Developing 21st century skills of primary school children through STEM: Drive for Future

Sheeza Farooq

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Supervisor

Farzana Ahmed

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National University of Sciences and Technology (NUST),

Islamabad, Pakistan.

Approval

It is certified that the contents and form of the thesis entitled **"Developing 21st century skills of primary school children through STEM: Drive for Future"** submitted by **Sheeza Farooq** have been found satisfactory for the requirement of the degree.

Advisor: Mrs Farzana Ahmed

Signature: _____

Date: _____

Committee Member 1/Co Advisor: Ms. Manzil Maqsood

Signature_____

Date: _____

Committee Member 2: Jaudat Mamoon

Signature _____

Date: _____

Committee Member 3: Erum Afzal

Signature _____

Date: _____

Dedication

Dedicated to my caring father and loving mother.

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Certificate of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by any other person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at NUST SEECS or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST SEECS or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics which has been acknowledged.

Author Name: Sheeza Farooq

Signature: _____

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Abstract

The use of new technologies and preparing students for the future is a concept for which the developed countries are working for a long time now. However due to political and social reforms In Pakistan there is little to no attention towards introducing new practices in Pakistani Schools. There is almost no research carried out about STEM education which is so important in today's era. Lack of new practices in classrooms yield poorly prepare youngsters who are not ready to face the challenges of this century's economy. This study introduces STEM education to improve elementary school children's critical thinking and creativity skills. An intervention was applied in summer school in Gujranwala district and at the end of it the impact of STEM education on students' 21st century skills were measured.

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Developing 21st century skills of primary school children through STEM: Drive for Future

1. Introduction

1.1. Background:

Today we have forget the necessary purpose of schools. Schools have become a path to achieve higher education and that's it. The real purpose of schools as explained by (Kaufman, 2013) is to educate a child as well as prepare him for the future. And for this development in a child schools need to be transformed so that they are able to promote creative thinking, problem solving, communication, collaboration and innovation, because these are the skills that are needed to be successful in work and life. Some authors (Carroll, 2007; Riddle, 2009; Trilling & Fidel, 2009) and Partnership for 21st Century Learning argue that "21st Century Learning Skills are critical for accomplishing the necessary transformation" (21st century skills for students and teachers, 2010). According to Tsupros, Kohler, & Hallinen (2009) the best approach for integrating 21st century skills in schools is through STEM. "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply Science, Technology, Engineering, and Mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy.

Here the question arises that how does the integration of STEM education in classroom help in developing the critical thinking and creativity skills of primary school children. There are several benefits of integrated STEM education. Its helps to make learning more connected and significant for students. It also helps making students better problem solvers, logical thinkers innovators, self-reliant, and technologically literate (Morrison, 2006). When students learn something by doing they can never forget the feel of it. STEM education is a student centered approach because it involves learning practices that helps students to solve

problems by using integrated skills like hands on learning, questioning, collaboration which results in deeper understanding and helps improves retention (King & Wiseman, 2001). Blessinger (2005) argued that students who experience STEM education early in their lives are most likely to be prepared with better understanding of STEM concepts later in their academic career. If the STEM is introduced in the elementary grades, students will apply the science, technology, engineering, and mathematics and the STEM Standards of Practice. They will begin to individually incorporate the STEM Standards of Practice as they progress through elementary school. (DEVANEY, 2016)

1.2. Motivation:

Pakistan's economic and societal development has been constrained due to the inability of governments to improve the system. The literacy rate of Pakistan is one of the lowest in world and according to (UNESCO), it is 55 percent and Pakistan is at 160th position in total countries of the world. There are a number of Primary schools in our country but only few are able to provide quality education. At present 42% population (ages 10+) is illiterate.

The total estimated population of primary school children is 21.4 million (age 5-9), out of which 14.7 million (68.5%) are enrolled in school. However, only 66.8% persist until 5th class and 33.2% drop out before completing primary school due to multiple reasons (teacher shortage and absenteeism, including shortage of nearby schools, , poor teaching quality, poor school environment, family poverty, insecurity, natural disasters and other factors) (Malik, et al., 2015). This report has also conducted several surveys on results of learning achievement due to poor education quality. Assessments of Grade IV students conducted in 127 districts of the country showed:

1. In the Language test, 24% students scored greater than the scaled mean score;
2. In the Mathematics test, only 19% of students scored greater than the mean score;
3. In the Science test, 33% students scored greater than the mean score;
4. In the Social Studies test, 43% of students got a mean score.

