

# INTEGRATION OF ROBOTIC ACTIVITIES IN STEM AND ITS EFFECT TO STUDENTS' PERCEPTION OF THE SUBJECTS

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**Abstract:** In most countries, Secondary schools play a great role in preparing students in their future careers. STEM subjects are perceived to be difficult and as such, there has been low interest by the secondary school students in these subjects. This calls for reconsideration of the way teaching is done in the STEM subjects in order to make STEM careers attractive and to retain students in these fields. This study developed robotic activities and integrated them in the STEM subjects and assessed the effects of the activities to the perception and interest in these subjects. The study was conducted in the secondary schools in Murang'a County in Kenya. The target population included 200 students selected through simple random sampling method. The selected students were introduced to robotics activities integrated in Physics and Mathematics topics. Questionnaires were used to collect data and were administered to the students before and after exposure to the robotic activities integrated in the subjects. The quantitative data obtained was analyzed using descriptive statistics and inferential statistics. From the findings of this study, the robotic activities had a significant effect on students' perception of Physics and Mathematics. The study recommends that the government should facilitate the integration of educational robotic activities in the current STEM curriculum in order to improve interest towards the STEM fields.

**Keywords:** STEM, Careers, Robotic activities, Integration, teaching and learning.

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## 1. INTRODUCTION

Secondary schools in any country play very important role in preparing students for the future careers. When the students are enrolled to secondary schools, they are exposed subjects which are meant to prepare them for the future career. At this level the students are expected to choose subject combinations that are relevant to their future career path. The process is very important and is characterized by challenges especially where learners are not properly guided. (Njeru, 2016; Kazi & Akhlaq, 2017).

According to Kopcha et. al, (2017) robots use in education has yielded fruits in that it has led to motivating learners of all education levels to Science subjects. The findings from their study indicated that use of robots through problem solving can support STEM in general. Jung and Won, (2018) indicated that activities around robots can be used to aid in education. According to them, some examples of robots that can support education include LEGO Mindstorms and other robot designs meant to aid the teaching process. They also noted that robot activities have been developed for learners in all education levels. The robot activities range from designing, programming and use of robots in education.

Science, Technology, Engineering and Mathematics careers are vital in providing manpower to a growing economy thereby enhancing innovation and greater productivity (DeCoito, 2016). The students should go through the preparation process towards the STEM careers which calls for new perspectives to be adopted by the schools to enhance the learning experiences, work integrity and interest in related career (Carnevale, Smith & Melton, 2011). Research in STEM fields has grown immensely, with the priority of many researchers being contribution to the growth of the field, improvement in the STEM workforce and to maintain more students the fields in post-secondary institutions. Furthermore, the students are trained the STEM field in a way that they can compete in the global market (Heilbronner 2011). According to Sadler *et al.*, (2012) students are prepared for the STEM related career long before they join post-secondary levels of education. This agrees with the findings of Malin, Bragg and Hackmann (2017), who indicated that secondary school education prepares the learners for the future career. The preparation process is complex, in that technology advances rapidly and therefore there is need to ensure tomorrow's job opportunities and the corresponding work force look different from today's (Hajkovicz *et al.*, 2016).

According to Mwangi *et al.*, (2022) robots employed in education have a great impact on the process of teaching and learning of STEM subjects. They further indicated that the use of robot activities in learning of STEM subjects could motivate them to pursue STEM related careers. The use of these activities had greater impact in the primary school levels as compared to other educational levels. They further noted that they could still be beneficial in higher educational levels with some improvements. The study showed that the use of robots has a promising future for use in educational purposes. In this study the effect of integration of robotic activities to science subjects in secondary school is investigated

## 2. LITERATURE REVIEW

Integration of developed robotic activities involves integrating concepts in different disciplines and expected learning outcomes into a theme. Chen and Chang (2018) conducted a study on integrated robotics STEM course. The study adopted the use of a sailboat robot theme. Prior to integrating the developed activities in STEM, the authors developed a web approach. The sailboat theme was chosen for the study since it was interdisciplinary requiring physics, mathematics and engineering concepts. Specifically, the sailboat robotic activities were integrated in teaching motion and force in Physics, trigonometry and functions in Mathematics and illustration and optimization in Engineering.

