WIP: The Phases of Robot Design: Storytelling Lesson for Students and a Survey Tool for Scientists

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***Abstract*— This work-in-progress innovative practice paper presents a storytelling lesson about robot design aiming to familiarize students with the multidisciplinary nature of robotics as a career. The lesson is based on an integrated STEM approach and structured as a narrative that follows the journey of roboticists in designing a robotic model of a rabbit by using the LEGO® Spike Prime robotic set. Students are immersed in the storyline as characters helping roboticists to test and evaluate their designs. This practical constructivist assignment includes two steps: 1) testing and evaluating assembly instructions and 2) testing and evaluating the two models (visually and by using programming exercises). The two models present distinctive styles of assembly instructions, standard LEGO® building instructions made in Studio 2.0 and 3D building instructions made in BuildIn3D. When it comes to design, the models display different orientations (vertical and horizontal), complexity (number of parts), and mechanics of movement. For this reason, this lesson also serves as a usability and comparative study. Lesson sheets narrate the story and guide the progression while also serving as a testing diary and reflection tool. This approach where students internalize lessons through personal involvement was chosen to facilitate engagement and support problem-solving and knowledge building, scientific inquiry, critical thinking, design thinking, think-pair-share, discovery, and discussion. The lesson was piloted during the teachers' training, after which teachers presented it to their students in elementary schools. Results are based on feedback from 42 students and 11 teachers. Results show that 17% of students included in the study never owned or assembled LEGO®. When it comes to assembly instructions, students considered standard instructions easier to navigate and follow with clearer illustrations and steps. On the other hand, they recognized that 3D instructions provided more detail and expressed that the interactive display from different angles positively affected their building experience. The easier assembly of model 1 was least affected by the clarity of instructions but rather attributed to fewer parts and the simplicity of the model. Although 95% considered model 2 more difficult to assemble, 59% expressed they would prefer to assemble that model over model 1.**

Keywords*— Design process, Engineering, LEGO® Spike Prime, Research methods, Robot design, Robotics, Scientific inquiry, STEM career, Storytelling

I. Introduction

Nowadays, with rapid technological advancements and changes in social atmosphere and circumstances, each decade brings a generational shift. The newest students of today's primary education are part of Generation Alpha or are so-called 'digital natives', digitally literate from an early age, open-minded, integrated with the rest of the world, self-aware, and willing to contribute to the world with their ideas [1]. To encourage students to solve problems by researching and designing their ideas while working as a group, putting those ideas to life, and operating the finished product, hence the development of 21st-century skills [7], teaching and designing the lessons should shift toward student-centred learning [2].

Studies [3], [4], [5] have shown that there is an increase in research applying STEM where the lessons are designed using a constructivist approach [6]. Moreso, STEM was shown to be suitable for team teaching (TT) and integration with humanistic subjects, e.g. storytelling [8] drama activities [9] or foreign language learning [10]. TT includes two or more teachers planning and carrying the lesson together while sharing the responsibility for their students [11]. It is a perfect example where two teachers with different specializations may design a lesson with its parent topic integrated through two different educational fields such robotics and storytelling [8], [12], [13]. While designing robotic lessons, a teacher should pay attention to the features of an available robot or consider desirable features to make a proper robot choice. Here, LEGO® Spike Prime was used as a robotic tool due to a high diversity of assembling pieces, modularity and familiar assembling principle. Besides being students' favourable choice [16], LEGO® is recognized for increasing students' problem-solving and social skills [14], contribution to students' engagement and achieving educational outcomes [15]. Also, storytelling was used as a pedagogical tool where students are active characters within the lesson that is designed as a story. This method facilitates experiential learning and deepens engagement with the material while students internalize lessons through role-play and personal involvement in the storyline.

The objective of this study was to analyse the experience of elementary school students with the assembly of two rabbit models differing in complexity and assembly instructions. Instructions as a tool to guide assembly can affect motivation, learning curve and cognitive load, task completion time, and number and type of errors [17],[18],[19]. Previous research has explored and compared the effects of various presentation methods, including paper instructions, mobile augmented reality (AR) 3D instructions [19], spatial AR instructions, computer assisted instruction (CAI) using a monitor-based display or a head-mounted display [17] and instructions on digital glasses with text or with text and audio [20]. On the other hand, this study utilized online instructions that are easily accessible across different technologies, hence suitable for the classroom environment, to observe the interconnectedness of the model, instructions and student preferences.

