110th Meeting of the 1909 Conference
Advancing Thought, Research, and Practice in Technology and Engineering Education

Crown Plaza Hotel, Memphis Downtown, TN

The potential of children using programmable robot construction kits

A comparative study of expected and actual abilities and skills of primary school children

#5, Session II: Exploring STEM Capabilities

Martin Fislake, presenter
University of Koblenz, Germany, fislake@uni-koblenz.de

Leah Marlene Christ, co-author
University of Koblenz, Germany

Lina Klaes, co-author
University of Koblenz, Germany

November 14, 2024

Author Note

According to the Section 67 (6) of the Rhineland-Palatinate School Act the data collection and observation of children at elementary schools was first displayed and approved by the Supervisory and Service Directorate. Also, the anonymity and voluntary nature of the children as well as the written consent of their legal guardians was provided.

Correspondence concerning this article should be addressed to Martin Fislake, Department of Technology Education, University of Koblenz. Universitätsstraße 1, 56070 Koblenz, Germany. Email: fislake@uni-koblenz.de

Abstract

Based on diverse experiences in dealing with participants of the summer school project technikcamps at the University of Koblenz and numerous informal conversations with their parents, the well-founded impression arose that many parents cannot really assess what their children are capable of when working or playing with educational robots.

In order to answer the related question of whether parents underestimate (or overestimate) their children, a study was conducted in which a total of 45 children from four different schools and their parents took part. The aim was to record the measurable abilities and skills of children in first to fourth grade to compare them with the assessments of their parents.

During the study, the participants were observed in teams of two as they built and programmed standard LEGO® Education SPIKE™ robots after a short instruction into the study. Their skills were evaluated using a previously defined observation protocol. At the same time, their parents were asked via online questionnaires about their assessments and expectations regarding their skills in building and programming those robots. A total of 42 parents received the link to the questionnaire, 35 of whom completed the questionnaire in full.

The observations of the children showed clear that comprehensive skills and abilities in connection with building and programming LEGO® Education SPIKE™ robots had already been developed at primary school age.

The subsequent comparison of the children's actual abilities and skills with the parents' expectations revealed a clear underestimation of the children across the board. While the underestimation was lowest in the first grade, it increased from the second grade onwards and led to a clear underestimation of the children by their parents in the fourth grade.

As a result, the children in the third and fourth grades in particular were assessed by their parents as being far below their actual capabilities and demonstrated very well-developed skills in building and programming educational robots.

Keywords: programmable robotics construction kits, children’s abilities, parent’s expectations

Introduction

Almost traditionally, many children grow up with a wide variety of construction kits and can thus playfully acquire various technology-related skills and abilities as well as a technical socialization that can be decisive for a later career choice, as Hornby claimed (Noschka & Knerr, 1986) and acatech multiple times (2009, 2011) proved.

However, access to these construction kits is generally provided solely by parents and, with regard to current robotics construction kits, predominantly by schools, so that the perception of educational effectiveness is important for approval and rejection of such kits.

Nevertheless, based on a variety of experiences in dealing with the participants of the summer school project technikcamps at the University of Koblenz and numerous informal discussions with their parents, the well-founded impression arose that many parents are unable to correctly assess their children's abilities in working and playing with these robotic construction kits.

This ultimately gave rise to the question of whether this impression could be verified by a study and what conclusions could possibly be drawn from it for technical education.

Related Work

Since the introduction of the first educational robots suitable for the market and mass production in the 1990s, a wide variety of studies about robotics construction kits and their use in schools been have carried out. A collection of research papers about educational robotics can be found for example in the annual proceedings of the International Robotics in Education Conference (Balogh, Obdržálek & Fislake, 2024). Many of these papers deal with how such robots can be used profitably in teaching, how they can be built or what developments can be expected.

Ortega-Ruipérez & Lázaro Alcalde (2022) also investigated the benefits of educational robots in schools. Assuming that teachers were more prejudiced about robotics and programming, they investigated teachers' attitudes towards learning programming and robotics, while also trying to determine the associated use in the classroom at different grade levels. It turned out that the initial attitudes of all teachers were quite similar, which also had interesting implications for the design of courses related to programming and robotics (Ortega-Ruipérez & Lázaro Alcalde, 2022).