Integration of sailboat robot as outlined in Chen and Chang (2018) involved 7 units. Under Unit 1, there was introduction on forces where different aspects such as frictional resistance, relationship between force and surface area were taught with students required to perform simulations, thus enhancing their understanding on manipulating sailboat movement. In Unit 2, geometry and buoyancy were instructed. Unit 3 involved understanding the programming aspects so as to manipulate the sailboat into performing different academic tasks while Unit 4 involved instructions on input/output analysis in electronics. Unit 5 was basics on repairs and maintenance of the sailboat robot, where students were even allowed to tailor-make the robot and if possible launch their own-make. In Units 6 and 7, important engineering concepts were introduced such as optimization, where optimal decisions were to be made such as cost decisions, stability among others.

A study by Benitti and Spolaor (2017) involved a systematic review of 60 publications to evaluate concepts considered in educational robots and how the robots are integrated in the school curriculum. Majority of the literature reviewed supported use of flexible robots to enhance integration across disciplines in the education curriculum. For Ching *et al.*, (2019), integration of robotics in elementary schools' curriculum should adopt a project-based learning (PBL) approach. The PBL approach enables the structuring of the overall curriculum by giving the students opportunities to investigate authentic topics or problems. In addition, students can engage in learning STEM related topics through active creation of artifacts with teachers acting as facilitators during the hands-on activities.

In the United States of America, Ntemngwa and Oliver (2018) conducted a study on how robots would be integrated in STEM instructions. The study was conducted using learners and teachers in Middle Level of education. LEGO Mindstorms EV3 based robots were used in the study. During integration of different robotic activities in STEM subjects, the study found it necessary to restructure the STEM curriculum in themes so as to align it within the project of the robotics. For instance, in this case, different themes were created such as the "Body Forward" to integrate anything that was related to the body systems of animals, "asteroid exploration theme" for teaching topics related to astronomy and scientific exploration of planets, "the color sorting project" whose aim was to teach topics related to optics, "acceleration theme" for Linear

Motion amongst others. This way, teachers would simply fit simple instructions into an existing theme thus making it easier to implement educational robots in learning.

Scaradozzi *et al.*, (2015) suggested an innovative approach of teaching using robotics. The approach suggested was tested using learners in a select Italian primary school. The study involved robots that ran on LEGO WeDo and LEGO MINDSTORMS NXT hardware and software. The robots were integrated in teaching Science and Mathematics topics. The study found that robotics should be integrated in teaching Science and Mathematics in line with the school curriculum so as to witness an upgrade in learning of the subjects. While integrating the robotic activities in Science and Mathematics, the aim should be to expose learners to hands-on opportunities that engage them in applying the knowledge and skills they have learned across disciplines.

Mwangi *et.al.*, (2022) developed robot activities and investigated how they could aid c learners understanding abstract concepts in STEM and concluded they were indeed very effective. They noted that use activities developed around robots made learning fun, and interesting. It was noted that teaching and learning of STEM was more effective with improved participation of learners.