II. METHODOLOGY

This lesson was developed for the robotics curriculum of the project RaSTEM [21] aiming to develop future problem solvers - researchers and entrepreneurs. The project promoted close cooperation of formal and informal education through 1) the development of three programs (robotics, climate changes, and entrepreneurship) in coordination with curricula subjects, 2) professional development and capacity building of teachers and 3) the implementation of programs in elementary schools as extracurricular activities.

A. Participants

1) 42 students (M=23, F=18) from three elementary schools, 4th to 7th grade

2) 11 teachers (M=2, F=9) from various fields of teaching, with teaching experience spanning from novice to experienced teachers, predominantly with no experience with educational robots

B. Robot models

LEGO® Spike Prime set promotes assembly and programming (visual, block and script programming). The principle of assembling the building parts of a robotic set is intuitive and familiar to young learners. With a variety and a considerable number (528) of parts, the set is modular and promotes engineering.

The first model was designed by Dimitrios Kravvaris [22] for which standard-looking instructions have been prepared by the first author of this paper using Studio 2.0. This type of instruction, in a PDF format, consists of pages that are navigated by mouse scrolling or by pressing the next arrow in a PDF reader. Every page displays a step number, list of parts and marks changes in the design with red colour, e.g. in Figure 1, the 44th step shows two rubber bands that should be stretched between black pins of the front and back legs.

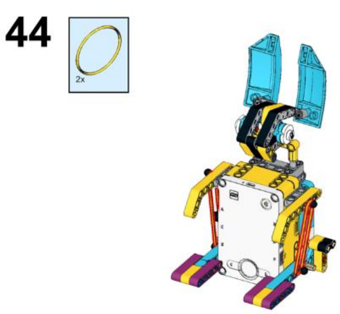

Figure 1. Model 1 and standard assembly instructions https://learn.hrobos.hr/zec-model1.pdf

The second model was designed by Coder Shah [23] and the building instructions were prepared by the FLLCasts team as 3D building instructions using BuildIn3D. This type of instruction provides more options when it comes to the navigation of the steps but also the view of the model which can be adjusted with interface buttons and a mouse in a 3D space to better observe the change introduced in the assembly step, e.g. in Figure 2, the tail has been added and marked with green colour.

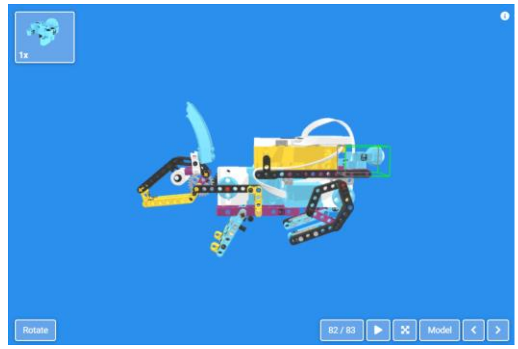

Figure 2. Model 2 and BuildIn3D assembly instructions https://bit.ly/zec-model2

C. Research questions and hypotheses

RQ1: Are 3D instructions preferred by students?
RQ2. What are the characteristics of models students prefer?
RQ3: Are 3D instructions preferred by teachers?
RQ4. What are the characteristics of models teachers prefer?
H1: Students prefer 3D instructions.
H2. Teachers prefer standard instructions.

D. Lesson design

The rabbit module is divided into three lessons. In the introductory lesson, students assemble two rabbit models, in the testing lesson the models are programmed to move, and in the refinement lesson robots are observed for additional functionalities such as playing music or displaying weather forecasts and evaluated for their functionalities. This WIP discusses only the introductory lesson.

The story begins with the introduction of roboticists as patient and dedicated to the task of designing a new robot model. Students are invited to join the journey and follow a design process phases: 1) problem definition, 2) brainstorming and selection of ideas for the design of the robot model, 3) drafting of the robot model and assembly instructions, 4) assembly of the prototype and testing, and 6) refinement of the design.

Roboticists recognized the need for a fun rabbit robot for teaching students about STEAM and asked students to link the letters of the acronym with its meaning given in Croatian and English. Roboticists continued to a research phase and explored what kind of rabbits exist by browsing the Internet and asking students to draw a rabbit from a cartoon and a rabbit found in nature (Figure 3). This was followed by a reflection on the environmental influence on rabbits' appearance such as size of ears, colour, size of legs, etc.

Figure 3. Drawing of a rabbit from a cartoon and found in nature

Roboticists found an interesting rabbit model by Antons Mindstorms [24] and invited students to watch the video to familiarize themselves with roboticists, their role and the possibilities of LEGO® Spike Prime. Further, the story defines the requirements and constraints of the design and asks students to inspect the content of the robotic set (controller, batteries, cables, sensors, motors, and building parts).

