DEVELOPING PROBLEM-SOLVING SKILLS IN SCIENCE THROUGH LEGO MINDSTORMS EV3 EDUCATIONAL ROBOTICS AT ELEMENTARY LEVEL

Igona Gorakhnath* and Jubilee Padmanabhan[1,2]

[1]Department of Education, Central University of Punjab
Punjab, Bathinda
***Email:** igonaa@gmail.com
[2]Current Address: Department of Education in Science and Mathematics, NCERT

This paper examines the effectiveness of integrated robotics learning packages using LEGO Mindstorms in developing problem-solving skills in science in elementary school students. The study was done throughout the 14 weeks in Class VI in a school in Pune city of India. A quasi-experimental design was selected for the study where two intact classes were taken and randomly assigned as experimental and control groups. The experimental group was taught with robotics intervention, whereas the control group was taught with the conventional method. The post-test scores of problem-solving skills in the science test were analysed for both the experimental and control group using ANCOVA (Analysis of Covariance). The results showed that there is a significant increase in mean scores on problem-solving tests in the post-test of the experimental group than the scores of the control group.

Keywords: Problem-solving, Science Education, Robotics, LEGO Mindstorms

Introduction

The utilisation of educational robotics (ER) has been used in education since the 1980s and different endeavours have been made to present robotics in school education, especially in primary and secondary education, generally in Science and Technology subjects. During the construction of robots, students apply their insight into logical inquiry and numerical estimations, which helps foster their problem-solving ability (Doerschuk *et al.*, 2016; Avsec *et al.*, 2014). Currently, robotics is considered an innovative medium that offers opportunities for design and construction in a learning environment. The latest educational robotic technologies have programmable blocks which empower students to control the conduct of their robots through a virtual environment (Resnick *et al.*, 1996). The integration of robots in-school programmes has been promoted worldwide to strengthen students' skills in logical inquiry and problem solving and to set them up for future industrial requirements (Bybee, 2013). Through hands-on educational robotics courses, students upsurge their curiosity in STEM (Science, Technology, Engineering, and Mathematics) subjects (Doerschuk *et al.,* 2016). Some studies have shown that by taking robotics courses, students think that their knowledge of science and hands-on skills have been developed (Sullivan and Heffernan, 2016; Abdel-Salam *et al.*, 2009). The contribution of education should be to prepare the learners for the challenges of the twenty first century and the constant development of digital advancements.

In the contemporary paradigm of training, the development and programming of robots have been created straight forwardly with the goal that students can participate in the building and programming of robots themselves. Pico-Crickets and LEGO-Mindstorms are two primary advancements that have been intended for students to take part in robotics technology from the Media Lab at MIT (Resnick, 2006, Resnick *et al.*, 1996). Ninety per cent of the investigators accepted LEGO mechanical units and showed that it decidedly affected learning outcomes (Benitti, 2012). Studies have determined that robotics technology incorporated courses could upgrade student's capacity to lead logical inquiry through investigating, thinking and connecting with robots in actual surroundings (Jojoa *et al.*, 2010; Williams *et al.*, 2008). The utilisation of robotics in the classroom additionally contributes to evolving problem solving through tackling genuine questions in given settings as students need to utilise their insight and abilities to discover an answer and build a robot to elucidate the problem (Jojoa *et al.*, 2010; Nunget *et al.*, 2016). Robotics is a multidisciplinary area that interests students because it gives real hands-on experience and programming opportunities. Research has shown that students have fun with robots as well as show positive learning results (Benitti, 2012). Subsequently, this research aims to create learning packages using educational robotics (LEGO Mindstorms EV3 kit) by integrating them into science subjects and testing their effectiveness on the problem-solving skills of Class VI students. LEGO Mindstorms EV3 Home edition (31313) robotic kits were utilised to create learning materials for executing science ideas dependent on the curriculum of Class VI science following the NCERT (National Council of Educational Research and Training). LEGO Mindstorms EV3 is the generation third robotics pack in LEGO's Mindstorms line. It is a blend of two Danish words, "leg godt," signifying "play well." It is simple to learn robotics that gives young students an active encounter through development units.

Theoretical Framework

The usage of robotics has been expanded as of late and the endeavours have been made to coordinate robotics technology in school instruction, particularly in science and innovation, by several nations. There should be a change in technology usage from learning innovation to learning with innovation. This will contribute to connecting students with genuine problem-based learning advanced with robotic exercises. Robotics activities depend on constructionism. The learning packages utilising instructive advanced robotics were created around constructionist learning, which is an instructive strategy established upon constructivist theory (Piaget, 1971). The students are associated with the plan and development of actual items in a knowledge setting which gives exercises inundated with problem-solving strategies to construct knowledge. This process concentrates on the role of concrete objects in the complex process of knowledge construction (Papert, 1980). At the point when students are occupied with the advancement of making objects and are intelligent about their plan, then knowledge is constructed. In several studies in which technology is utilised to create a setting, constructionism is valued as it enhances 'learning by doing and learning by design. Constructivist theories like traditional knowledge (Brown *et al.*, 1989) and cognitive flexibility theory (Spiro, 1988) demonstrate an association with constructionism. However, constructionism is particular in nature as it focuses on 'learning by creation' and 'objects to think with' (Papert and Harel, 1991). LEGO resources give potent ways for learners to evaluate and change their comprehension of science ideas while cooperating in planning, building, assessing and adjusting objects significant to them (Puntambekar and Kolodner, 2005). Educational robotics is the strategy during which learners construct and programme robots to play out the specific conduct for educational purposes. In this manner, educational robotics from an academic point of view is observed as grounded in the speculations of exemplary constructivism (Piaget, 1971) and explicitly in constructionism (Papert and Harel, 1991). The learning environment around robotics provides tasks embedded with problem-solving skills, which leads to building the adequate knowledge of learners as they are indulged in designing and constructing the real objects that have some meaning for them.