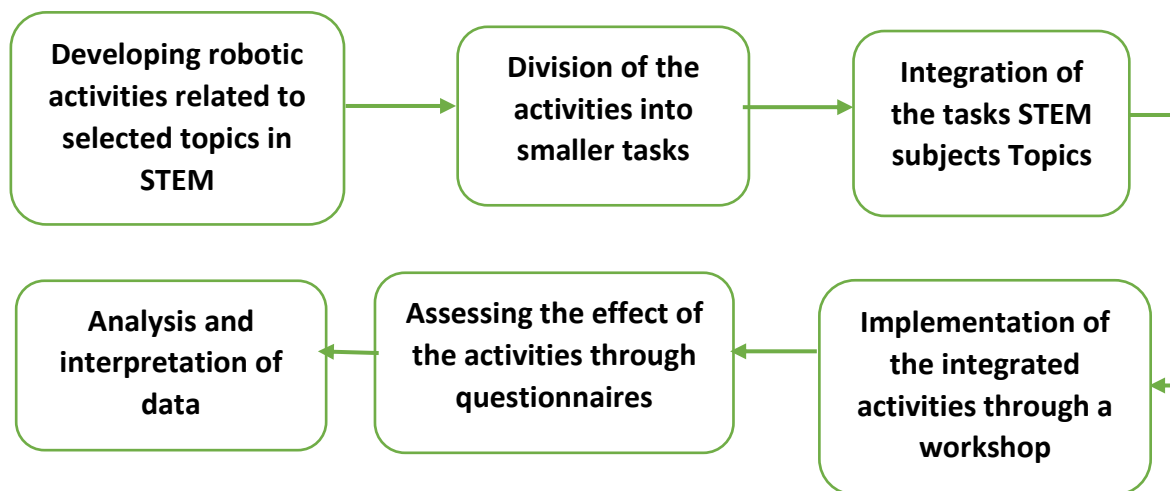
In Canada, Khanlari and Mansourkiaie (2015) evaluated the perceptions of teachers on using educational robots in STEM education. One research questions involved teachers providing sample topics in primary/elementary STEM subjects that would be easily taught using robotics. This was after the participants were exposed to functional robots that used hardware and software of LEGO MINDSTORM. From the findings, it was evident that the teachers indicated that robots can be used in teaching some Mathematics topics such as geometry, multiplication, addition, subtraction, division, measurement, shapes, orientation and movement of bodies. Teachers also stated that science topics such as circuits, force, motion, force, matter and structures.

### 3. METHODOLOGY

#### 3.1 Integration of Robotic Activities.

Some studies have been done investigating the implementation of integrated STEM lessons within courses that have a single subject science focus. Ntengwa and Oliver (2018) examined and generated an account of the implementation processes. In their study qualitative data was collected from interviews. The researcher adopted both quantitative and qualitative methods of data collection in the integration of the robotic activities to Physics and mathematics.

The block diagram on the process of integration of the robotic activities is shown in Figure 3.1.



Source: Researcher (2021)

Figure 3.1: Blockchain Diagram on Integration of the Educational Robotic Activities

In this study, robotic activities were developed from a robotic car and a robotic arm designed by the researcher. The activities were broken into smaller tasks for purposes of integration. The tasks were then integrated into STEM subjects’ learnt by the

students in class. In this study Physics and mathematics were the subjects selected. The main focus of the robotic activities was to relate the robotics with Physics and Mathematics. The integration included general topics in physics like electricity and electronics.

The emphasis on the practical aspects included building electrical circuits, assembling different. The educational robotic activities developed were applied in teaching some concepts like kinematics and dynamics which were studied through the movement and interaction of the robot with the environment. The other set concept that were learnt are in modern physics like the photoelectric effect that governs the operation of the light sensors (phototransistors) which were easier to explain and provided an avenue of describing the propagation of electromagnetic waves. The ultrasonic sensors used and programmed in the robot, similarly allowed the students to learn about the dispersion of sound waves. The activities were also integrated in topics such as forces, Linear and circular motion. In Mathematics the educational robots were integrated in topics like geometry, Linear motion, Trigonometry, Area and Perimeter among others.

After this consideration, a workshop on Educational Robotics was conducted, which included developing robots and programming different parts of robotic arm and car.

### 3.2 Effect of the integrated robotic activities

In order to establish the effect of integrating the robotic activities, the learners filled a questionnaire with items assessing the effect of the robots in understanding, creativity and interest. The questionnaires were administered before and after exposure to the integrated robotic activities.

In the first session the learners were taken through basic programming of the robots, using the designed robotic car. They moved the car forward and backwards in linear motion at constant speed, acceleration or deceleration. The students learnt to program their robot to move forward and backward in linear motion using the Arduino Uno programming environment.

