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Lessons from delivering a STEM workshop using educational robots given language limitations

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Abstract. Educational robots are increasingly being used in schools as learning tools to support the development of skills such as computational thinking because of the growing number of technology-related jobs. Using robots as a tool inside the classroom has been proved to increase motivation, participation and inclination towards STEM subjects at both primary and secondary levels; however, language has usually not been considered as a mitigating factor. This paper reports our experience delivering nine workshops in English, using Thymio robots, to over two hundred students aged 9-12 across a week in the French cities of Nancy and Metz. Our goal was to test whether students would still have fun, learn something new and gain an interest in STEM even when the workshop was conducted in a foreign language. Our results indicate that using language that is easy to understand, although foreign, has a strong direct correlation ($p \sim 10^{-3}$) with having fun and that the latter positively affects learning and increased interest in STEM.

Keywords: Educational robots, bio-inspired robots, biomimicry, foreign-language workshop, Thymio

1 Introduction

Coding is steadily gaining importance in school classrooms as a result of society's demand for skills related to Information and Communication Technologies (ICT) [1]. A report by the European Schoolnet [2] (a network of 34 European Ministries of Education) noted that countries such as Belgium, Estonia, France, Israel and Spain have been offering coding as an optional subject in primary education since 2015, while others include it in their mandatory curriculum, as is the case in Finland, Slovakia and state maintained schools in UK. As part of this, educational robots are increasingly being used in schools as learning tools to support the development of skills such as computational thinking [3]. Many believe the technology improves the learning experience of students [4, 5] and is a useful aid for improving STEM interest at both primary and secondary levels [6].

Several educational robots with different functionalities, purposes and costs have been proposed and used. Some examples are LEGO Mindstorms [7], Edison [8], Boe-Bot and Scribbler [9], e-puck [10], Finch [11], mBot [12], Nao and Pepper robots [13], and Thymio [14]. B. V. Benitti [15] has found LEGO Mindstorms to be most commonly used in research studies; however, despite its impressive functionality, its high price point limits its suitability as an educational robot for use in schools [16]. Some robots are even more expensive, such as the e-pucks, whose target market is mainly higher education institutes, costing in excess of £600 per unit [14]. Others have been primarily designed for use as peers, tutors or socially assistive robots, e.g. Softbank Robotics' Pepper and Nao. Among the low-cost alternatives, Thymio (version II) has the widest range of sensors and actuation capabilities making it a good choice when the trade-off between functionality and cost is taken into consideration [14]. It has been demonstrated in practical workshops that Thymio robots appeal to children and adults of both genders, are a suitable tool for different activities and coding skill levels and make the user feel that they have learnt something new [17].

Educational robots have been proved to increase motivation, participation and attitude towards STEM subjects [18]; however, language has never been considered as a mitigating factor, i.e. workshops are often in the participants' native language. Do educational robots keep their motivational value even if the workshop is in a foreign language? To the best of the authors' knowledge, there is currently no work reporting the educational outcomes of a robotic workshop where participants are non-fluent in the language used.

This paper reports our experience delivering nine robotic workshops in English, using Thymio II robots, to over two hundred students aged 9-12 across a week in the French cities Nancy and Metz, under the umbrella of the Science in Schools British Council international outreach program. Our main goal was to test whether students would still have fun, learn something new and gain an interest in STEM subjects even when the workshop is delivered in a foreign language using educational robots, i.e. whether the benefits and gain of using educational robots would be language invariant. Moreover, does language and the ease of use of the robots contribute to these three outcomes? From a qualitative perspective, the other goals of the workshop were to help students practice a foreign language, introduce them to coding and robotics and expand their understanding of related research. Our approach follows the philosophy of the "Robots vs Animals" project which trained early career researchers in developing workshops on bio-inspired robotics aimed towards children [19].

2 Methods

Although educational robots are believed to have an impact on students' learning experience and attitudes towards STEM, B. V. Benitti notes in [15] that factors other than the use of robots also play an important role. Many important features found in successful robotic workshops, as identified in the literature and summarised by Benitti, were incorporated into our workshop design, with

particular attention paid to the language limitations of the students¹. These features and a small description of their implementation are given as follows:

- **Teachers play a big part in stimulating students [20, 21].** Three facilitators were in charge of delivering each workshop and assisting students, but most importantly, students were also assisted by their teachers.
- **Students should have a big space to play with the robots and explore different solutions [21].** Workshops took place in the schools' computer rooms, which allowed the students to use the robot on either the tables or the floor, as seen in figure 1.
- **Each robot should be used by a maximum of two to three students [21].** In most workshops, students shared one Thymio between two. In a few cases, it was necessary for a single robot to be shared by three.
- **The workshop should address content relevant to the students [21].** As the workshop focused on bio-mimicry, the content was related to ecology and animals' behaviour, relevant topics in their science subjects.
- **Students perform better if they are familiarised with the robots before facing problem-solving activities with them [22].** School teachers were informed a few weeks in advance of the type of robots used in the workshop. Most of them introduced the robots to the students or had used them in their science classes prior to the workshops. In addition, students were tasked with exploring the pre-programmed behaviours of the Thymios before attempting the coding challenges of the workshop.
- **Middle-school students should be guided to help them make the link between the robotic activities and the science/engineering behind [23].** For this reason, our workshop was split in to three different sections: 1) Presentation, where we presented our research work on bio-inspired robotics and how bio-mimicry works; 2) robot interaction, where students faced coding challenges to mimic animal behaviour, and 3) questions and answers (Q&A) session, where students had the chance to ask the facilitators questions about their lives and research.
- **High-level activities as opposed to low-level ones are believed to be more successful [24].** Coding challenges were kept simple and high-level through the use of animal behaviour examples. For example, rather than asking the students to use conditional statements, we instead asked them to consider how a chameleon changes colour in response to different stimulus and whether they could replicate this on the robots.

In the next subsections, a more detailed description of the workshop and materials is given.

¹ Material used in the workshops including the presentations, worksheets, questionnaire participant responses are accessible at <https://caidin.brl.ac.uk/k2-digumarti/data-for-rie2019-carrillo-zapata>



Fig. 1: Example of one session.

2.1 Thymio specifications

The Thymio robot [17] was developed as a low-cost, robust and open hardware educational tool with the purpose of introducing children to software and robotics. The multitude of sensors on the robot (distance, touch and audio) and the actions that it can perform (move, change colour and play sounds) make it a suitable choice to demonstrate several bio-mimetic behaviours (fig. 2). These robots can be programmed and interacted with, in a desktop setting next to a computer or as part of larger group where they can perform collective behaviours. The Thymios were chosen as they have been proved to be well-suited for educational activities and come with a suite of pre-programmed behaviours (friendly, explorer, fearful, investigator, obedient, and attentive [25]) that significantly reduced our preparation workload. This also means that the workshop is easily reproducible on other Thymios, even with little to no coding expertise. In addition, these robots have been deliberately designed to appeal to children of all genders across diverse age groups, to be easy and quick to use and to promote creativity [14].

2.2 Description of Workshop

The workshop was repeated over a period of five days with a maximum of two sessions per day, with a total of 219 primary and secondary school students taking part. Their demographics are presented in table 1. The workshop was delivered entirely in English, with occasional translation into French by teachers at the schools. Care was taken to avoid scientific jargon and ideas were conveyed pictorially, as this is suggested as an effective way to communicate to children [27]. Each session lasted for three hours (including approximately 30 min in breaks) and comprised of three segments (table 2). First, the students were introduced to the concept of bio-inspired design of robots through numerous examples presented using both textual and visual media. This was followed by a short activity demonstrating the emergence of order from chaos, a common

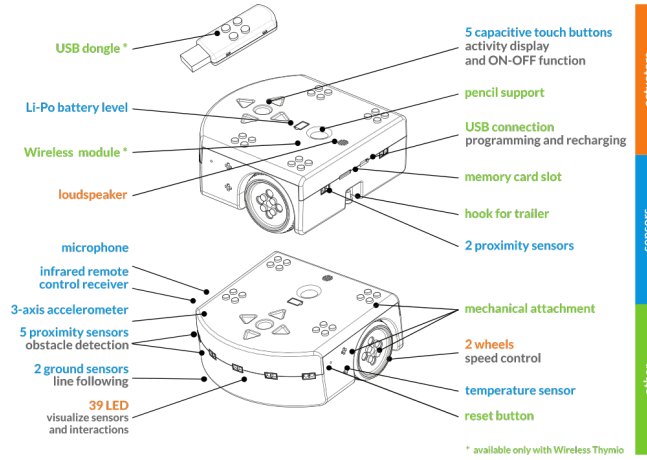


Fig. 2: Thymio Hardware Specifications [26]

