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Impact of STEAM Robotics Laboratories on Students' Higher Order Thinking Skills

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Abstract

STEAM robotics laboratories are frequently used in different schools of private sector in Pakistan to engage student's effectively in learning and make them higher order thinkers. Higher order thinking skills are thinking logically, critically and reflectively. While computational thinking and problem solving are also higher order thinking skills. The objectives of this research were; to investigate the influence of robotics laboratory on the thinking skills of students; to examine the impact of STEAM robotics laboratory to develop the higher order thinking skills in students. The purpose of research was to find the influence of STEAM robotics laboratories on the student's higher order thinking skills and importance of robotics in schools at primary level. Cluster sampling technique were used for sampling and clusters were Grade 4, 3 of Nova City School at Wah Cantt. Research was descriptive mixed method research was applied. Questionnaire, work sheet and observations were used as research instrument. Data were collected through personal visits. Results of study revealed that STEAM education system is supporting STEAM robotics laboratories and playing vital role to enhance the higher order thinking of students. Moreover, STEAM robotics laboratories had an effect on student's higher order thinking. It is recommended that Government should include STEAM robotics as a subject at primary and elementary while public and private sectors should collaborate to develop STEAM robotics laboratories at schools.

Keywords: Higher order thinking skills. STEAM education, STEAM robotics laboratories,

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Introduction

Through the previous decade robotics has captivated the attention of the teachers and researchers as a valued instrument to improve cognitive and social skills of students at elementary level of school to support learning in science, mathematics, technology, informatics and other school subjects or interdisciplinary learning activities. Educational Robotics had found as an exclusive learning tool that can provide hands on activity, enjoyable activities in an attractive learning environment nourishing the student's curiosity and interest. The main theories that based the Educational Robotics are progressivism and constructivism. Teachers perform the role to provide the opportunities for learners to involve them in active learning and guide them to create new knowledge in the learning environment (Nicholes & Radziwill, 2018).

Robotics program inside the school for students is the chance to learn through learning by doing and active learning approach. Robotronics (type of robotics) Program allows children to use their mind to discover new knowledge and connect that slice of knowledge to real world applications (Shabbir, 2019). It provides an experience that is significant for success in the 21st century. Robotics Programs were integrated with in the school curriculum and covers lesson plans with specified learning outcomes, assessments and teacher training for implementation of these program. Robots in school curriculum will support the quality of education for pupils by allowing teachers to use innovative learning resources and enhanced teaching approaches. The hands-on project keep students self-motivated. Innovative teaching specialists work with the elementary classroom teachers to develop STEAM projects related to their curriculum (Geldis, 2014).

STEM was integrated with "arts" and became STEAM (Science, Technology, Engineering, Arts and Mathematics), STEAM education offers a pathway for effective teaching and learning the inter-relationships of in what the subjects are related to the actual life. As STEAM education will be entertaining and meaningfully conveyed in more appealing and deeply embedding ways within the previously well-established realm of education. STEAM learning aims to bring useful literacy to all learners (Afari, 2017). Students can engage themselves in activities proposed by the STEAM teacher. Students are doing effort on their projects and become impartial thinker and explorer. STEAM robotics is the gateway to the new educational technology, it will enhance higher order thinking skills in learners. STEAM robotics enables to think critically, logically, analytically and develop creative thinking

skills in the learners. In short it develops the higher order thinking skills (HOTS) in learner (Land, 2013).

HOTS is referred as multifaceted cognitive skills including analysis, evaluation, synthesis, judgment and creativity. Higher-order thinking requires that learners should go beyond to just remembering the facts. Whereas, students are estimated to practice with the material that they are learning. As higher order thinking skills (HOTS) of students are recognizing relationships among the thoughts, joining and applying the concepts to solve a different problem, or producing entirely innovative concepts based on what learner have learned (Budsankom et.al, 2015).

Robotics laboratories are used in different schools of private sector to enhance the thinking skills of students. Robotics laboratory support students to think like a scientist and engage students to learn actively. This innovation in educational system of private schools force the researcher to scrutinize the influence of robotics laboratory on the learners thinking skill (Shabbir, 2019).

Different private educational institution taking pace forward to enrich the thinking skills in students. They introduced STEAM robotics laboratory and advised to add robotics as a subject in curriculum at primary and elementary level. So to aware the school administrators about the importance of robotics laboratories, as the researchers had study the impact of the robotics laboratories on the thinking skill of the learners. Research had guided the students, teachers and school administrators for the future use of robotics laboratories in school. As study was delimited to the primary level of Nova City Schooling System.