In the 2<sup>nd</sup> session, the main focus was physics where the students were reminded the basics of motion at constant speed and were asked to program their robot to move forward and then backward at constant speed. They were instructed to assemble an ultrasonic sensor on their robot in order to detect the distance from a stable object. They also assembled and programmed infra-red sensors on the robotic car in order to detect a black path drawn on some wooden boards. In this session, the students were also reminded on the concept of acceleration, deceleration, circumference and perimeter of particular shape.

In the 3<sup>rd</sup> session Mathematics activities took the Centre stage. The students were guided on the process of assembling the robotic arm. The arm was used to illustrate various concepts in Mathematics. These include; Geometry, Angles, Circular motion, Rotation, Translation, Forces and Energy among others.

## 4. RESULTS AND DISCUSSION

### 4.1 Integration of Robotic Activities to Physics and Mathematics Topics

In this study, the developed activities were integrated with the subjects' students learn in class. Using the robot car movement and the robotic arm rotation, several topics such as force, Light and sound, Linear and circular motion, Basic concepts of electricity, Geometry and friction were discussed. The integration process involved including the developed activities to be part of the hands-on activities to aid in learning topics in Physics and Mathematics as part of the curriculum. Therefore, themes were developed based on the nature of the activities and the topics in which the activities could be integrated. The integration process was done based on four themes which included;

- i. Interdisciplinary nature of the activities
- ii. Adaptability of the activities to educational settings
- iii. Interest and participation in Classroom activities
- iv. Problem solving

The Four themes and the corresponding activities integrated into various topics in this study are demonstrated in table 1.

**Table 1: Themes in Integration of Robotic Activities in Physics and Mathematics**

Theme	Activities for integration	Remarks
Interdisciplinary nature of the activities	Technical drawing activities. Drawing of basic shapes 2D and 3D Line following activities Basic programming activities Obstacle avoidance robot activities. Robotic arm rotational dynamics activities.	The activities involved the two subjects
Adaptability of the activities to educational settings	Basic electronics activities Basic programming. Robot part identification and assembly Line and Obstacle following robot activities. Robotic arm rotational dynamics activities.	The activities were adaptable in teaching the Physics and Mathematics topics indicated
Interest and participation in Classroom activities.	Basic electronics activities Basic programming. Robot part identification and assembly Line following robot activities. Obstacle avoidance robot activities. Robotic arm rotational dynamics activities.	The activities improved learners interest during lessons in the topics integrated with the activities.
Individual and group problem Solving	Basic electronics activities Robot part identification and assembly Line and obstacle following robot activities. Robotic arm rotational dynamics activities.	The activities were implemented in groups and as such it improved learners' ability to work in teams.

**4.2 The effect of Integration of robotic activities to learning of STEM subjects.**

In order to assess whether the integration of the developed activities to Physics and Mathematics topics had an effect on students' perception towards the subjects, the researcher formed the basis of seeking opinion from the students. The students were therefore presented with questionnaire items that assessed how the integrated activities aided in understanding of Physics and Mathematics, made learning of Physics and mathematics fun, enhanced creativity, interest & motivation and how the integrated activities made Physics and Mathematics easier. The students were presented with these items prior and after exposure to the educational robot. The pretest responses findings are reported herein.

On a Likert scale of Strongly Disagree to Strongly Agree, the participants were presented with several statements regarding robotic activities and integration in Physics and Mathematics. The findings are as presented in Table 2.

**Table 2: Pretest Results Integration of Activities and Students' Perception of Physics and Mathematics**

	Strongly Disagree	Disagree	Neither nor Disagree	Agree	Strongly Agree
The use of robotic activities in learning various topics in Physics and Mathematics can aid in understanding the sciences	6 (3.1%)	5 (2.6%)	35 (18.2%)	102 (53.1%)	44 (22.9%)
The use of the robotic activities can make learning of Physics and Mathematics fun	3 (1.6%)	13 (6.8%)	43 (22.4%)	82 (42.7%)	51 (26.6%)
The use of the robotic activities in learning of Physics and Mathematics can improve my creativity	0 (0.0%)	7 (3.6%)	36 (18.8%)	86 (44.8%)	63 (32.8%)
Integration of robots in educational activities could raise the interest of the students in participating in the classroom activities	16 (8.3%)	19 (9.9%)	62 (32.3%)	59 (30.7%)	36 (18.8%)
Educational robotics should be used as a learning object to motivate student's classroom instruction on Physics and Mathematics Education	12 (6.2%)	23 (12.0%)	55 (28.6%)	61 (31.8%)	41 (21.4%)
Educational Robotics can aid in making learning of Physics and mathematics topics easier	23 (12.0%)	27 (14.1%)	38 (19.8%)	65 (33.9%)	39 (20.3%)