In the underlying work at MIT media lab, researchers began the advancement of LEGO or Logo (Resnick and Ocko, 1991). They consolidated LEGO Technic items with the Logo programming language, enabling children to build and programme robots. This learning-by-doing strategy has accomplished much consideration in the current years. As indicated by our thought, robotics-based education using problem-based tasks cannot just increase the advancement of important cognitive and metacognitive abilities and capacities; it can likewise be a crucial factor for creating essential speculation in the present young learners. Moreover, higher-order thinking skills such as problem-solving, creativity, decision-making and critical thinking are essential for twenty first-century skills needed in the present society (Sendag and Odabasi, 2009).

There has been a change in science education from focusing on simply teaching science ideas to help students figure out phenomena and design solutions to problems (Krajcik, 2015). This new view, additionally indicated as a practice turn, puts importance on making an epistemic culture by allowing students effectively work in genuine logical inquiry processes (Forman, 2018); it is, along these lines, grounded in the image of science learning as training (Lehrer and Schauble, 2015) or as cooperation (Sfard, 1998). Acquiring logical comprehension through solving problems that are attainable, beneficial, contextualised, significant, moral and supportable (Krajcik, 2015) makes it essential to coordinate content, procedural and epistemic information (Kind and Osborne, 2017). Besides, this multidimensional teaching methodology frequently includes various domains like science, technology, engineering, mathematics (STEM) and software engineering simultaneously. Empowering students to resolve this sort of interdisciplinary and real problem requires an overall epistemological framework structure that upholds problem-solving by giving a set of general scientific procedures and techniques that reflects the wide range of different scientific approaches that may be required. LEGO Mindstorms can provide a learning environment that contributes to presenting situations embedded with problem-solving procedures to students.

The LEGO Mindstorms unit demonstrated an astounding teaching tool for so many reasons. Principally, the framework shows students problem-solving skills since they are allowed the chance to configure, create and test their robot. Students appear to be content to play with the robot to get it to play out the capacities they need it to. Students know promptly when they have committed an error because the robot will not move in the way they anticipated. Such "disappointments" are a tremendous learning opportunity for the students. Since, they mostly see the justification for their disappointment as something they did or did not do, they can get back to the computer programme, analyse it and make transforms they accept will resolve the issue. Student groups can work through various problem-solving stages before teacher mediation. For many reasons, the LEGO Mindstorms kits have proven to be a promising teaching tool. The programme primarily shows problem-solving skills to students since they have the opportunity to configure, build and work with their own robots. Students seem eager to engage with the robot to make it carry out the necessary tasks.

Literature Review

A robot is a result of the transaction of science, technology and engineering. It may very well be utilised to comprehend the incorporation of knowledge in STEM fields (Alimisis, 2013; Avesc *et al.*, 2014; Benitti, 2012). The robot market is developing since an ever-increasing number of schools are keen on using robots for instructing and learning (Rusk *et al.*, 2008). Robots from various organisations are made accessible for students to gather components physically, such as LEGO, Arduino, Fischertechnik and Raspberry (Araújo *et al.*, 2015; Avesc *et al.*, 2014). In light of the review of the current literature and curricula, researchers have called attention to the fact that robotics courses which generally center around robot mechanical constructions, electronic parts, programming and designing plan (Alimisis, 2013; Benitti, 2012; Seul, 2013; Slangen *et al.*, 2011) and the demonstration and explanation of the utilisation of the components and the assemblage of the robotics constructions ordinarily takes much time in class (Avsec *et al.*, 2014). Robotics technology courses generally stress on programming or assembly of a robot, but they have an absence of knowledge integration of STEM subjects (Benitti, 2012).

Moreover, Alimisis (2013), Altin and Pedaste (2013), and Benitti (2012) studied the research on robotics education for as long as ten years and reached the conclusion that limited studies had drawn on the learning results; significantly fewer had analysed each of the four STEM disciplines. Maybe the more significant part of the investigation examines students robotics abilities or attitudes towards integrated robotics education. Alimisis (2013) and Benitti (2012) suggested that the robotics integrated educational programme ought to be successfully coordinated with different subjects and expressed that, there is a requirement for the advancement of suitable robotics educational programmes and instructing systems.

Some theoretical investigations and experimental studies have shown that playing with robots lets students of different ages build their problem-solving abilities. Problem-solving is a stimulating process that welcomes the students to manage rationale, semantics and once in a while, dynamic speculation to consider and take care of the problem (Jackson *et al.*, 2019). By tackling real problems, students are vigorously involved and support their exploratory disposition having motivating forces to contemplate science and technology. The interest in research is progressed, and students are empowered to act as researchers and find their unique thoughts and answers, thus strengthening their self-viability (Barker *et al.*, 2012). Problem-solving is viewed as a significant stage in the advancement of a programme. It is frequently viewed as a challenging skill to master. Jenkins and Davy (2002) states that problem-solving is a complex process that requires different abilities. The problem has to be recognised and perceived. Whitfield *et al.* (2007) express that problem solving is an intricate interaction that requires different abilities.

A number of organisations, like LEGO and Fischertechnik, offer robotic kits with descriptions of activities such as hindrance aversion, following, weighting and shooting, utilising wheeled robots (Jojoa *et al.*, 2010; Somyürek, 2015; Yuen *et al.*, 2014) or strolling robots (Jojoa *et al.*, 2010; Pa and Wu, 2012). Benitti (2012) pointed out that, ninety per cent of researchers utilised LEGO robotic kits and that they positively affected learning. However, Park and Kim (2011), explained that one of the objectives of robotics education is to allow students to pick materials and apply what they have comprehended in the class to make their own robots.