After brainstorming, roboticists put the selected ideas into action and created two draft models of a robot in the shape of a rabbit (Figure 4). Before students assembled the prototypes and tested the instructions, based on (Figure 4) they have reflected on models' characteristics and own preferences (see Table 2).

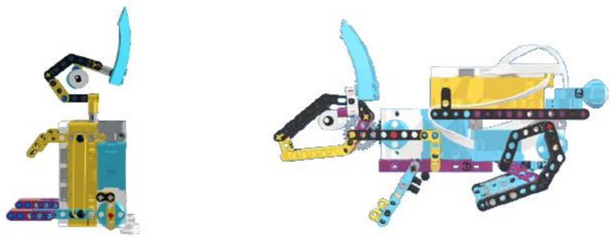

Figure 4. Model 1 and model 2 preview

To assemble the prototypes, the roboticists compiled two types of instructions and invited students to familiarize themselves with the instructions. As this lesson is convenient for Easter time, the theme can be further amplified by dividing students into teams that will assemble model 1 or model 2 by playing an egg hunt game with eggs being balls of paper in two colours.

After time for assembly, the story tells that the roboticists, in addition to being engineers who design robots, and programmers who program what robots can do, can also be scientists. In the scope of a testing log, the lesson embeds a set of reflection questions (see Table 3). Critical thinking, exchange of experiences and open communication are encouraged by applying the Think-Pair-Share strategy [25].

Reflection also consists of a few calculus challenges where students calculate the time needed to assemble the models and an average time in the class. Another task is to note the number of parts used to assemble the models where students can subtract the count of the remaining parts from the total number of parts of the set or count the parts in each step of the instructions.

The lesson is finished by filling out a survey in Google Forms followed by a discussion. The survey consists of background questions (Table 1), perception questions (Table 2), and the assembly log questions (Table 3).

III. Results and Discussion

A. Students

Results show that 17% of students did not assemble LEGO® building blocks before taking part in the project (Table 1) while experienced mostly assembled LEGO® DUPLO (54%). According to Table 2, most students (95%) thought model 2 was more difficult to assemble, yet the preference for building model 2 prevailed over model 1. 93% of students perceived the appearance of model 1 as cartoon-like and model 2 as nature-like, which in 80% of the sample corresponded with their drawings.

Table 1. Background questionnaire

Before the robotics program of the RaSTEM project, I did not assemble LEGO® building blocks.	17%
I've had LEGO® building blocks since I was little.	85%
I often assemble LEGO® building blocks.	56%
Before the robotics program of the RaSTEM project, I was familiar with the standard instructions for assembling LEGO® building parts. An example of standard instructions is the instructions for assembling model 1.	78%
For the first time, I encountered interactive 3D instructions for assembling LEGO® building parts. An example of interactive 3D instructions is the instructions for assembling model 2.	75%

The majority of students who preferred model 1 (12 out of 17 students) chose it because it was easier, one student because it was more interesting, two students because it was assembled from fewer parts, and four students because the model was more beautiful. On the other hand, ten students (out of 24) chose model 2 because it was more difficult, six students because it was more interesting, six students because it was more fun, seven students because it was made up of more parts, bigger, more complicated or had more options. Four students stated that the model 2 was prettier. From the analysis, it is clear that the difficulty of assembling the model was the main reason for choosing the model: the students chose a more difficult model because it is difficult (which in most cases makes it more fun), and the students chose the easier model because it is easier.

Table 2. Student initial perception

Which model would you prefer to build?	Model 1	41%
	Model 2	59%
Does one of the models look more like your drawing of a cartoon rabbit and the other more like your drawing of a rabbit from nature?	Yes	80%
	No	20%
Which model looks more like a rabbit from a cartoon, and which one looks more like a rabbit from nature?	Model 1 cartoon, Model 2 nature	93%
Which model do you think is more difficult to assemble?	Model 1	5%
	Model 2	95%

Students hypothesized correctly that model 1 is easier to assemble and only 2% changed their mind. The most important reason was the fewer parts, and the least important was the clarity of instructions (Table 3). In addition, they recognized shorter assembly time as more important for cognitive load than the clarity of instructions, and seemed to be very confident in their abilities.

Students considered model 1 easier to assemble and would recommend it to beginners. Standard instructions were rated with an average of 4.29, and 3D instructions with 4.05 out of 5. Despite describing the interactivity of 3D instructions positively (71%) and recognizing the details they provided (78%), students considered standard instructions easier to navigate and follow, with clearer steps and illustrations disproving H1.

