KAERA Research Forum, *1(2),* 3-8

RESEARCH ARTICLE

Playing with a Robot to Learn English Vocabulary

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A robot-based English curriculum called *The Missing Code* has been developed to teach English vocabulary to young children whose home language is one other than English. Guided by theories in children's learning and motivation, the curriculum was designed to be developmentally appropriate and engaging for children who were 3-5 years old, carefully balancing the familiar and the new. The development process was characterized by iterative cycles of initial design, user testing, and refinement. Through multiple observations of child-robot play in situ, it was noted that children easily learned how to interact with the robot and showed sustained interest and engagement in the curricular activities with the robot.

Keywords: educational robotics, robot-assisted language learning (RALL), humanoid robots, learning English as a second/foreign language

Atti is a humanoid robot that targets preschool or kindergarten aged children, using the metaphor of a toy friend who does activities with a child. A variety of advanced technological capabilities are embedded in the robot that works in conjunction with a smartphone, including multimedia, bodily movements, optical and proximity sensors, speech recognition, learner interaction logs, and accompanying materials (e.g., physical books and cards). Children can play with Atti and learn educational topics with Atti's assistance.

A next step would be equipping Atti with high quality educational apps to run through the robot. The app development seems to be much more than developing a new mobile app; each part of the curriculum should make use of the robot's unique technical features and social affordance that conventional mobile phones do not have. A collaborative partnership, therefore, was formed between the Atti developer, SK-Telecom (SKT, http://www.sktelecom.com) and the university-based design team (http://create.usu.edu/projects.html), led by Dr. Yanghee Kim, Associate Professor of Instructional Technology and Learning Systems at Utah State University (USU). Sponsored by SKT, the USU team was charged to develop an English learning app for children who learned English as second or foreign language (ESL or EFL). This paper introduces a vignette of this robot-based curriculum development effort.

TRENDS IN EDUCATINAL ROBOTICS

In the recent decade, interest in robotics has emerged rapidly across the world. Robotics is seen by many as offering new benefits in education at all levels (Johnson, 2003). The educational robotics market is also growing. Research by the Japan Robotics Association, the United Nations Economic Commission, and the International Federation of Robotics projects tremendous market growth for personal robots, including those used for both entertainment and educational purposes. Very likely, this trend will continue in the coming decades (Kara, 2004).

The LEGO Mindstorms (http://mindstorms.lego.com) pioneered educational robotics by combining toys with advanced technologies a decade ago. This system was acclaimed by educational researchers and practitioners for its potential to improve motivation and learning of STEM topics with upper-grade students. Since then, the application of robotic technology in public schools has been steadily growing. Nowadays, trends in educational robotics include a wide range of robot applications for engaging young people in learning diverse subject matters (Rusk, Resnick, Berg, & Pezalla-Granlund, 2008). One of those subject matters is English as a Second/Foreign Language (ESL/EFL). In Japan, Korea, China, and other countries pursuing innovations in educational technology, EFL learning is the domain that has most actively used robot assistants.

In those countries, the demand for effective EFL teaching pedagogy has been high. At the same time, the shortage of qualified native English-speaking instructors has been a constant challenge. To solve this problem, many EFL educators have sought to take advantage of advanced technology and have committed to Computer Assisted Language Learning. Recently, some industry partners have developed several humanoid robots and explored opportunities for using the robots to fill the gap in ESL/EFL education. However, the high cost of producing humanoid robots (approximately US $3,000-5,000) has been a major drawback in putting them on the market for the general public. Companies are racing to produce more affordable and feasible robots in school and at home and, also, to develop quality robot apps to assist young ESL/EFL learners. With a new mix of a smart phone, robot toy, and learning tool, SKT's *Atti* seems to open up a whole new field of possibilities for affordable, educational robots.