The objectives of this research were:

1. To examine the awareness of STEAM in the students of STEAM robotics laboratory.
2. To investigate the influence of robotics laboratory on the thinking skills of students.

Literature Review

STEM was introduced by national science foundation in United States. Firstly, it was named as SMET then words were rearrange as STEM (science, technology, engineering and math). Head of the NSF (National Science Foundation) invented the term STEM she was director at NSF (Catterall, 2017).Then they practice stem education globally. Although Sputnik moment was a political movement by President Obama in 2011 but STEM education was beneficiary of movement

(Shabbir, 2019; Catterall, 2017). Some of the people think that it was educational movement, while movement was politically tabulate the education. Just like "Thereeke Deoband" in Sub-continent.

NELS (National Educational Longitudinal Survey) eventually started to call it STEAM. Science, Technology, Engineering, Art and Mathematics. When NELS hired artist and observed teachers are teaching science with arts technique. Further in 2015, President Obama signed "Every Student Succeeds act into law" (Guyotte, 2015). The law comprises mandates and funding, to deliver STEAM education at schools. The teachers who were at "STEAM-mandated" schools were not aware that how to do it. Because they had no professional development, training and way of implementing STEAM. They had no idea, that what dose STEAM mean (Catterall, 2017).

Now a days to pursue a better future for learners, the leading nations of the world are modernizing their high school education by integrating Science, Technology, Engineering, Arts and Mathematics (STEAM).The most well-articulated practice for instructing STEAM education is through functional robotics which incorporates the entire spectrum of STEAM and provides a bright perspective of the integration of science and arts. Different STEAM robotics clubs are offering robotics education through several different means, but advanced educational robotics kits and age-specific curricula are used (Nicholes & Radziwill, 2018).

As world leaders in education alike Finland, Hong Kong, Singapore, South Korea and US have previously implemented robotics-based STEAM education at various public schools. Because of this innovation in educational trends, a student's experience with some form of STEAM education at high school interprets to a considerable benefit when applying will result as essential skills of critical thinking and problem solving. Different after school session and academies are offering STEAM robotics courses on weekend and monthly bases. They are offering summer course of robotics to enhance critical thinking, reflective thinking and problem solving. These clubs are belonging to private sectors but fruitful for our national development (Washington, 2003).

Robotics Laboratories was introduced and established from the need to create "love for science" among the learners in school at Pakistan. As in various nations the number of students that select an education in Science and Technology is gradually declining (Shabbir, 2019).

The innovative approach to STEAM education needs the right tools and resources. Teachers have a marvelous challenge ahead of them and the future depends on the skills and knowledge they are able to teach their students. Through robots that helping teacher and educators while teaching

learners about mechanics, engineering and coding, to animation studio and green screen production kits that boost student self-expression, transforming them from simple consumers to producers, learning digital literacy and inventor's rights. Teacher should preview at the entire line for all the STEAM products available before teaching (Guyotte, 2015).

This is the way STEAM (science, technology, engineering, arts and math) education is supporting the idea of robotics laboratories. STEAM robotics clubs and laboratories are following the form of STEAM education (Washington, 2003).

Science Technology Engineering Mathematics (STEM) is frequently educated apart from creativity, art and design as STEAM (science, technology, engineering, art and mathematics) is an extension of Science Technology Engineering Mathematics (STEM), by integrating "art". Art is the element which is a positive, rich and powerful element in civilization (Liliawati, 2017).

According to the founder of Education Closet Susan Riley, "STEAM is an educational approach to learning that uses Science, Technology, Engineering, the Arts and Mathematics as access points for guiding student inquiry, dialogue and critical thinking (Alvi, 2019). The end results are students who take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration and work through the creative process. These are the innovators, educators, leaders and learners of the 21st century" (Guyotte, 2015).

They require gathering and using evidence to create knowledge or solve problems. STEAM learning happens naturally on daily bases as learner explore, produce and try new things. Once the learner have the chance to investigate the world around them, they learn and experiment with new STEAM skills. STEAM education motivate learners to solve their problem through themselves and enable them to think critically (Lin Binti Yahaya& Lajium, 2018).

STEAM education will enable inquiry, encourage engagement and challenge limitations. Artistic engagement in STEM boosts learners to interpret the material based on personal experience, thus increasing the value and entire enjoyment for the learning (Land, 2013)

Educations through the ground of robotics have described that robotics have a major impact on students 'learning in different subject areas such that Physics, Mathematics, Engineering, Informatics and more. As a personal development including cognitive, meta-cognitive and social skills, such as: research skills, creative thinking, decision making, problem solving, communication and team working skills, all of

them being essential skills necessary in the workplace of the 21st century (Afari, & Khine, 2017).

