "hears" into words it recognises [2]. This makes it capable of having human conversations. However, after conducting several functional tests, we concluded that its existing built-in speech recognition capabilities are insufficient for this project. For example, in a test to see how well the robot could understand spoken numbers between 1 and 10, it often got confused between the German words for two, three and ten ("zwei", "drei" and "zehn"). Hence, although a conversational approach was initially considered as the main mode of communication between the user and the robot, it was ultimately rejected as too problematic and likely to affect the user experience. For this project, C++ was used to develop the application with the support of the Qi libraries provided by Aldebaran.

The idea is that, the robot could engage in "conversations" with the children, ask questions and provide quiz sessions as well as a brief introduction to the topic selected by the user. It could interact with the user in a few ways: a) it provides the user with a few options (for example, "yes" or "no") and prompting the user to confirm their choice by touching one of its sensors; b) the user can "answer"

¹ <https://aldebaran.com/en/nao6/>

quiz questions using QR codes attached to certain objects like number cards and three-dimensional geometrical forms.



Fig. 1: Some QR codes of avatar names and answer blocks that the children can use to interact with the robot during the learning session

Communication between the user (i.e. the child/children) and the robot takes place entirely independently of an app. When the programme is started, the robot prompts the user to select and confirm a few options as part of setting up the learning session, including the language and difficulty level. Users can navigate through the options by touching the robot's top and bottom head sensors, and confirm each selection by touching the middle head sensor. They can also set the number of users for the current session and assign names to each user by scanning a QR code with a name encoded as a string value. After that, the user can select either quiz mode or practice mode. In quiz mode, the user must answer five questions on the selected topic and difficulty level. Example questions include "What is 2×3 ?" and "I have four sides of equal length. What shape am I?". The robot will evaluate each answer and state whether it is correct. If the question is not answered correctly, the correct answer will be revealed. In practice mode, the user can choose to listen to a short introduction for the selected topic and difficulty level first. They can then practise their knowledge of the topic with a total of four practice questions. At any time during the programme, users can access instructions on how to operate the robot by touching the sensor on its left hand.

3. EVALUATION THROUGH PRACTICAL EXPERIMENT

To evaluate the final outcome, we ran two interactive sessions with groups of ten fifth-grade students, each lasting one hour. During the session, we prepared a total of 100 number cards, each with a corresponding QR code printed on the back. We also created some QR codes with avatar names on them for children to choose from. The numbers ranged from 1 to 100, with 100 being the highest possible answer (as 10 multiplied by 10 equals 100). Each child was given a stack of 10 number cards. The children had the opportunity to test their multiplication skills through several quiz sessions, each consisting of five questions. A time limit of 30 seconds was set for each question. At the end of both sessions, we collected some feedback from the children and they expressed increased interest and enthusiasm about engaging with the robot. Some even suggested additional use cases for learning robot assistants like this one. Through our observation, although the children were already familiar with multiplication, the children remained highly engaged throughout the session, showing little to no signs of losing focus. They also mentioned a couple of minor setbacks in their experience, including some QR codes that the robot could not read clearly, and said that they wished they had more time to answer each quiz question.

4. CONCLUSION

In conclusion, this project demonstrated a significant potential for optimising education for young children in a classroom setting. However, there are still several aspects that can be improved and further developed to better meet the diverse learning requirements of different groups of children. Although the children could understand the robot's speech well, tweaking some of the word spellings and the speed of its speech would produce a more natural-sounding flow and enhance the experience further (For example, we found out that the pronunciation of the word "Quiss" was more accurate than its original spelling "Quiz"). In the future, we also plan to consult with educators and collaborate with them to explore and tailor the design of the experience, as well as the content of the lessons and quizzes, to suit the needs and interests of primary school children. We are currently working on several projects and measures to further refine the user experience and increase the flexibility of the application. These include the development of a separate application for parents, teachers, or supervisors responsible for conducting the learning sessions with children, as well as the migration of previously hard-coded content — such as topic modules, questions, answers, and spoken responses — to a *Content Management System* (CMS), which provides a centralized service for delivering relevant content dynamically to the application.

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