Though not every one of the reported results of utilising robotics is positive, LEGO advanced mechanics camps can improve student's physics content knowledge, but it was found that it has no significant impact on scientific inquiry skills (Williams *et al.*, 2008). Moreover, Hussain *et al.* (2006), examined that there are negative attitudes toward LEGO robotics programmes and they have no significant impact on problem-solving skills. However, these investigations included only small or isolated groups (Alimisis, 2013), with short interventions (Benitti, 2012). To have an invasive perspective on the robotics integrated educational programmes (Benitti, 2012; Rihtaršic *et al.*, 2016; Slangen *et al.*, 2011), the effect of a regular educational programme should also be evaluated (Benitti, 2012; Eguchi, 2016). Along these lines, this research investigated the effectiveness of learning packages using LEGO Mindstorms educational robotics kits on elementary students and the outcomes were compared with those of learning in a regular classroom with the conventional method.

Purpose and Research Questions

The fundamental purpose of this study was to develop problem-solving skills by integrating LEGO Mindstorms EV3 educational robotics into elementary science education for 11–12 age children. In addition, this research compares the problem-solving skills of students who participated in the intervention of integrated robotic learning packages with those who did not participate in the intervention. Specifically, the following research question was framed:

What is the effectiveness of the integrated robotics learning package on problem-solving skills in science for Class VI students?

Research Design

The present study is quasi-experimental in nature. Non-equivalent control group design was utilised for research. In this present design, both the experimental and control groups are administered with a pre-test which can be used to establish that the two groups are equivalent despite the fact that they have not been assigned randomly. To diminish a portion of the dangers and reinforce the examination, the analyst has bent over backward to incorporate gatherings that are pretty much as comparable as could be expected.

To decrease some of the threats and strengthen the study, the researcher has tried to make both the groups as equivalent as possible (Gay *et al*., 2017). The design is given in Figure 1:

Experimental	O_1	X	O_2
Control	O_3	X	O_4

Fig. 1. Design of the study

The broken line separating the parallel rows in the diagram of the non-equivalent control group indicates that the experimental and control groups have not been equated by randomisation. Here, O_1 and O_3 are pre-test measurements of the dependent variables of the experimental and control groups, respectively. O_2 and O_4 are the post-test measurements of the dependent variables administered in the experimental and control groups. X represents the experimental intervention given to the experimental group (Cohen *et al*., 2017). The design begins with the natural setting of the intact classrooms appointed randomly to experimental and control groups. Both the groups ought to be as identical as possible. This design was found to be appropriate in the current investigation in order to find out the impact of learning packages constructed by utilising educational robotics on problem-solving skills in the natural setting without having any influence on the classroom setting by either controlling or manipulating variables. The details of the design are given in Figure 2.

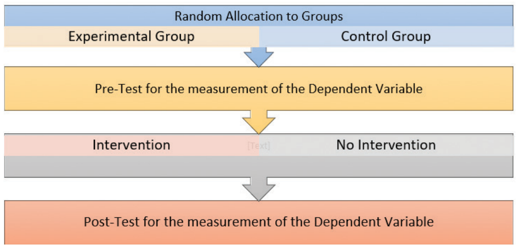


Fig. 2. Non-equivalent control group design

The study population is elementary school students studying in Class VI of the CBSE (Central Board of Secondary Education) syllabus. A purposive sampling technique was used to choose the sample. The basis of the selection of the school was the feasibility of the research and data collection and getting all the facilities required. The schools which have no exposure to robotics activities were selected. This was done to ensure that the studies desired outcomes were not affected. However, students needed to have some basic knowledge of computers and their applications; therefore, only those schools were selected which had the basic computer facilities. The selected schools were affiliated with CBSE (Central Board of Secondary Education), located in Pune city. These two schools were taken for the study as an experimental and control group. The entire Class of VI had been selected as randomisation was impossible because it would have affected the class time tables. There were 40 students in the experimental group and 37 in the control group primarily for the study. However, one student in the experimental group could not attend the pre-test and was removed from the data. Hence, the study sample was reduced to 39 students in the experimental group and 37 in the control group. Necessary consent was taken from the institution and the parents of the students before conducting the study.

Procedure

Science has been taken as a core area for developing the learning package. Flexibility, innovation and creativity are essential skills in this changing world. These different imperatives were in mind while shaping the structure of the learning package. The curricular contents of NCERT (National Council of Educational Research and Training) Class VI science gave the foundation of the learning package. The researcher reviewed various design models for learning packages and after reviewing them, the ADDIE model was found to be appropriate for developing learning packages using ER. This model was initially designed in 1975 for military training (Watson, 1981). ADDIE is an acronym where every letter describes each model phase: Analysis, Design, Development, Implementation and Evaluation. This model gave direction for the iterative development of the learning material. The framework of the learning package (LP) development is shown in Figure 3.