CHILDREN'S MOTIVATION AND LEARNING

Seminal psychologists have established that children's learning and development is a social and cognitive process. Young children learn in a social context while they play with others (Carpendale & Müller, 2004). Their play is similar to scientific experimentation; they do hypothesis testing while they play with others (Gopnik, 2012). Children's psychological and behavioral changes often occur through vicarious experiences; they learn as they observe and interact with others (i.e., social models) (Schunk, 1991; Schunk & Hanson, 1985). Further, their learning is better promoted when the context is meaningful and relevant to them (Lave & Wenger, 2001). A simple computer screen without social contexts would not be as effective for young children as a technology design that embeds a social and interactive context in its application (Perkins, 2001). With a robot friend, children could learn a language and literacy in a social and meaningful context.

For literacy instruction, Wigfield (1997) has emphasized the importance of understanding both motivation and cognitive process in children's learning. Guthrie and Alao (1997) specified three key aspects of motivation: goal orientation, self-efficacy, and social interaction. Later, Guthrie and other researchers also noted the importance of interest or curiosity in motivation to read (Guthrie et al., 2006). Significantly, Gregory and Chapman (2013) remind us that when we study motivation, we must also remember that "basic needs have to be met first" and two of these important needs include feeling "liked and included." One way to both capture students' interest and help them to feel safe is to infuse learning with elements of fantasy. Fantasy not only captures students' imaginations, but can also help them work through past difficulties (Guthrie & Alao, 1997). During playtime with a robot, a child could be placed at the center of interaction and safely co-explore fantasies.

DESIGN AND DEVELOPMENT PROCESS

The design and development team at USU consisted of multidisciplinary experts in educational curriculum design, graphic design, and software engineering. These experts had had such diverse experiences as consulting with American toy companies and educational television shows and developing applications for public schools and corporate partners. The team was also very culturally diverse; many members of the team had grown up learning English as a second or foreign language and therefore could relate directly to the target population of learners.

The development process incorporates the guidelines of software engineering and design-based research that emphasize the need for highly contextualized data collection. The process is characterized by iterative cycles of design, development, and evaluation and the use of authentic contexts for user testing (Design based research collective, 2003).

The Design phase produced written scripts of the curricular content and robot-child interaction scenarios. Following that, a low-fidelity prototype (a print-based mockup without a robot) was developed. This mockup was taken to three target-aged ESL children, using a Wizard of Oz method, where a designer acts as the missing components of the robot application (Rapp). Our designer played with the children one-on-one at their homes. This mockup test was used to verify the curricular flow, observe the learners' reactions, and determine revision needs in the curricular content and interaction scenarios.

The Development phase began with the refined curricular design. The curriculum was implemented to develop a beta version of the Rapp. This draft app was taken to the target aged children in school. We allowed boys and girls to spend about an hour in playing with the robot on a one-on-one basis at the corner of the classroom. This phase was used to observe seamless interactions between the child and the robot and also to assess coding completeness. The draft Rapp was refined repeatedly as the team continued with the testing.

Evaluation was on going while our team engaged in design and development. At the end of the development, we conducted another round of evaluation, bringing the refined Rapp to school for field-testing. Four to seven-year-old boys and girls spent 30 minutes to an hour individually or in a pair at the corner of a media center. This high-fidelity setting resembled an ordinary classroom, having distractions by peers and environmental noises, leading to further refinement for increased fidelity and completion of the Rapp.

ROBOT-BASED CURRICULAR APP

The curriculum design was focused on learning outcomes and, at the same time, creating learning activities that were developmentally appropriate and engaging for children who are 3-5 years old. The activities and resources were also chosen to carefully balance the familiar and the new. This balance in the materials was achieved with songs and the accompanying book and cards (familiar educational tools), connected to the robot and app (new educational tools). The balance of familiar and new in content also came from having familiar items that are identifiable and easily recognizable (items from home, simple colors and shapes) and new, imaginative content (spaceships, secret labs, etc.).

As presented in Figure 1, three activities (songs, games, and a book) were designed to play a specific role in mastery of three objectives: identifying basic shapes (triangle, circle, square, rectangle); basic colors (red, orange, yellow, green, blue, purple), and initial consonant sounds.

