

# Inquiry learning with a social robot: can you explain that to me?

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**Abstract.** This paper presents preliminary results of a study which assesses the impact a social robot might have on the verbalization of a child's internal reasoning and knowledge while working on a learning task. In a comparative experiment we offered children the context of either a social robot or an interactive tablet for verbally explaining their thoughts, while keeping the content of the learning task identical. Results suggest the context of a social robot leads to a faster response time from the children.

**Keywords:** Social robot, child-robot interaction, inquiry learning, verbalization, interactive explaining

## INTRODUCTION

Talking with other people can provide a context for articulating and explaining ideas. This can facilitate greater understanding of ones own ideas en knowledge. For the past 15 years, research has proved that generating explanations leads to deeper understanding when learning new things [1], [2], [3]. There are two forms of explaining: (1) explaining the subject of interest to oneself, which is called self-explaining and (2) explaining the learned subject to another person, which is called interactive explaining [9]. Several studies have provided successful examples of self-explanation activities [1], [11]. However, a social partner may implicitly create more opportunities for explanations, which are difficult to trigger in the case of self-explanation.

The role of a partner can range from being a passive one, who just listens, to an interactive one who provides support and feedback to the learner [3]. Although there are some similarities between an activity with a partner who just listens and self-explanation activities, the presence of another person can provide the benefit of an audience effect [3]. Generating explanations to another person has been associated with the construction of knowledge [8], [10]. This is because the addition of a social partner might lead to more verbalization of reasoning and explanations, which relates to the development of metacognitive skills.

This study investigates the effect of a social robot on the explanatory behavior of young children when working on an inquiry learning task. Inquiry learning is based on constructivism, which we have combined with aspects of the socio-cultural theory about collaborative learning [12]. This choice was based on the following arguments: (1) inquiry learning provides an open-ended task, (2) the collaborative aspect provides a clear role for the robot as a peer learner, (3) children can use different strategies in operating inquiry tasks

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and the verbalization of these strategies can provide insights in the way children approach such tasks.

Inquiry learning is often described as a cycle or spiral that involves several processes. Klahr's [5], [6] Scientific Discovery of Dual Search (SDDS) model identifies hypothesis generation, experimentation, and evidence evaluation as the core processes of scientific inquiry learning [7], [4], [13]. In the phases of hypothesis generation and evidence evaluation the child has the most opportunities for verbalization of his/her thought process.

## DESIGN

The purpose of the present study is to assess the effect of a social robot on the verbalization of reasoning and knowledge during a collaborative inquiry task. The inquiry task focused on exploring the phenomenon of balance using a balance beam. The study employed a between-subjects design with two conditions. In the first condition, children performed the balance inquiry task together with an expressive *social robot*, the RoboKind Zeno R25. The robot was presented as a peer but with well-developed inquiry skills. Futhermore, the children received a tablet. Through this tablet the children could indicate they wanted to move on to the next assignment or ask for additional help. In the second condition, children performed an identical inquiry task about balance with a *tablet* only. The tablet provided the same assignments, suggestions and questions. In both conditions the robot or tablet would ask the child to verbally explain their hypothesis and conclusion at the specific stages in the inquiry task.

It was hypothesized that the presence of a social robot would trigger children to give more explanations than with the tablet. Furthermore, in the robot condition it was expected that the time between asking a question and the childs response was shorter than in the tablet condition.

Participants were 12 Dutch elementary school students (33.3% female) with an average age of 8.8 years (SD = 2.1). The students were randomly assigned to either the robot condition (n = 6), or the tablet condition (n = 6). A review of school curricula showed that students were not yet educated in the phenomena of balance. Therefore, it was expected that the students had little or no prior knowledge.

## METHOD

This experiment focuses on measuring the *duration* of verbalization and the *response time* of a child's response to questions from the system. Both measures were assessed from videos recorded during the sessions, which were annotated on three levels.

The first level was child speech and contained one label: *verbalization*. This label was used when children provided explanations about the assignment or balance and was used directly to assess the *duration*.

The second level was system speech and contained three labels: (1) *giving explanation*, this label was used when the system (robot or tablet) would give an explanation or a verbal response to the child or answer of the child, (2) *asking question*, this label was used when the system would state a question, and (3) *waiting for response*, this label was used when the system had stated a questions and was waiting for a response of the child, effectively measuring the *response time*.

The third level was child actions and contained two labels: (1) *interacting with balance*, this label was used when the children were working with the balance, for example placing or removing pots or removing the wooden blocks, (2) *pressing button*, this label was used when the child would press one of the button of the tablet (in both conditions).

Future work will investigate the remaining annotation levels, however this paper focuses on reporting the *duration* and *response time* as discussed above.

## RESULTS

In total 149 annotations were identified for the label *verbalization* of which 77 annotations refer to the robot condition and 72 annotations to the tablet condition. The total duration for all annotations with this label was 758.11 seconds (SD = 4.20). The mean duration for the robot condition was 5.80 (SD = 4.94). The mean duration for the tablet condition was 4.32 (SD = 3.09). An independent sample t-test showed no significant difference between both conditions concerning the *duration*,  $t = 1.264$  ( $df = 10$ ),  $p = .118$  (one-tailed).

The label *waiting for response* was annotated 146 times of which 71 annotations refer to the robot condition and 75 annotations to the tablet condition. The total duration for all annotations with this label was 217.22 seconds (SD = 2.79). The mean duration of this label in the robot condition was .94 (SD = 1.14) and 2.00 (SD = 3.67) for the tablet condition. An independent sample t-test showed a significant difference between both conditions concerning the *response time*,  $t = -2.54$  ( $df = 10$ ),  $p = .015$  (one-tailed).

## CONCLUSION

This study investigated the effect of a social robot on the duration of verbalization and the response time to questions in the context of an inquiry-learning task. To assess this effect the social robot was compared with the use of a tablet. It was hypothesized that providing the children with the context of a social robot would lead to more verbalization about the task than when the children would only use a tablet. Results indicated that children in the robot condition verbalized more than children in the tablet condition but this difference was not significant. The second hypothesis concerned the response time of children when a question was asked. The results showed a significant difference between the robot condition and the tablet condition in favor of the robot condition.

It seems that children verbalized more easily (shorter response time) when a social robot was used compared to a tablet, but not necessarily more extensively. However, the sample was very small ( $n = 6$  per condition) and a larger sample with more participants may provide more information.

## FUTURE WORK

For our future work we want to repeat this experiment with a larger sample in order to increase the external validity. Furthermore, for the repeated study we are planning to perform a qualitative analysis of the answers children give to the questions in order to gain insight in the reasoning of children. Since this experiment was done in the context of inquiry learning, the reasoning of children might give us some interesting insights in what they have learned from the experiment and whether there is a difference in learning between the participants in the tablet condition compared to the robot condition.

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