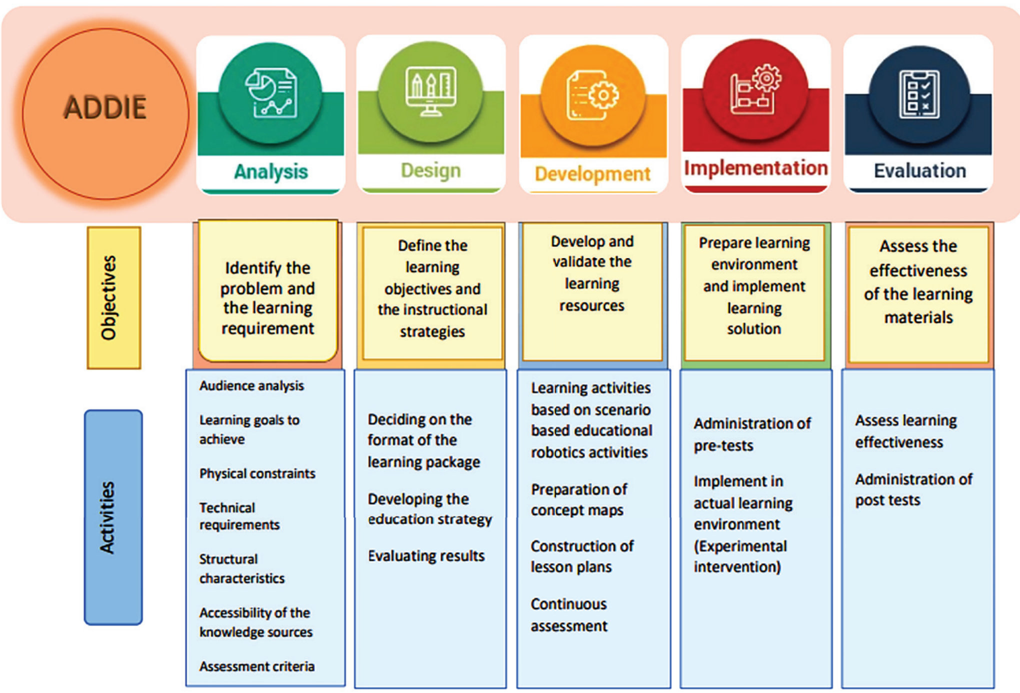


Fig. 3. Framework of development of learning package based on ADDIE Model

Analysis: In this phase, the complete analysis of the instructional problem, goals and objectives were recognised. Identifying the learning environment and learners existing knowledge and skills were also analysed.

Design: In this phase, the structure of the learning package was decided. The full description of the topics and the instructional objectives which tend to be achieved is clearly mentioned. Detailed planning of instructional strategy and its selection was analysed in this stage.

Development: In this phase, the development of the learning package took place. It was aimed to accomplish three main goals— (1) deciding the format of the learning package, (2) developing the education strategy and (3) finalising all the learning materials.

Implementation: In this phase, the pilot study of the learning package was done for ten days in an actual learning environment and the adequacy of the learning strategy was assessed and modified accordingly.

Evaluation: In this phase, the learning package was implemented during experimentation and after completion of the intervention, the effectiveness of the learning package was evaluated with the help of a post-test.

The present study adopted the activity-centred instructional strategy. The learning package was divided into several tasks which require different abilities and skills. In each class period, topics were taught with the help of a task. The learning package consisted of five modules dependent on selected units of Class VI science. A total of 60 lesson plans were prepared, which were taught in 60 class periods. The selected topics were motion, measurement of distances, electricity, light and fun with magnets. At the beginning of the intervention, the researcher briefly introduced LEGO Mindstorms EV3 kits and all their parts to the students. The designed activities were conducted in groups that consisted of six students in each group. Each group constructed and programmed a robot. Step-wise instruction on constructing robots had been given to each group and also, they were provided with the programming steps. The experimental group participated in the intervention during their science class for 14 weeks. The assessment instrument was a 21-item problem-solving test in science with four alternatives in which there was only one correct answer and rest three were distractors created by the researcher. Each assessment question was derived from the Class VI science curriculum. The experimental group participated in the intervention during their science class for 14 weeks. The students were presented with a task. For example, the teacher presented a problem by asking how to design a robot that could move from one point to a different point in a straight line and asked the students to come up with their ideas. The students constructed their robots in groups in a step-wise manner:

1. Building the motor and wheel assembly
2. Building the castor wheel assembly
3. Adding the EV3 brick
4. Mounting the infrared sensor
5. Connecting the colour sensor
6. Building the touch sensor bumper
7. Attaching the cables

After the robots construction, the students were asked to write the EV3 programme. Figure 4 shows the working of students with robots.

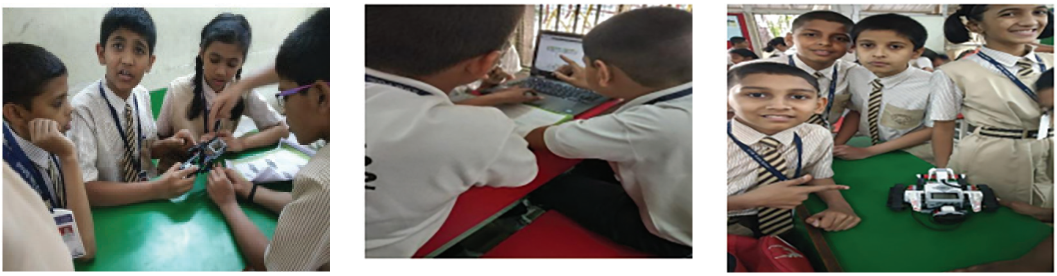


Fig. 4. Students are constructing and programming robots

In the control group, the students were taught using the conventional method. They were also taught for 14 weeks with the same topics. After completing all the topics, they were assessed with the same problem-solving test assessment instrument.

Example

Activity: Let us construct the robot (there and back programme)

The teacher will ask the students to construct the robot and programme it to travel a particular distance and then measure the distance travelled by the robot.

The "There and back" programme will make the TriBot move forward one metre, turn around, then return to where it started. Some measuring is required to solve this problem.