Main Screen Book

Figure 1. *Examples of the App*

The activities build on each other by introducing, reinforcing, and extending understanding of the target English vocabulary. For introducing, the song portion of the app was designed to expose users to all of the target vocabulary. The songs are based on familiar children's songs (i.e., "Twinkle, Twinkle Little Star"), and after each verse the robot invites the user to repeat target vocabulary or sounds multiple times. For reinforcing, the game portion of the app allows the user to practice all of the target vocabulary introduced in the songs. Users either find the correct matching card (with shapes or colors), or identify the correct initial sound for objects in an OX (true/false) game with both letters and pictures as visual cues. For extending, the book extends what children have already learned by giving new context to the vocabulary. Children see the target words used in the text and hear the robot ask for their help to find shapes, colors, and words in the spaceship.

OBSERVATIONS AND IMPLICATIONS

Easy to Use

In user testing, the team observed that the children were able to work independently and also work either alone or with a peer during interaction with the robot and materials. A big challenge in designing educational software for young children is ensuring that they are able to navigate and use the interface easily. After repeated tests with children as young as three years of age, it was clear that young children could easily figure out how to use each part of the application. The youngest children particularly enjoyed the songs, and the older children (ages 5-7) seemed to particularly enjoy the book. No matter what the activity, however, children were able to participate with minimal instructions from a member of the team.

Sustained Attention and Engagement

It was exciting that children were engaged and focused during their time with the robot. Children were eager to touch the robot and follow it if it moved from one space to another. Even when the robot did not respond automatically (there were a few bugs in the prototype), the children were willing to try interacting again and again until the robot responded. Children normally do not have a long attention span. But the children aged 3 to 7 used the robot app and attended to it for over an hour even after repeated use – a response that cannot be attributed to the novelty effect. Further, as we observed their interactions with the robot, we noticed that even when they were not looking directly at the robot, children would still repeat the English words it spoke and sing along as it sang songs. Overall, we were impressed by the amount of excitement and intensity in children's expressions while they played and learned with the robot. If we returned for repeated testing, the children were always ready to play with the robot again, and even if they were repeating the same activities, they still displayed high levels of engagement.

Rich Learning Experiences

The robot app supplied a variety of learning activities, integrating established strategies and materials into a new environment. Easily recognizable and memorable songs were used to prepare children for more intense practice/instruction. Games helped children get quick practice with concepts and enabled the children to repeat a task again and again until the concepts were mastered. The interactive book was full of context rich sentences. Based on our observations, teachers and parents of young children can expect to see learners engaged with the creative, fun, fantasy-filled world of the robot. Also, the robot app could be used either one-on-one or in small groups of two to three children. In individual use, the child had a time to build confidence with a friend-like robot; in small-group use, the robot served as a center for collaborative work among human peers. Overall, the robot app helped the children with explicit, systematic, and personalized instruction to learn English, as well as building their confidence in the use of English.

CONCLUSION

As a result of our design, development, and evaluation, the USU team is confident in the potential of future educational robots. Due to the relatively low cost of the robot Atti and the relatively short time it takes to develop new apps, this could be a scalable, educational resource for children both in school and at home. There are many other curricular areas that could be created in future apps: English instruction in a wide variety of subjects at a wide variety of levels and instruction connecting early mathematical or scientific concepts and language development, and so on.

The diversity of the design team could be an asset to make the curriculum for market that targets a wide audience of learners. Based on our conversations with the teachers and parents in testing, once a school or parent has observed a child's engagement in a robot, it is very likely that they would continue to obtain new materials and applications that teach students English. Because the robot interacts with them like a friend, children may be more likely to use English to interact with others rather than learning English by decontextualized, rote memory. Particularly, the fantasy that a humanoid robot can afford might open up endless creative opportunities for future designers and developers. In the future, there could be an entire universe where Atti and children zip from place to place to learn English from unique friends in new worlds.

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