In contrast, Toh, Causo, Tzuo, Chen & Yeo (2016) presented a summary of studies that dealt with parents' perceptions and the influence of robots on the development of children's various skills. They described that the development of skills took place primarily in the cognitive, conceptual, linguistic and social areas and stated that most parents perceived educational robots as positive, but felt insecure about using robots and teaching their children (Toh, Causo, Tzuo, Chen & Yeo, 2016, p. 153).

As a result, although some of the aforementioned studies deal with programmable robot construction kits, the differences in students' abilities and also with parents' insecurities in dealing with robots, they leave the question raised here unanswered.

Research design

A laboratory test with the LEGO® Education SPIKE™ Essential robot construction set and an online questionnaire for parents were developed for the actual study. The LEGO set has the advantage of being conceptually underpinned, readily available, robust and state-of-the-art.

According to the manufacturer (LEGO® Education, 2023), the LEGO® Education SPIKE™ Essential Robotics Kit can be used in elementary school to learn the basics of programming, robotics and engineering by building and programming various models (Gervais & Patrosio, 2022, p. 201 f.).

According to Körei & Szilágyi (2022, p. 251 f.), the LEGO set with the simple symbol blocks (see Fig. 1) and the Scratch-based text blocks (see Fig. 2) offers two age-appropriate approaches to programming that build on each other.

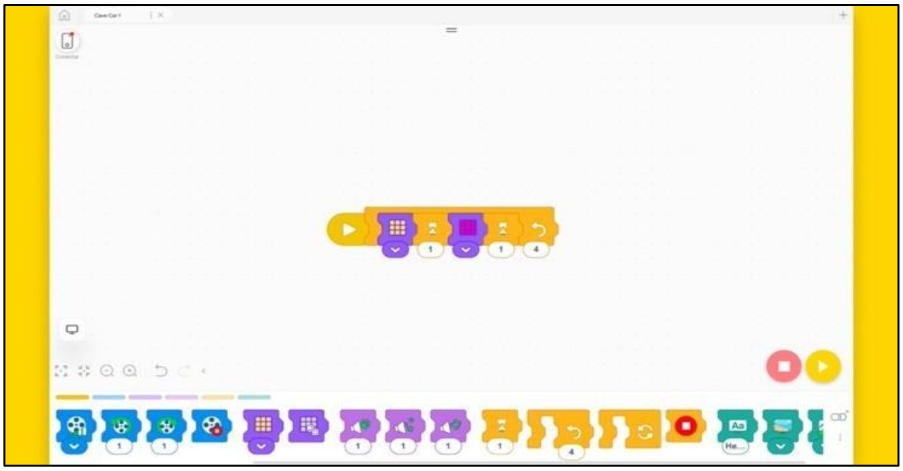

Figure 1: programming with simple symbol blocks (LEGO® Education, 2023)

The five learning units contained in the software are also described as age-appropriate. They deal with everyday stories in which users can solve problems in a playful way and are introduced to independent and solution-oriented thinking. Each of these 45-minute learning units comprises seven to eight linguistic or mathematical tasks and is sufficient for around 50 hours of lessons (LEGO® Education, 2023).