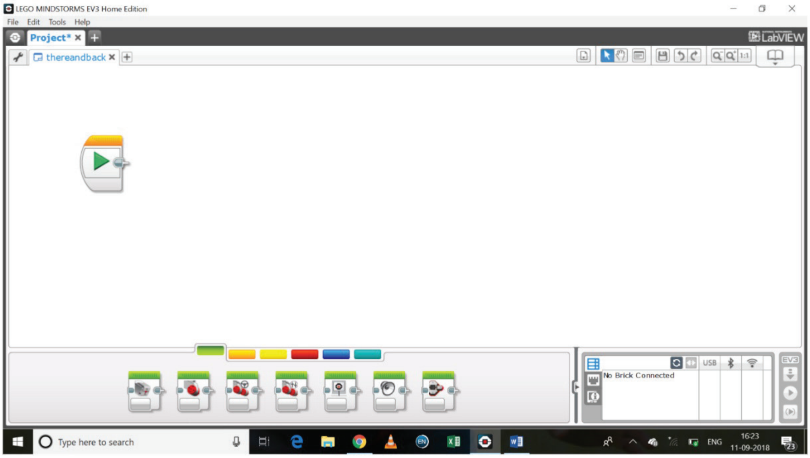
This programme uses three move steering blocks: one to move forward, one to spin the robot around, and one to move the robot back.

Moving forward: The first block needs to move the robot forward one metre, but a metre is not one of the duration options. How do you figure out how far one metre is in degrees and rotations? Let us consider rotations.

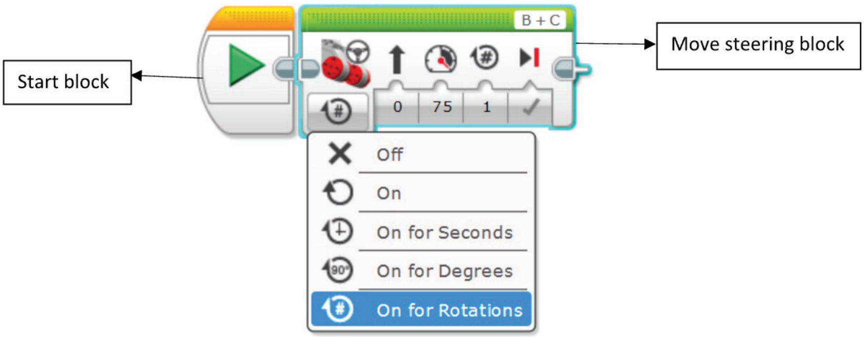
One way is to write a programme that moves the robot a long distance, say ten rotations. Before running the programme, mark your robot's starting position on the floor; now, run the programme and measure how far the robot moves in centimetres. Divide the distance moved by the number of rotations to determine how far the robot moves in one rotation. For example, if my robot moves 130 cm in 10 rotations or 13 cm in one rotation, then if I want my robot to go 90 cm, I divide 90 by 13 to find the duration setting needed to move 90 cm. Start with the calculated value and adjust the setting until you get what you need.

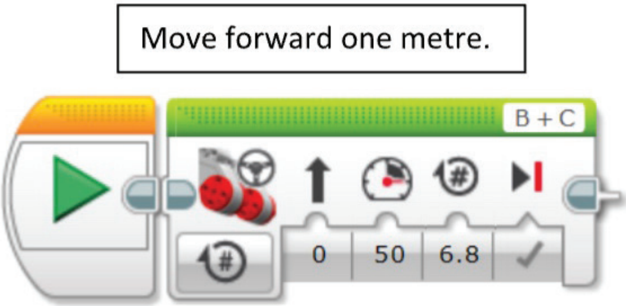
When you know the duration, you can start writing the programme. Here are the steps of moving forward:

Step 1: Create the new programme called "There and back."



Step 2: Add a move steering block next to the start block. The mode will be set to on for rotations' by default





Step 3: Set the rotations parameter to the number you calculated

Test these settings by running the programme several times across a measured distance. Your robot should stop very close to the same spot each time. If it does not, try lowering the power parameter. Adjust the duration if the robot stops at the same spot but does not travel the correct distance.

Turning around: A second moving steering block will turn the robot around for the return trip. Finally, move the steering slider all the way to one side to make the TriBot spin. (Choose either side; the direction is not essential).

Research Instrument

After a rigorous review of the literature regarding the problem-solving process, the researcher adopted the framework given by Merrill *et al.* (2017), for the development of a test for problem-solving and based on this framework, dimensions or constructs of the test have been developed. The identified dimensions and their explanation are given in Table 1.

Table 1: Problem-Solving Dimensions and their Description

S. No.	Dimensions or constructs	Description
1.	Identifying the problem	Exploring the problem situation, observing it, interacting with it
2.	Defining the problem	Specifying a problem, stating hypotheses
3.	Generating solutions	Developing explanations and solutions
4.	Evaluating, choosing, enacting solutions	Testing solutions, observing data, choosing alternatives, organising and representing data
5.	Assessing the outcome	Evaluating data and observations or making validations

While constructing the items, the age of the students and the grade in which they are studying were kept in mind. The items were framed according to their intelligence level and syllabus per the NCERT curriculum. The test items were based on the objectives of science and the content of the science curriculum for Class VI in NCERT and also covered the dimensions of problem-solving skills. Test-retest reliability was found for the problem-solving test. The test was administered to 208 students with proper instructions, and after a gap of 15 days, test was again administered to the same group of students. The Pearsons product-moment correlation was calculated for the reliability of the test, and it was found to be 0.79. The estimated value showed the stability of test scores over time and reflected that the scores were reliable. Internal consistency was also estimated for the problem-solving test. It indicates the homogeneity of the test. The estimates are based on the relationship between items within a test and are derived from a single test administration. To estimate the test's internal consistency, coefficient alpha (Cronbach, 1951) was used because coefficient alpha is more broadly applicable and has become the preferred statistic for estimating internal consistency (Reynolds *et al.*, 2011). The coefficient alpha of the test was found to be 0.78. The items of the PS test were constructed based on dimensions of problem-solving skills. The internal consistency and reliability of each dimension were calculated using test-retest reliability. The reliability coefficient of all the dimensions ranged from 0.66 to 0.76, suggesting that all the dimensions were reliable. The dimension-wise reliability coefficient is presented in Table 2.