Named advantages of model 1 were: the model was easier to assemble (15 students), had fewer steps or parts (14), was simpler (9) and faster (5). Eight students said that the instructions were clear and not confusing. The disadvantages of model 1 were: it was too simple, had few parts, and took a short time to assemble (12 students), it was small (3), uglier than model 2 (4), the instructions were unclear (4), the instructions did not have a 3D display (2) and the students did not like the capabilities of the robot (5). Eight students said that there are no flaws in model 1.

Listed advantages of model 2 were: it was more beautiful or had a more realistic appearance (9 students), it could do more things (6), the assembly instructions were clear or had 3D instructions (8), it was more interesting (5), it allowed longer assembly with more steps or parts (4), it was bigger (3) and more challenging (3). Four students said that there was no advantage (all these students previously declared that they preferred model 1). The disadvantages of model 2 were: it was more difficult to assemble (15 students), there were more assembly steps and more parts, or it took more time (10) and the 3D assembly instructions were not clear (9). Six students said that model 2 had no flaws (although four of them preferred model 1).

Table 3. Assembly observations questionnaire

Which model was easier to assemble?	Model 1	93%
	Model 2	7%
Did your hypothesis about the severity of assembly match the answer to the previous question?	Yes	93%
	No	7%
Rank in order of importance with numbers from 1 to 4 the reasons that contributed to the easier assembly of the model. (1 is the most important reason and 4 is the least important)	fewer parts	1
	shorter assembly time	3
	simplicity of the model	2
	clarity of instructions	4
What model would you recommend for students who don't have much experience with the LEGO® SPIKE Prime robotics set to build?	Model 1	90%
	Model 2	10%
Rate your experience building a model using standard instructions. (1 is the lowest and 5 the highest rating)	1	0%
	2	2%
	3	20%
	4	24%
	5	54%
Rate your model building experience using the interactive 3D view. (1 is the lowest and 5 the highest rating)	1	2%
	2	7%
	3	10%
	4	44%
	5	37%
Which instructions were easier to follow?	Model 1	83%
	Model 2	17%
Which instructions provided more detail?	Model 1	22%
	Model 2	78%
Which instructions contained clearer illustrations for assembling the model?	Model 1	54%
	Model 2	46%
Which instructions contained clearer steps?	Model 1	61%
	Model 2	39%
In which instructions was it easier to navigate the assembly steps?	Model 1	66%
	Model 2	34%
How did the interactive display of Model 2 from different angles affect your model building experience?	Positive	71%
	Negative	24%
	Neutral	5%

B. *Teachers*

Diverse backgrounds of teachers, including biology, chemistry, geography, physics, and informatics, imposed different expectations but also yielded a broad range of perspectives. As a result, this work highlights preferences and recommendations regarding assembly instructions and robot design of STEM teachers.

All teachers considered that model 1 was easier to assemble, yet two teachers had a different presumption. Also, all would recommend this model for beginners. According to the majority, the simplicity of the model was the most important factor, closely followed by fewer parts, while the least important factor was the clarity of instructions, the same as for the students. The average grade for the standard instructions was 4.64, and 3.82 for the 3D, confirming H2.

Unlike students, teachers (64%) thought that model 2 instructions contained clearer illustrations. They appreciated the interaction with the model by zooming in, changing the view and angle and highlighted that the interaction contributed to maintaining attention and facilitated understanding of how the parts fit together. On the other side, they proposed some advancements, like a bigger parts list, greater contrast and highlighting the pieces.

When it comes to the favourable characteristics of the models (RQ4), teachers appreciated that model 1 is simple, with clear instructions, fewer pieces, and steps but also more stable and easier to handle during assembly. On the other hand, model 2 was perceived as more interesting and mobile. The average assembly time for model 1 was 35 min for teachers and 39 for students while assembling model 2 took an average of 65 min for teachers and 60 min for students.

IV. Conclusion and Future Work

The innovative practice lesson engaged students in critical and design thinking by integrating context and content in the storyline and promoted solving authentic problems followed by reflection. Data collection using Google Forms facilitated quick visual feedback and supported discussion while also enabling further data analysis of the appropriateness of assembly instructions and robot models for teaching.

Students showed a good perception of complexity and a preference for challenging tasks but ultimately found standard instructions easier to navigate. Teachers' feedback mostly aligned with students, yet especially noted the benefits of zooming in on model 2.

Limitations include a small sample size and the interconnectedness of instructions and models. Future research should involve a larger sample, presenting results from all three lessons, highlighting qualitative data, using inferential statistics to considering gender, age and background differences, measuring performance and collecting feedback on the experience with the storyline.

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