Source: Research Data (2021)

Table 1 shows that 53.1% (102), 22.9% (44), 18.2% (35), 3.1% (6) and 2.6% (5) of the participants indicated that they agreed, strongly agreed, neither agreed nor disagreed, strongly disagreed and disagreed respectively that the use of robotic activities in learning various topics in Physics and Mathematics aid in understanding the sciences. The statement “The use of the robotic activities made learning of Physics and Mathematics fun” had 42.7% (82), 26.6% (51), 22.4% (43), 6.8% (13) and 1.6% (3) of the students agree, strongly agree, neither agree nor disagree, disagree and strongly disagree. Table 4.6 also shows that 44.8% (86) and 32.8% (63) of the students agreed and strongly agreed that the use of robotic activities in learning of Physics and Mathematics improved their creativity; 18.8% (36) neither agreed nor disagreed and 3.6% (7) disagreed.

In total, 49.5% (95) of the respondents agreed and strongly agreed that integration of robots in educational activities could raise the interest of the students in participating in the classroom activities; 32.3% (62) neither agreed nor disagreed, 9.9% (19) disagreed and 8.3% (16) strongly disagreed. Also evident from the findings is that 31.8% (61) and 21.4% (41) of the respondents agreed and strongly agreed that educational robotics should be used as a learning object to motivate students’ classroom instruction on Physics and Mathematics education; 28.6% (55) neither agreed nor disagreed, 12.0% (23) disagreed and 6.2% (12) strongly disagreed. The findings also showed that 54.2% (104) of the respondents agreed and strongly agreed that educational robotics aid in making learning of Physics and Mathematics topics easier.

After being exposed to the educational robot, and working with the robots on their own, the students were presented with the same questionnaire items. The Likert scale responses on robotic activities and integration are as presented in Table 3.

**Table 3: Post-test Results Integration of Activities and Students’ Perception of Physics and Mathematics**

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The use of robotic activities in learning various topics in physics and mathematics aided in understanding the sciences	3 (1.6%)	4 (2.1%)	5 (2.6%)	90 (46.9%)	90 (46.9%)
The use of the robotic activities made learning of physics and mathematics fun	3 (1.6%)	0 (0.0%)	13 (6.8%)	82 (42.7%)	94 (49.0%)
The use of the robotic activities in learning of physics and mathematics improved my creativity	6 (3.1%)	2 (1.0%)	9 (4.7%)	76 (39.6%)	99 (51.6%)
Integration of robots in educational activities raised the interest of the students in participating in the classroom activities	4 (2.1%)	4 (2.1%)	52 (27.1%)	83 (43.2%)	49 (25.5%)
Educational robotics should be used as a learning object to motivate student’s classroom instruction on Physics and Mathematics Education	8 (4.2%)	12 (6.2%)	39 (20.3%)	66 (34.4%)	67 (34.9%)
Educational Robotics aid in making learning of Physics and mathematics topics easier	5 (2.6%)	5 (2.6%)	29 (15.1%)	66 (34.4%)	87 (45.3%)

*Source: Research Data (2021)*

From the findings, 46.9% (90), another 46.9% (90), 2.6% (5), 2.1% (4) and 1.6% (3) of the respondents strongly agreed, agreed, neither agreed nor disagreed, disagreed and strongly disagreed respectively that the use of robotic activities in learning various topics in Physics and Mathematics aid in understanding the sciences. From the findings, it is evident that 49.0% (94), 42.7% (82), 6.8% (13) and 1.6% (3) of the respondents strongly agreed, agreed, neither agreed nor disagreed and strongly disagreed respectively that the use of robotic activities made learning of Physics and Mathematics fun. It is also clear that 51.6% (99) of the participants strongly agreed that the use of robotic activities in learning of Physics and Mathematics improved their creativity; 39.6% (76) agreed, 4.7% (9) neither agreed nor disagreed, 3.1% (6) strongly disagreed and 1.0% (2) disagreed.