Table 2: Reliability Coefficient of each Dimension of the PS test

S. No.	Dimension	Internal consistency (Cronbach's Alpha)	Test-retest reliability Coefficient
1.	Identifying a problem	0.74	0.69
2.	Defining a problem	0.73	0.72
3.	Generating solutions	0.71	0.66
4.	Evaluating, choosing, enacting solutions	0.76	0.65
5.	Assessing the outcome	0.72	0.76

Analysis and Results

The research question was framed in order to examine the effectiveness of the integrated robotics learning package in developing problem-solving skills. Analysis of covariance (ANCOVA) was conducted to determine if there was a significant difference between the two groups with intelligence scores as the covariate. Raven's progressive matrices were administered to both groups to find out the intelligence of both groups. ANCOVA is a robust test for detecting minor variance between the means. The pre-test and post-test mean scores of experimental and control groups are shown in Table 3.

Table 3: Showing Mean Scores of Experimental and Control Groups

Group	Pre-test Mean (SD)	Post-test Mean (SD)
Experimental (n=39)	6.87 (1.834)	16.23 (2.823)
Control (n=37)	7.08 (2.019)	13.91 (3.522)

The mean and standard deviation values of the pre-test control group on pre-test are 7.08 and 2.019, respectively. In contrast, the mean and standard deviation of the experimental group which was given intervention with learning packages using educational robotics on the pre-test are 6.87 and 1.834, respectively. Furthermore, the mean and standard deviation of the control group on the post-test are 13.91 and 3.522, respectively, whereas the mean and standard deviation of the experimental group on the post-test are 16.23 and 2.823, respectively. Hence, there is an increase in the mean scores of post-test of problem-solving skills in both experimental and control groups from pre-tests.

Analysis of covariance (ANCOVA) was applied to find the significant difference between the control and experimental group on post-test by covariate the intelligence test scores because there is a correlation between intelligence and problem-solving skill.

Table 3 depicts that the difference in mean scores on the post-test of problem-solving test of the control and experimental groups is significant, with the calculated value of $F=26.415$ at $p \longleftarrow 0.001$, which is greater than the table value of $F=11.67$ at $p \longleftarrow 0.001$. Therefore, the null hypothesis, which stated that there was no significant difference between the experimental and control groups on post-test when intelligence scores were taken as a covariate, is rejected and the alternative hypothesis, that is, there is a significant difference between experimental and control groups when intelligence scores were taken as a covariate is accepted. F ratio of 26.415 is significant, which definitely indicates that the intervention with learning packages using educational robotics is effective in developing problem-solving skills in science classes at the elementary level.

Discussion

The experimental group was taught an integrated robotics learning package, whereas the control group was taught with the conventional method. Both the groups showed an increase in mean scores on the problem-solving test in science from pre-test to post-test. The mean scores of the experimental group on the post-test were significantly higher than that of the mean scores of the control group on the post-test. This result validated the studies that showed LEGO robotics could enhance student's positive attitude toward the importance of integrated STEM courses (Binns *et al.*, 2016 and Nugent *et al.*, 2016). The students performed well with robotics intervention and showed tremendous eagerness and interest in learning scientific ideas through robotics kits. Robotics construction gave students a stage to assemble and plan their own innovativeness. These learning materials are intended to make learning more visual and experiential, permit students greater adaptability in learning, show capability and increase their basic reasoning. It can be said that there should be more focus on developing integrated robotics courses to help students construct their knowledge. Researchers call this effort 'constructional design' (Resnick *et al.*, 1996). It includes designing new objects and activities, which helps students in their design activities. Robotics tasks depend on collaboration, participation, and connection among individuals and groups, encouraging intellectual capacity through conflicts at the cognitive and social level as students are required to portray their thoughts, considerations, and feelings and justify their answers. This investigation is in accordance with the findings of Eguchi (2016) that students can tackle problems that emerge in the development of robots during assignments and finish it and think intelligently.

Open educational robotic construction kits motivate students to find out about the development and execution of a robot, and through this, the students acquire how to solve complex problems and reason (Sullivan and Heffernan, 2016). The implications of the results of this research are significant as they offer strong support for the combination of robotic strategies in the educational programme of elementary education. Fundamentally, robotics can be utilised as an instructive innovation to help change and improve the traditional elementary curriculum with the goal that students can be instructed about problem-solving skills required in the 21st century (Zhong and Xia, 2018).

Conclusion

By using LEGO blocks, students can comprehend the ideas of parts of robotics as well as figure out how to plan and consolidate its automated parts to make various articles with enhanced logical information and authentic problem-solving skills. The studys findings support the use of integrated educational robotics courses to teach science concepts in the classroom. However, more research is required to validate the effectiveness of these types of courses with different populations. Using robotics makes learning fun and interesting for the students in the classroom environment. It motivates students to solve complex problems and increases their engagement in learning and attitudes towards education. Therefore, the utilisation of robotics in teaching science concepts is unquestionable. However, a few issues are yet open in the research and practice of educational robotics and one among them is the challenges in consolidating robotic activities in school educational programmes. Substantially more research is required in integrating robotics activities in school subjects.