The effectiveness of STEAM is no astonishing as "Science, technology, engineering, mathematics and the arts all have very similar intellectual ancestors: some of the same philosophical underpinnings, some of the same inquiry questions (Zhbanova, 2019).

STEAM robotics laboratories are highly collaborative, with students working together to grasp innovative material using multiple facts. STEAM learners learn to share their responsibility and compromise by working on group projects that incorporate multiple disciplines (Mosley, et.al. 2016). Several STEAM education projects contain teamwork and thoughtful dialogue in which students exchange ideas and discuss ways to problem-solve (Guyotte, 2015).

CTI robotics are one of form of STEAM educational robots that will enhance computational thinking of students in this type of learning students are using computers to solve problems. As earlier a problem can be tackled, the problem itself and the ways in which it could be solved need to be understood (Zhbanova, 2019). Computational thinking includes taking that complex problem and dividing it down into a series of small, more manageable problems (decomposition). Each of these smaller problems can then be looked at individually, considering how similar problems have been solved previously and focusing only on the important details, while ignoring irrelevant information as abstraction. Next, steps are algorithm simple steps or rules to solve each of the smaller problems can be designed. (Bocconi, et.al. 2016)

STEAM educational projects need pupils to systematically think through problems, applying the information they learn along the way about technology and engineering to figure out the best solutions. Curricular integration of assignments also involves various parts of minds of learners, so that they are see the not only their projects but as well as the world through different aspects (Khanlari, 2013).

Bloom was an intellectual person who present the categorization of thinking skills in two categories as "lower" and "higher" thinking skills first time. In 1950s, Bloom's Taxonomy was developed and still broadly standard by educationists today (Budsankom et al., 2015). In the context of Bloom's Taxonomy, skills are thought to form step by step, initial with the most simple skills (recall and comprehension), developing through more composite skills (application and analysis). Concluding with higher-order thinking skills such as synthesis, evaluation and creation (Saputri et.al, 2019).

Bloom's taxonomy has been revised by Lorin Anderson in 2001, hoping to add relevance for 21st century students and the revision includes minor yet significant changes (Budsankom et al., 2015). Bloom's six levels were changed from noun to verb forms as the lowest level, knowledge, was renamed remembering, understanding and analysis while higher order thinking levels are analysis, evaluation and creation (Gunn, 2017).

Higher order thinking is the process of using the thinking widely to find new challenge. Higher order thinking demands someone to apply innovative information or knowledge that he has achieved or attain then further manipulates the information to reach possibility of answer in new situation (Gunn, 2017).

Methodology

The research was cause and effect research as the STEAM education is independent variable affects the higher order thinking skills of learners that is the dependent variable of research. Cause effect research will find to what extent independent variable will effect dependent variable. Population of study was students of STEAM robotics clubs of Nova City School.

Sample was the targeted group or set of population. There were different sampling technique and cluster sampling technique had been used. The selected clusters were the Grade 4 and Grade 3 from the primary level of Nova City School at Wah Cantt.

Work sheet and questionnaire were developed by researcher and used as instrument of research. The questionnaire and work sheet is developed according to blooms taxonomy cognitive domain lower and higher order level of thinking. Researcher has also kept in mind STEAM education model. Work sheet is also asked by students. Moreover, STEAM education work sheets had been use as instrument of research to analyze problem solving skills of students.

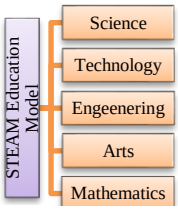


Figure 1: STEAM Education Model

Data were collected through personal visit to the school. Mean and percentage formula were used by the researcher analyze respondent's response to questionnaire. While qualitative data analysis was used to analyze the students responded on work sheets. Observation is also analyzed through statement and one relevant point of view.

Results

Analysis and interpretation of questionnaire:

1. Remembering

Table 1

Do students know facts?

	No 1	May be 2	Yes 3	Mean
Frequency	2	4	24	2.73
Percentage	6.66	13.33	80	

Table 1 shows that 80% respondent stated yes while 13.33% stated that may be they can and only 6.66 % students responded no. Mean is 2.73 that showed that maximum students remember the fact that they acquired.

2. Understanding

Table 2

Can student explain facts?