The findings also showed that a total of 68.7% (132) of the respondents agreed and strongly agreed that integration of robots in educational activities could raise the interest of the students in participating in the classroom activities; 27.1% (52) neither agreed nor disagreed, 2.1% (4) disagreed and another 2.1% (4) strongly disagreed. The results also showed that 69.3% (133) of the respondents agreed and strongly agreed that educational robotics should be used as a learning object to motivate students’ classroom instruction on Physics and Mathematics education; 20.3% (39) neither agreed nor disagreed, 6.2% (12) disagreed and 4.2% (8) strongly disagreed. From the results, it is also evident that 45.3% (87), 34.4% (66), 15.1% (29),

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2.6% (5) and 2.6% (5) of the participants strongly agreed, agreed, neither agreed nor disagreed, disagreed and strongly disagreed respectively that educational robotics aid in making learning of Physics and Mathematics easier.

General observation of the pretest and posttest results reveal differences in responses on questionnaire items regarding the themes developed. Through a paired sample t-test, the difference in the responses was assessed. First, the variables (items) under the ‘robotic activities and integration’ were compressed into one pretest variable, pre robotic activities integration, and one posttest variable, post robotic activities integration, through the use of the mean for the 5 items in this section. Paired sample t-test was then conducted. The null hypothesis tested was:

From the paired sample statistics, the mean for the pretest responses is lower, pretest mean=3.9708, as compared to the mean for the posttest responses, posttest mean=4.4094 (see Table 4).

**Table 4: Means on Pre-Robotic and Post-Robotic Integration of Activities**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-robotic activities integration	3.9708	192	.64685	.04668
	Post-robotic activities integration	4.4094	192	.61950	.04471

Source: Research Data (2021)

The paired samples test shows that the p-value<0.0001 (see Table 5).

It can therefore be concluded that the two means are significantly different. The fact that the posttest mean is greater is a clear indication that the themes developed during robotic activities integration in teaching Physics and Mathematics significantly improved students’ perception on understanding, fun, creativity, motivation and interest as a result of robots in learning Physics and Mathematics.

**Table 5: Paired Sample t-test on Pre-Robotic and Post-Robotic Activities Integration**

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-robotic activities integration – post-robotic activities integration	-.43854	.88476	.06385	-.56449	-.31260	-6.868	191	.000

Source: Research Data (2021)

**5. CONCLUSION AND RECOMMENDATION**

**5.1 Conclusion**

From the research finding it can be concluded that

- i. The use of robotic activities in learning various topics in physics and mathematics can aid in in the learning of STEM subjects by making the learning of the subjects’ fun.
- ii. Learning through the integrated robotic activities improved learners’ creativity and also enhanced their ability to solve difficult STEM problems. This agrees with findings of Afari, E., & Khine, M. S., (2017)
- iii. Integration of robots through educational activities raised the interest of the students in participating in the classroom activities and consequently improved their interest in STEM subjects which agrees with the findings of Ben-Bassat Levy, R., & Ben-Ari, M. (2017, April).
- iv. Educational robotics should be used as a learning tools in order to motivate student’s classroom instruction on STEM subjects in that they made teaching and learning of the subjects easier.
- v. That integration of robotic activities in Physics and Mathematics should be based on themes that enhance creativity, innovation and excite learners while being taught different topics.

## 5.2 Recommendations

Robotic activities should be integrated in STEM subjects to promote teaching and learning of the subjects. This will require the government of any given country to facilitate the integration of the activities in the current STEM curriculum. Through policy makers in education, the curriculum should be reviewed so as to adopt educational robots and integrated activities to be utilized in the teaching and learning process

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