Geographical location	Bar-le-Duc		Metz		Uxegney	Saint Mihel		Nancy	
Session	1	2	3	4	5	6	7	8	9
Age-group	10-11	10	10-11	10	9-10	11-12	10	10-11	10
No. of students	26	27	22	22	19	23	20	30	30
English proficiency	A1	A1	A1	A1	A1	A1	A1	B1	B1

Table 1: Participant demographics from each of the nine sessions in five different locations. A1 and B1 refer to language proficiency as defined by the common European framework of reference for languages (CEFRL).

concept in bio-inspired swarms [28]. Participants were challenged to synchronise their claps, starting from random clapping speeds. Eventually, they were expected to self-organise into a single clap. This particular activity—inspired by swarms of fireflies synchronising their flashes—was chosen because it requires no additional resources and presents an interesting and observable natural behaviour. Any other activity with similar results could be chosen.

In the second segment of the workshop, participants interacted with the robots. For this segment, two worksheets were handed out. The first one helped students familiarise themselves with the robots through a task (activity 2 in table 2) aimed at identifying the built-in behaviours of the robots (sec. 2.1). Each behaviour is uniquely associated with a colour. The activity required the participants to play with the robots, observe them in each colour mode to discover their behaviours and fill in the worksheet. The worksheet consisted of a matching task where the students had to match each colour with the description of the behaviour and the corresponding adjective (or name) in English.

The second worksheet presented the programming challenges. After being given an introduction to the Visual Programming Language (VPL) and a reference sheet, students had to solve three programming challenges (table 3) to

Introduction (45min)	Researchers and workshop introduction Introducing bio-inspired robotics with examples Activity 1 - Synchronised clapping - Emergence of order from chaos
Interaction with the robots (1h 30min)	Introduction to Thymios Activity 2 - What behaviours can you see? Introduction to Aseba visual programming interface Challenge 1 - Chameleon colours Challenge 2 - Fast and slow Challenge 3 - What other animals can you copy? (Open-ended)
Q&A (45min)	Q&A with the researchers

Table 2: Outline of the workshop.

Challenge 1: Chameleons can change their colour to match their environment. It helps them to hide from predators. They also change their colours to communicate with other chameleons. Tasks: Can you program your robot to change colours when you touch different buttons? Can you use this to communicate with another robot in the room?
Challenge 2: Tortoises move slowly to save energy. Cheetahs move very fast to catch prey. Tasks: Can you program your robot to be slow like a tortoise? Now, can you program your robot to move fast like a cheetah?
Challenge 3: Natural inspiration Task: What other animals can you program your robot to copy?

Table 3: Programming challenges for participants to implement on the Thymio robots using the Aseba Visual Programming Language.

put the concept of bio-mimicry into practice, as well as learning how to program the robots using VPL. For the first two challenges, a short informative sentence about the animal that is being used as inspiration for a behaviour was presented in English followed by a set of programming tasks to mimic this behaviour on the robots, as shown in table 3. The third challenge was open-ended but confined to the bio-mimicry aspect of the workshop and was included with the varying programming abilities among participants in mind. Those new to programming could apply skills learnt from the previous challenges whereas more experienced students could apply their knowledge to the context of bio-mimicry.

Finally, the third segment of the workshop, a Q&A session, allowed students to ask the facilitators any questions they had relating to the workshop, robotics or a research career.

Q1: Was the workshop fun?
Q2: Was the language easy to understand?
Q3: Were the robots easy to use?
Q4: Did you learn anything new today?
Q5: Are you now more interested in Science, Technology, Engineering and Mathematics?

MCQ: Which activity was most fun?

Table 4: The five categorical (Q1 - Q5) and multiple-choice questions (MCQ) asked on the questionnaire.

2.3 Questionnaire

At the end of the workshop, participants were handed out a questionnaire to assess their opinion of the activities. It consisted of five categorical questions and one multiple-choice question (table 4). This questionnaire was designed to assess the outcome of the workshop in terms of participants having fun, learning something new and being more interested in STEM subjects, even if delivered in a foreign language. To overcome the language barrier, the questions included translations in French provided by the teachers at the schools. Additionally, the words in English were deliberately chosen from common parlance and with an unambiguous equivalent in French. Each of these questions had five options (from 1 to 5) to express their level of satisfaction, ranging from extremely negative to extremely positive. Images with facial expressions (emoji) with same colour were used instead of words to label the options. In addition to the categorical questions, there was a single multiple-choice question which asked participants to select the parts of the activity that were the most fun.