	No 1	May be 2	Yes 3	Mean
Frequency	10	0	20	2.33
Percentage	33.33	0	66.66	

Table 2 shows that 66.66% respondent stated yes while 33.33% stated that cannot describe or comprehend their knowledge and 0 % students responded may be. Mean is 2.33 that showed that approximately all students comprehend or explain the remembered facts.

3. Applying

Table 3

Can students use their knowledge in their daily life activities?

	No 1	May be 2	Yes 3	Mean
Frequency	1	3	26	2.83
Percentage	3.33	10	86.66	

Table 3 shows that 86.66% respondent stated yes while 10% stated that may be they can and only 3.33% students responded no. Mean is 2.83 that showed that maximum students apply their knowledge to the daily routine activities.

4. Analysis

Table 4

Does students compare and contrast two things or concepts?

	No 1	May be 2	Yes 3	Mean
Frequency	4	8	18	2.46
Percentage	13.33	26.66	60	

Table 4 shows that 60% respondent stated yes while 26.66% stated that may be they can and 13.33% students responded no. Mean is 2.46 that showed that extreme numbers of students compare and contrast two or more concepts and ideas.

5. Evaluation

Table 5

Combine different concepts and make decision which is best?

	No 1	May be 2	Yes 3	Mean
Frequency	5	3	22	2.56
Percentage	16.66	10	73.33	

Table 5 shows that 73.33% respondent stated yes while 10% of them stated that may be they can and 16.66 % learner had responded no. Mean is 2.56 that showed that students can evaluate different concepts and make decision to choose one and move forward to creation level.

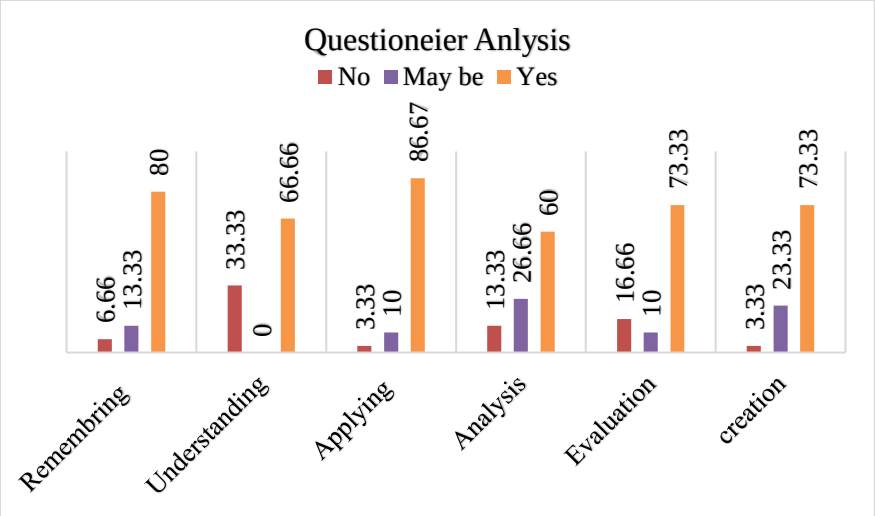
6. Creation

Table 6

Can students create something new?

	No 1	May be 2	Yes 3	Mean
Frequency	1	7	22	2.7
Percentage	3.33	23.33	73.33	

Table 6 shows that 73.33% respondent stated yes there are 23.33% students stated that maybe they can and only 3.33% students responded no. Mean is 2.7 that showed that maximum students can create something.



2. Analysis and interpretation of work sheets

2.1 What problem do student need to solve?

This question is well answered by all respondents. Respondents need to solve the problem of transport. Some of them responded that to solve "travelling issues" and few of them stated that "they want to resolve travelling problems". Above mentioned responded proves that learners are able to identify problem. Because if someone want to resolve problem, he should be aware that "what is problem he need to resolve."

2.2 What supplies learners use during their STEAM robotics projects?

Students were unable to explain that what kind of supplies they had used in their STEAM projects. They enlisted the connection, dc motors, frame, tires and panels that they had used during projects. Above statements showed that STEAM robotics enable students to make their learning permanent and they are able to express and present knowledge.

2.3 What was the plan of students?

Some students responded, "they want to make a bus". Few of them stated that "they will make a car" while few of them stated that "light plane". One of the groups responded that "their plan is to make swing carousel". Rest of class stated that "they are making train and sport car".

Above analysis explained that students are thinking out of the box although there are only two new concept rest of them are trying to

innovate car, bus and train. STEAM robotics also enable students to involve themselves in brainstorming. As they were thinking what should their plan that will solve their problems of transport.