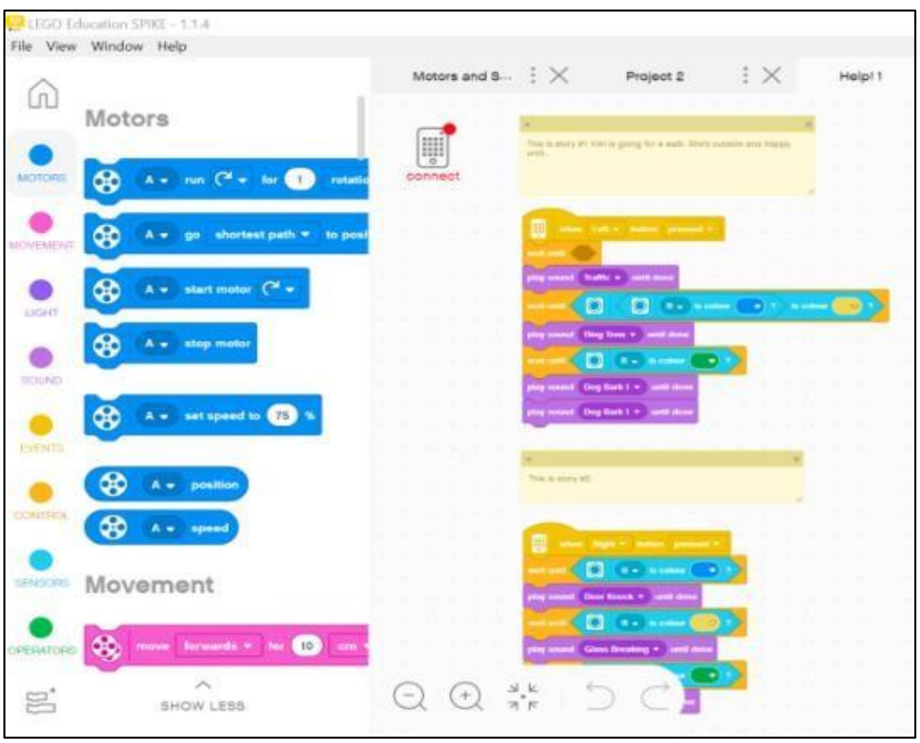

Figure 2: programming with Scratch-based text blocks (LEGO® Education, 2023)

With the aim of developing their skills over time, learners are encouraged to develop ideas together and come up with creative solutions by touching and trying things out (LEGO® Education, 2023).

In preparation for the intended study, substantial pretests were carried out with these construction kits in order to ensure the required quality criteria, test the procedure, evaluate the test set and eliminate possible problems or misconceptions. This also showed that, despite the target group's homogeneous lack of previous experience with programmable robot construction kits, different abilities and skills are to be expected.

As a result, a standardized observation was chosen, in which the recording took place with guiding questions and a division into categories (Reinders, Ditton, Gräsel & Gniewosz, 2011, p. 103 f.) according to a fixed scheme. Aspects such as

- - Behavior
- - Cooperation
- - Problem solving
- - Technical skills
- - Communication skills
- - Interest

The observations were carried out in a room provided by the respective schools, often an empty classroom or an undisturbed open space. There, the children were alone with the observers and could move and build freely.

The sample comprised four elementary school with a total of 408 pupils. Three of the schools were located in rural areas and one in the city of Koblenz. Between two and four children were drawn from each of the four grade levels using simple random sampling according to Stroebe, Hewstone, Codol, & Stephenson (2013, p. 8). A total of 45 children were observed, 18 girls and 27 boys. The questionnaires, on the other hand, were sent to all parents of the observed children, resulting in 45 potential interviews, of which 35 questionnaires were completed in full.

The questionnaire intended for the online survey comprised 13 questions and took a maximum of 5 minutes to complete. It has a typical structure and consists of instructions, an introductory and warm-up section, one or more main thematic sections and a conclusion (Reinders, Ditton, Gräsel & Gniewosz, 2011, p. 55).

The questionnaire began with general questions on the topic, age, class and gender of the child, while from question four onwards the parents' assessment of their child's general development was the focus. This was followed by increasingly specific questions about skills and previous experience with digital devices and construction kits.

Finally, in question 11, parents were asked specifically how they rated their child's handling of a LEGO® robot construction set and the tasks set on a Likert scale. They were asked, for example: Your child is able to

- - build a robot from LEGO® components with the help of instructions.
- - create a robot from LEGO® components without instructions.
- - be able to connect the control unit to the tablet independently.
- - correct errors during assembly independently.
- - to independently develop further functions of the robot.

Question 12 also asked about the child's estimated level of knowledge of the components and their functions. These included motors, lamps, sensors and the central control unit. The last question, on the other hand, focused on programming the robot and asked the parents whether they thought their child was able to program a robot independently using a tablet so that...

- - ...the robot moves straight ahead?
- - ...the robot turns in a circle (left and right)?
- - ...the lamp lights up in one color?
- - ...the lamp lights up in different colors?
- - ...the robot makes noises?
- - ...the robot can be controlled using sensors?