References

Abdel-Salam, T., N. El Sawaf, and K. Williamson. 2009. Robotics Explorations to Enhance Information Technology Literacy in Rural Schools. *Journal of Communication and Computer.* Vol. 6, No. 3. pp. 55–63.

Alimisis, D. 2013. Educational Robotics: Open Questions and New Challenges. *Themes in Science and Technology Education.* Vol. 6, No. 1. pp. 63–71.

Altin, H. and M. Pedaste. 2013. Learning Approaches to Applying Robotics in Science Education. *Journal of Baltic Science Education.* Vol. 12, No. 3. pp. 365–377.

Araújo, A., D. Portugal, M. S. Couceiro and R. P. Rocha. 2015. Integrating Arduino-Based Educational Mobile Robots in Ros. *Journal of Intelligent and Robotic Systems.* Vol. 77, No. 2. pp. 281–298.

Avsec, S., D. Rihtarsic and S. Kocijancic. 2014. A Predictive Study of Learner Attitudes Toward Open Learning in a Robotics Class. *Journal of Science Education and Technology.* Vol. 23, No. 5. pp. 692–704.

Barker, B. S., G. Nugent, N. Grandgenett, L. Johnston, J. Gamon and R. Spangler. 2012. *Robots in K-12 Education: A New Technology for Learning*. IGI Global.

Benitti, F. B. V. 2012. Exploring the Educational Potential of Robotics in Schools: A Systematic Review. *Computers and Education.* Vol. 58, No. 3. pp. 978–988.

Binns, I. C., D. Polly, J. Conrad and B. Algozzine. 2016. Student Perceptions of a Summer Ventures in Science and Mathematics Camp Experience. *School Science and Mathematics.* Vol. 116, No. 8. 420–429. (https://doi.org/10.1111/ssm.12196)

Brown, J. S., A. Collins and P. Duguid. 1989. Situated cognition and the culture of learning. Educational researcher, Vol. 18, No. 1, pp. 32-42.

Bybee, R. W. 2013. The case for STEM education: Challenges and opportunities. NSTA Press.

Cohen, L., L. Manion and K. Morrison. 2017. *Research Methods in Education.* Routledge.

Cronbach, L. J. 1951. Coefficient Alpha and the Internal Structure of Tests. *Psychometrika.* Vol. 16, No. 3, pp. 297–334. (https://doi.org/10.1007/BF02310555)

Doerschuk, P., C. Bahrim, J. Daniel, J. Kruger, J. Mann and C. Martin. 2016. Closing the Gaps and Filling the Stem Pipeline: A Multidisciplinary Approach. *Journal of Science Education and Technology*. Vol. 25, No. 4. 682–695.

Eguchi, A. 2016. RoboCupJunior for promoting STEM Education, 21st-Century Skills, and Technological Advancement Through Robotics Competition. *Robotics and Autonomous Systems.* Vol. 75. pp. 692–699. (https://doi.org/10.1016/j.robot.2015.05.013)

Forman, E. A. 2018. The Practice Turn in Learning Theory and Science Education. In D.W. Kritt (Eds.), *Constructivist Education in an Age of Accountability.* Palgrave Macmillan, Cham. pp. 97–111

Gay, L. R., G. E. Mills and P. Airasian. 2017. Educational Research: Competencies for Analysis and Applications (13th Eds.). Pearson Education Inc.

Hussain, S., J. Lindh and G. Shukur. 2006. The Effect of Lego Training on Pupils' School Performance in Mathematics, Problem-Solving Ability and Attitude: Swedish Data. *Educational Technology and Society.* Vol. 9, No. 3. pp. 182–194. (http://www.ifets.info/journals/9_3/16.pdf)

Jackson, A., N. Mentzer and R. Kramer-Bottiglio. 2019. Pilot Analysis of the Impacts of Soft Robotics Design on High School Student Engineering Perceptions. *International Journal of Technology and Design Education.* Vol .29, No. 5. 1083–1104. (https:// doi.org/10.1007/s10798-018-9478-8)

Jenkins, T. and J. Davy. 2002. Diversity and Motivation in Introductory Programming. *Innovation in Teaching and Learning in Information and Computer Sciences.* Vol. 1, No. 1, pp. 1–9.

Jojoa, E. M., J. E. C. Bravo and E. B. B. Cortes. 2010. Tool for Experimenting with Concepts of Mobile Robotics As Applied to Children's Education. IEEE *Transactions on Education.* Vol. 53, No. 1, pp. 88–95. (https://doi.org/10.1109/TE.2009.2024689)

Kind, P. and J. Osborne. 2017. Styles of Scientific Reasoning: A Cultural Rationale for Science Education? *Science Education, 101(1), 8–13.*

Krajcik, J. 2015. Three-Dimensional Instruction. *The Science Teacher.* Vol. 82, No. 8, 50.

Lehrer, R. and L. Schauble. 2015. The Development of Scientific Thinking. In R. M. Lerner (Eds.), *Handbook of Child Psychology and Developmental Science.* Vol. 2. pp. 671–715. Wiley.

Merrill, K. L., S. W. Smith, M. M. Cumming and A. P. Daunic. 2017. A Review of Social Problem-Solving Interventions: Past Findings, Current Status, and Future Directions. *Review of Educational Research.* Vol. 87, No. 1. pp. 71–102.

Nugent, G., B. Barker, N. Grandgenett and G. Welch. 2016. Robotics Camps, Clubs and Competitions: Results from a US Robotics Project. *Robotics and Autonomous Systems*. Vol. 75. pp. 686–691.