3 Results

A statistical analysis of the responses to the questionnaire was performed to study correlations between answers to questions and to understand which part was more engaging. Analysis of the data was performed using MATLAB and R software. A histogram of responses was calculated to understand the spread of responses. This is shown in figure 3. The mean response was then calculated for each question, found to be 4.78, 3.61, 4.59, 4.57 and 4.45 respectively. We then performed a chi-squared test of independence with one degree of freedom between each pair of categorical questions to test for statistical correlation between the responses to the questions. Such responses were split into binary groups of YES and NO to ensure that each group had sufficient number of respondents to be amenable to a chi-squared test. The splitting of participants into groups was based on the mean response to avoid using a hard-coded threshold. In practice, this meant that every answer above the mean for such question was categorised as YES, and as NO for the opposite. The contingency tables for each pair of questions are shown in table 5.

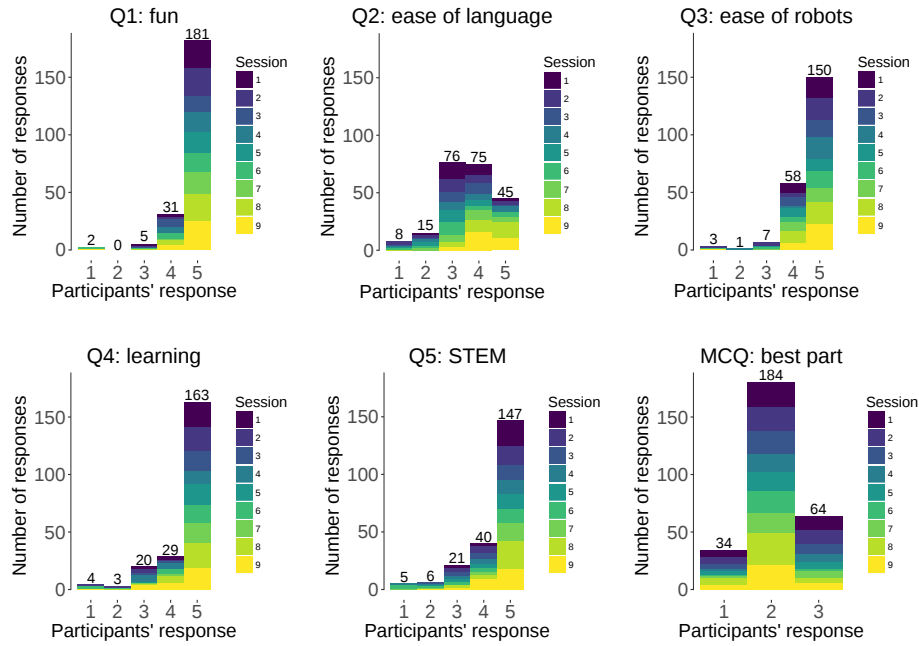


Fig. 3: Histogram of responses from all 9 sessions of the activity to questions 1-5 and multiple-choice question. (See table 4 for the questions.)

The null hypothesis in each test was that responses on the pair of questions were independent, while the alternative hypothesis was that there was a relation between responses to the questions. The corresponding p-values resulting from the chi-squared test are shown in table 6a). Finally, the odds ratio was used as a statistical measure to quantify the strength and direction of association between every pair of questions. The corresponding values are shown in table 6b).

4 Discussion

Results from the p-values from table 6a) strongly support that participants having fun is the most important aspect of a workshop if the desired outcome is for them to learn something new and become more interested in STEM, as also stated in other works [18]. This is also supported by the higher values of odds ratios (in particular higher than one) for comparison between these responses, indicating a strong positive association. This implies that students who had fun were also more likely to report that they had learnt something new and were more interested in STEM. Conversely, the ones who gave a negative response to fun were more likely to give a negative one to the other two.

The chi-square results also strongly suggest that easily understandable language has a direct correlation with having fun and therefore, it is an important

	Q2		Q3		Q4		Q5		Q3	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Q1	No	26 12	No	19 19	No	20 18	No	24 14	No	38 61
	Yes	73 108	Yes	50 131	Yes	36 145	Yes	48 133	Yes	31 89
	Q4		Q5		Q4		Q5		Q5	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Q2	No	30 69	No	42 57	No	18 51	No	29 40	No	27 29
	Yes	26 94	Yes	30 90	Yes	38 112	Yes	43 107	Yes	45 118

Table 5: Contingency tables between each pair of questions. (See table 4 for the questions.)

Table 6: Results of the chi-square test of independence for each pair of questions. (See table 4 for the questions.)