Conducting the Study

Before the start of each 45-minute test, the children being observed in pairs were given a tablet computer with the LEGO® Education SPIKE™ app and asked to watch the first five steps of the LEGO tutorial before starting to actually build and program their robot.

It should be noted that building and programming robots could be done in different ways. The children could decide whether they wanted to build a robot freely and without assistance or proceed with the help of instructions. For the choice of building instructions, there was a wide range of possible instructions from which the candidates could choose freely. When programming, a distinction was also made between programming using symbol blocks (see Fig. 1) and text blocks (see Fig. 2).

They were also given the option of building their own models afterwards if they had enough time. Otherwise, only hints and food for thought were given during the test runs, if these were necessary, and the remaining time was pointed out. After the start of the test, observation focused on the children's initial reactions in the form of expressions and/or gestures and facial expressions. The main focus here was on the visible emotions and recognizable motivation of each individual child when they saw and discovered the LEGO® Education SPIKE™ Essential Set.

This was followed by a key question on "Technical skills when building a robot" and was observed on the basis of how the children's comprehension of the construction and functioning of the robot was seen. The next questions on observation, the various programming functions were listed, allowing direct comparability with the parents' answers. “Are the pupils able to build the robot in such a way that the...”

- - robot moves straight ahead?
- - robot can turn in a circle (left and right)?
- - lamp lights up in one color?
- - lamp lights up in different colors and patterns?
- - robot makes noises?
- - robot detects obstacles using the color sensor and stops?

In the further course, the question “Can the pupils name the individual components and explain how they work?” focused on the correct use of terms and part names, while the key question “Can the pupils use the individual components appropriately (use components in a way that makes sense for the robot they have built)?” focused more on the use of the components. For completeness, the children's independent correction of errors within the test pairs was also observed and documented.

The parents' online questionnaire was created and sent via the online survey platform SoSci. The participants gave their prior written consent and provided their e-mail address, which they then used to receive the link to the questionnaire. The survey period started on 04.04.2023 and ended on 21.05.2023.

Results and Implications

The results from the observations and the online questionnaire of the first grade showed a clear heterogeneity with regard to building and programming a robot. These differences were also reflected in the parents' assessments, as they both overestimated and underestimated their children and often selected “undecided” or “I don't know”.

This is particularly noticeable when programming the robot and correcting errors. In first grade, there were seven overestimations, five correct estimations and five underestimations. In addition, there were three uninformative assessments (selection “undecided”), each of which amounted to over 40% of parents.

An overestimation took place primarily in the area of programming the robot in the straight direction of moving as well as turning to the left and right, whereas the programming abilities of the light and the color sensor were significantly underestimated.

Naming the components and explaining how they work was more difficult for the children than their parents assumed. In this case, the parents overestimated their children for almost every component, with the exception of the color sensor. Here, the parents' assumptions matched the children's abilities.

The second-grade children generally showed greater homogeneity in their technical skills and abilities in relation to building and programming a robot. A closer look at the skills involved in building a robot reveals that the children tended to be underestimated by their parents.

The parents' assessment of whether their children would be able to build the robot with the help of instructions was correct. However, the children's programming skills were consistently underestimated by the parents, as were their ability to recognize and correct errors. The naming and explanation of how the individual components work was underestimated in relation to the motor and the light, but parents were able to assess their children well in relation to the color sensor and the control unit.

The parents also accurately and correctly assessed their children's ability to operate the tablet-computer. Nevertheless, this shows that the children in the second grade were repeatedly underestimated by their parents in terms of their abilities and skills as well as their knowledge in the area of creating and programming a robot.

In summary, there were zero overestimates, seven correct assessments and ten underestimates. In the second grade, it only happened once that more than 40% of parents were unable to give an estimate for a question.

The children in the third grade already showed strong skills in building and programming a robot. Parents rated their children well below their capabilities in all categories, indicating a clear underestimation of their ability to build and program a robot. Overall, there were no overestimates, one correct estimate, eleven underestimates and seven times no estimates could be given.

The children in the fourth grade showed the most advanced building and programming skills of all grades. Many children already had previous experience and had no difficulty in building a robot, which was made clear by the fact that almost all pairs of participants chose to build without instructions and thus built an individual robot and programmed it with a wide variety of functions.