Pa, P. S. and C. M. Wu. 2012. Design of a Hexapod Robot with a Servo Control and a Man-Machine Interface. *Robotics and Computer Integrated Manufacturing.* Vol. 28, No. 3. pp. 351–358. (https://doi.org/10.1016/j.rcim.2011.10.005)

Papert, S. 1980. *Mindstorms: Computers, Children, and Powerful Ideas*. Basic Books.

Papert, S. and I. Harel. 1991. *Constructionism.* Ablex Publishing.

Park, I. W. and J. O. Kim. 2011. Philosophy and Strategy of Minimalism-Based User-Created Robots (Ucrs) for Educational Robotics-Education, Technology and Business Viewpoint. *International Journal of Robots, Education and Art.* Vol. 1, No. 1. pp. 26–38. (https://doi.org/10.4156/ijrea.vol1.issue1.3)

PIAGET, J. 1971. The Theory of Stages in Cognitive Development. In D. R. Green, M. P. Ford and G. B. Flamer (Eds.). *Measurement and Piaget* pp. 1–11. McGraw Hill.

PUNTAMBEKAR, S. AND J. L. KOLODNER. 2005. Toward Implementing Distributed Scaffolding: Helping Students Learn Science from Design. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching.* Vol. 42, No. 2, pp. 185–217.

RESNICK, M. 2006. Computer As Paintbrush: Technology, Play and the Creative Society. *Play= Learning: How Play Motivates And Enhances Children's Cognitive and Social-Emotional Growth*. pp. 192–208.

RESNICK, M. AND S. OCKO. 1991. LEGO/Logo: Learning Through and About Design. In I. Harel and S. Papert (Eds.), *Constructionism.* pp. 141–150. Ablex.

RESNICK, M., R. F. MARTIN, SARGENT. AND B. SILVERMAN. 1996. Programmable Bricks: Toys to Think with. *IBM Systems Journal.* Vol. 35, No. 3.4, pp. 443–452.

REYNOLDS, C. R., R. B., LIVINGSTON AND V. WILSON. 2011. *Measurement and Assessment in Education.* Pearson.

RIHTARŠIC, D., S. AVSEC AND S. KOCIJANCIC. 2016. Experiential Learning of Electronics Subject Matter in Middle School Robotics Courses. *International Journal of Technology and Design Education.* Vol. 26, No. 2. pp. 205–224. (https://doi.org/10.1007/s10798-015-9310-7)

RUSK, N., M. RESNICK, R. BERG, AND M. PEZALLA-GRANLUND. 2008. New pathways into robotics: Strategies for broadening participation. *Journal of Science Education and Technology,* 17, 59–69. (https://doi.org/10.1007/s10956-007-9082-2)

ŞENDAĞ AND H. F. ODABAŞI. 2009. Effects of an Online Problem Based Learning Course on Content Knowledge Acquisition and Critical Thinking Skills. *Computers and Education.* Vol. 53, No. 1. pp. 132–141.

SEUL, J. 2013. Experiences in Developing an Experimental Robotics Course Program for Undergraduate Education. *IEEE Transactions on Education.* Vol. 56, No. 1. pp. 129–136.

SFARD, A. 1998. On two metaphors for learning and the dangers of choosing just one. *Educational Researcher.* Vol. 27, No. 2. pp. 4–13.

SLANGEN, L., H. VAN KEULEN AND K. GRAVEMEIJER. 2011. What Pupils Can Learn from Working with Robotic Direct Manipulation Environments. *International Journal of Technology and Design Education.* Vol. 21, No. 4. pp. 449–469.

SOMYÜREK, S. 2015. An Effective Educational Tool: Construction Kits For Fun and Meaningful Learning. *International Journal of Technology and Design Education.* Vol. 25, No. 1. pp. 25–41. (https://doi.org/10.1007/s10798-014-9272-1)

SPIRO, R. J. 1988. Cognitive Flexibility Theory: Advanced Knowledge Acquisition in Ill-Structured Domains. *Technical Report* No. 441.

SULLIVAN, F. R. AND J. HEFFERNAN. 2016. Robotic Construction Kits As Computational Manipulatives For Learning In The Stem Disciplines. *Journal of Research on Technology in Education.* Vol. 48, No. 2. pp. 105–128.

WATSON, R. 1981. *Instructional Systems Development* (ED209239). ERIC

WHITFIELD, A. K., S. BLAKEWAY, G. E. HERTERICH AND C. BEAUMONT. 2007. Programming, Disciplines and Methods Adopted at Liverpool Hope University. *Innovation in Teaching and Learning in Information and Computer Sciences.* Vol. 6, No. 4. pp. 145–168.

WILLIAMS, D. C., Y. MA, L. PREJEAN, M. J. FORD AND G. LAI. 2008. Acquisition of Physics Content Knowledge and Scientific Inquiry Skills in a Robotics Summer Camp. *Journal of Research on Technology in Education.* Vol. 40, No. 2. pp. 201–216. (https://doi.org/10.1080/15391523.2007.10782505)

YUEN, T. T., M. BOECKING, J. STONE, E. P. TIGER, A. GOMEZ, A. GUILLEN AND A. ARREGUIN. 2014. Group Tasks, Activities, Dynamics and Interactions in Collaborative Robotics Projects with Elementary and Middle School Children. *Journal of STEM Education: Innovations and Research.* Vol. 15, No. 1. pp. 39–45.

ZHONG, B. AND L. XIA. 2018. A Systematic Review on Exploring the Potential of Educational Robotics in Mathematics Education. *International Journal of Science and Mathematics Education.* pp. 1–23.