	Q2	Q3	Q4	Q5		Q2	Q3	Q4	Q5
Q1	2.8×10^{-3}	1.2×10^{-2}	6.3×10^{-5}	2.9×10^{-5}	Q1	3.21	2.62	4.48	4.75
Q2	-	6.5×10^{-2}	1.9×10^{-1}	9.7×10^{-3}	Q2	-	1.79	1.57	2.21
Q3	-	-	1	7.2×10^{-2}	Q3	-	-	1.04	1.80
Q4	-	-	-	7.6×10^{-3}	Q4	-	-	-	2.44

a) p-values b) Odds ratios

consideration when designing a workshop, especially if there are limited language capabilities. Although students were not fluent in English, the first histogram of figure 3 shows that most of them reported having fun, implying that our methodology was successful over the nine workshops. The role of the teachers was also very important in overcoming language barriers, especially when helping students understand a difficult concept, e.g., the difference between the verbs describing the pre-programmed behaviours “explore” and “investigate”, which happen to be very similar in French. We found that it is important to constantly check whether students understood an important concept/task, and ask them to explain it to their classmates. This was particularly useful in cases of students with mixed English language abilities, as often the more able students would explain things to their peers using English words they were more familiar with. Furthermore, we found that the language barrier could be significantly lessened by using other means of explaining concepts, e.g., visually using images or physical movements. Thymios and the VPL were particularly good for this, due to their use of symbols and being able to physically demonstrate the robot.

Although the interaction with robots was chosen by most students to be the best part of the workshop (last histogram in figure 3), we believe the whole experience is important for success, as described at the beginning of section 2. For example, the Q&A section was also highly rated, and we feel that giving the students the opportunity to freely question the experts facilitating the workshop helps them to link their robotic experience with the bigger science/engineering

picture, as noted by Nugent et al. [23]. It is important to leave enough time for wider questions beyond the scope of the workshop. Based on our experience, the first few questions might be about concepts covered in the workshop, but they later can begin to start asking deeper questions, e.g. applications of robotics, possible robots that they could create or about our research and ourselves.

Finally, the survey carried out by Riedo et al. [17] with Thymios robots suggests that the accessible design of the robot made participants feel they had fun; however, surprisingly we found insufficient evidence to support an association between ease of use of the robots and either gaining interested towards STEM or having fun (due to a total of ten multiple comparisons, p-value for an overall 5% probability of error should be 5×10^{-3} applying Bonferroni correction). This could be attributed to the students having little to no experience with any type of robot and thus having no baseline to measure the ease of use against. A possible follow up study with a different robot and/or a control group might offer more concrete conclusions.

5 Conclusion and future work

This paper shares the results from a bio-inspired robotics workshop in English using the educational robot Thymio for a total of 219 students from French schools over nine sessions. The novelty of our work is that it investigated whether the fact that workshops were delivered in a language in which students were beginners affected their perception of having fun, learning something new and being more interested in science, technology, engineering or maths (STEM) subjects, as well as whether the ease of use of robots had a correlation with those. Our study suggests that there is a strong, direct correlation between having fun in the workshop and both learning something new and becoming more interested in STEM, as stated in the literature of educational robotics. Most importantly, our study also suggests that there is a strong, direct correlation between the language being easily understood and the ability to have fun, and therefore learning and engaging in STEM subjects.

The main contribution of this work is to demonstrate that a fun, highly-interactive and motivating robotics workshop in a foreign language can still be successful even if language is somewhat of a barrier for users, provided that factors identified in the literature such as teachers' participation, low ratio of students per robot, large room space, relevance of the topic, pre-familiarisation with the robots, guidance during the process and high-level activities are taken into account. We believe our workshop uses those features to be motivating, despite the students' lack of fluency in the delivered language. In particular, the role of teachers before, during and possibly after the workshop is crucial to overcoming language limitations. Moreover, the advantage of our methodology is that it can be easily adapted to different ages/expertise by changing the scientific depth of explanations (talking more/less about the scientific and technical concepts) or how challenging the coding tasks are, while ensuring the general structure is maintained. It could also be used as an introduction to robotics in

the first lessons of a technology class, or as a tool to explain another topic apart from biology in a science class. If used this way, training for teachers would be key for robots acceptance and subsequent success [15]. Moreover, it could be used as an integration and teaching tool in environments where language is a barrier, e.g., a coding club for refugees.

Finally, we have identified that having a questions and answers session with the experts facilitating the workshop supports overall student satisfaction. We firmly believe that educational robots are an excellent tool to improve the learning journey, but other aspects, such as having a human conversation, also play a big role in making the experience more complete.

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