The parents' assessment was therefore surprising, as here too the children's potential and abilities were significantly underestimated or not assessed at all. In summary, there were no overestimates here either, only one correct assessment and twelve underestimates. Seven times no assessment could be given for different areas.

The overall view of the available results and their comparisons shows that only in the first grade did parents clearly overestimate. The underestimations, on the other hand, increased with increasing grade level, so that comparatively in the first grade there were only five underestimations by the parents, but in the fourth grade there were twelve underestimations.

Parents were able to assess their children correctly by around a third in grade one and half in grade two. From the third grade onwards, however, they were only able to assess their children correctly in the sub-area of the assessment of competence in using a tablet-computer.

It was also noticeable that parents found it more difficult to make an accurate assessment with increasing grade level and were sometimes unable to give an opinion on certain questions. One explanation could be that these parents may have little or no connection to this topic themselves.

The assumption made at the beginning that parents and guardians are not able to assess their children correctly, or only to a limited extent, was thus confirmed by the results just mentioned. Children's abilities and skills should therefore not be underestimated.

Further research

Even if the assumption that parents underestimate their children when using educational robotics construction kits could be partially substantiated with the results, further studies could increase the quality and validity.

This includes increasing the sample to a larger number of test subjects and expanding the selection of schools to evaluate more rural schools. In addition, the question of possible differences between urban and rural schools could also be investigated.

A revised research design could use a test and control group to compare children with prior experience with those without prior knowledge and compare these with the heterogeneous groups from the different elementary school. The question of possible gender differences could also be investigated in more detail.

Furthermore, additional data from kindergartens and secondary schools could be collected in parallel in order to gain more insight into the development of the pupils' abilities and skills over a longer period of time and to investigate this.

The children who have already been observed could also be tested again in the course of a long-term study after they have completed the next grades in order to be able to draw conclusions about how their abilities and skills develop or change.

Finally, an investigation into how teachers assess their pupils according to robotics construction kits could lead to didactic recommendations.

Literature

acatech - German academy of science and engineering & VDI - The Association of German Engineers. (2009). Nachwuchsbarometer Technikwissenschaften. *Careers in Science and Engineering: Trends, Expectations and Attitudes of Young People*. Berlin: Körber Stiftung.

acatech - German academy of science and engineering. (2011). *Monitoring von Motivationskonzepten für den Techniknachwuchs (MoMoTech)*. Heidelberg: Springer.

Balogh, R., Obdržálek, D., Fislake, M. (eds) *Robotics in Education*. RiE 2024. Lecture Notes in Networks and Systems, vol 1084. Springer, Cham. https://doi.org/10.1007/978-3-031-67059-6_6

Gervais, O., & Patrosio, T. (2022). Developing an introduction to ROS and Gazebo through the LEGO SPIKE prime. In M. Merdan, W. Lepuschitz, G. Koppensteiner, R. Balogh, & D. Obdržálek, *Robotics in Education: RiE 2021 12* (S. 201-209). Springer International Publishing https://doi.org/10.1007/978-3-030-82544-7_19.

Körei, A., & Szilágyi, S. (18. 11 2022). "From Scratch to Python-Lego Robots as Motivational Tools for Coding". *Multidiszciplináris Tudományok 12.3, Vol.12*(No. 3), 247-255.

LEGO® Education. (2023). *SPIKE Essential*. 29.04.2023. https://education.lego.com/de-de/products/lego-education-spike-essential-set/45345

Noschka, A., & Knerr, G. (1986). *Bauklötze staunen: 200 Jahre Geschichte der Baukästen*. Hirmer.

Ortega-Ruipérez, B., & Lázaro Alcalde, M. (2022). Teachers' perception about the difficulty and use of programming and robotics in the classroom. *Interactive Learning Environments*.

Reinders, H., Ditton, H., Gräsel, C., & Gniewosz, B. (2011). *Empirische Bildungsforschung: Strukturen und Methoden 1. Auflage.* Springer-Verlag.

Stroebe, W., Hewstone, M., Codol, J., & Stephenson, G. (2013). *Sozialpsychologie: Eine Einführung.* Berlin Heidelberg: Springer-Verlag GmbH.