2.4 What learner had done in his project?

Learners had stated their whole experience of joining panel to the execution of their projects. Now each learner was stated his contribution to the project. STEAM robotics enable students to reflect their ideas and experiences. Students were relating their knowledge and practical work with daily life problems.

3. Analysis of observations

As it was observed that students were working in group and they were guide a general topic or problem then suggest solution. Further learner solved their work sheet that what they plan and what they were using to made their STEAM robotics group projects. Learners were engaged in cooperative learning through STEAM robotics laboratories. Students were learning by doing. Enviroment was highly cooperative students at STEAM robotics laboratories.

STEAM robotics laboratories were observed students centred as students were doing what they want, they were given fifteen to twenty minutes to make their projects teacher will ask them after the time limit completed. But whatever they create new by using their prior knowledge. Teachers were not interrupting students during the time they had given for projects. Students are choosing panels and collecting other items they want.

Researcher observed that students were disassemble their projects and place all items in box placed in rack from where they had picked. They arrange their class by themselves.

Researcher had observed that teacher was listening to students at learner's project times time and students listen teachers rest of time. Teachers were giving introduction of concept so that students were start brainstorming what they do how they do. They were done concept mapping on their work sheet that had given them after small introduction by the teacher side.

Results

The results of study were:

1. Table 1 shows that 80% respondent stated yes which presented that maximum students remember the fact that they acquired and table 2

shows that 66.66% respondent stated yes that showed the approximately all students comprehend or explain the remembered facts.

2. Table 3 shows that 86.66% described that maximum students can easily apply their knowledge to the daily routine activities while table 4 shows that 60% respondent stated yes that explained there were extreme numbers of students compare and contrast two or more concepts and ideas.
3. Table 5 shows that 73.33% respondent stated yes which showed that students can evaluate different concepts and make decision to choose one and move forward to creation level. Whereas table 6 shows that 73.33% respondent stated yes which described that maximum students can create something new by using their prior knowledge.
4. In work sheets students identify the problems that they observed they planned to make robot to solve problem and achieved their desired goal which explained that STEAM robotics laboratories were engaged students in problem solving, critical thinking, creative thinking and reflective thinking. Students were giving advanced ideas and thinking out of the box which showed the healthy contribution of STEAM robotics laboratories to higher order thinking skills of the students. STEAM robotics laboratories projects provide opportunity to learner in integrated classroom environment and STEAM robotics laboratories were students oriented.
5. Teachers were giving students direction student had to do his project by himself and STEAM robotics laboratories are practicing learning by doing. Students are thinking critically analyze each other views. STEAM robotics laboratories encourage students that they take a pace to do something new and involve them in active learning.

Discussion

The research was aimed to investigate the effect of STEAM robotics laboratories to the student's higher order thinking. As it was observed students were working in group and they were guide a general topic or problem then suggest solution after that they were start their STEAM robotics group projects. STEAM robotics laboratories were engaged students in cooperative learning. STEAM robotics laboratories environment was highly cooperative students were learning by doing. While the classroom environment were one of the factor that can effect students higher order thinking as classroom environment and the family characteristic directly affect the intellectual characteristic (Budsankom, et.al. 2015).

Therefore, STEAM robotics laboratories were giving the environment that will fruitful to enhance students higher order thinking skills.

Research contributed to the STEAM educational system as they had claimed through STEAM education system students learn actively. STEAM education system had used the inquiry-based learning method and boost students to inquire or discover something innovative. Promotes student's skill of problem solving were one of the aims of STEAM education system. STEAM robotics laboratories are enhancing students analytical, critical and problem-solving skills.

Conclusion

STEAM robotics laboratories are innovation in teaching and learning process. As STEAM education model claim that their learning production were healthy because students become higher order thinkers, critical thinkers and reflective thinker. STEAM robotics laboratories enable learners to learn actively. They are practicing cooperative learning, inquiry-based learning and discovery learning. STEAM robotics clubs engage students and provide hands on activity. STEAM robotics laboratories are playing vital role in the development of higher order thinking skills of students. STEAM robotics laboratories had positive influence on higher order thinking skills of students and give healthy contribution to the field of educational technology. As this method of learning enhance students higher order thinking. They enhance student's skills of socialization and encourage them to invent something advance.

Recommendation

There are four recommendations:

1. Government should collaborate with private sector to promote new ways of learning
2. Government should include STEAM robotics as a subject at primary and elementary level.
3. Public and private sectors collaborate to developed STEAM robotics laboratories at primary and elementary level.
4. STEAM robotics teacher training will be given all primary and elementary level teacher alike STEAM robotics laboratories schools had their teachers.

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