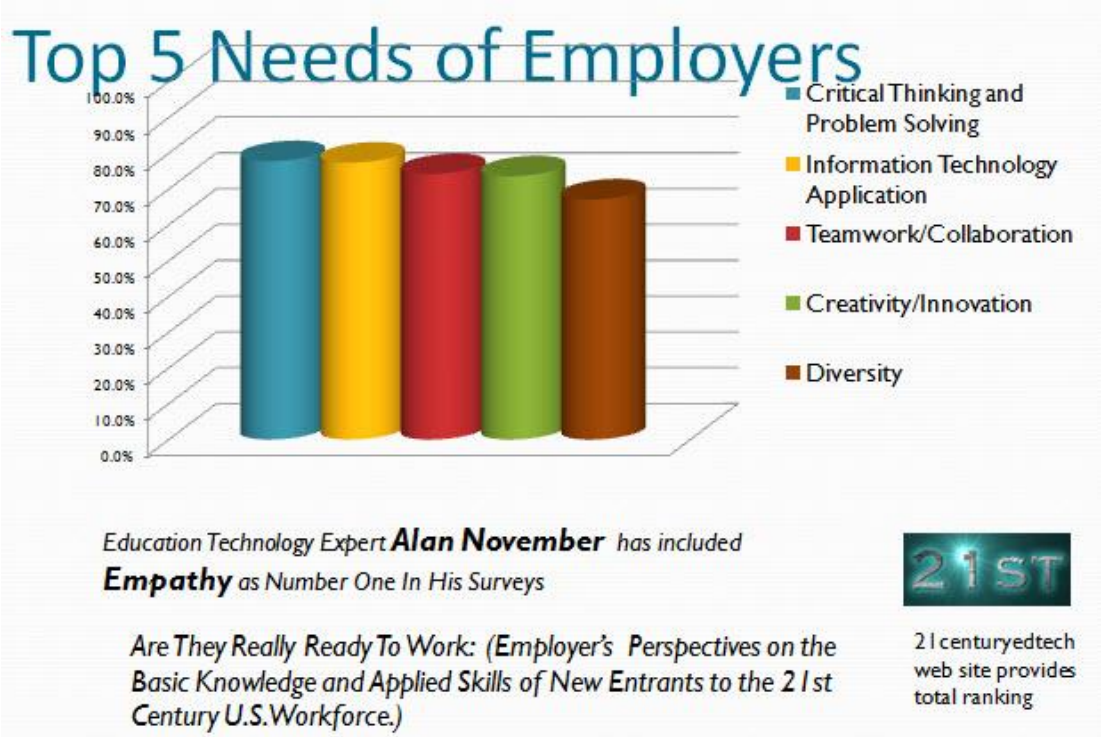
A survey conducted by The British Council (2009) found that half of respondents believed that they lack skills that are required to work in modern day industry. Due to corruption and discrimination even educated students face difficulty in getting decent work.

Improving the quality of education is one of the key objectives of the National Plan of Action (2013) for education, however not enough measures are being carried out for the action. The old teaching methods should be replaced with new ones with the blend of technology. (Atiq-Ur-Rehman, Anis, & Khan, 2009) Investigated if the existing methods for students to choose their field of is optimal with respect to the national interests of Pakistan. The results showed a huge difference between the skills that were required versus the available skills.

Government of Pakistan is introducing many projects in schools for the promotion of technological tools. However the Pakistani students have an important need to deal and understand with more difficult and challenging social realities of their society as well as the fast paced globalized world other than just learning a few technical skills that will soon become obsolete. "Employers from over the world say that recently hired workers, including postsecondary graduates, are ill-prepared of the key skills for successful work in the 21st century" (Trilling & Fadel, 2009). Mirza, Jaffri, & Hashmi (2014) showed that gaps between the required skills and available skills causes heavy costs because for developing countries like Pakistan it is very costly to import the skilled manpower.

From all over the world, Companies claimed that the workers they hire, even educated ones with post graduate degrees are poorly prepared for 21st century task force. They lack necessary skills need to thrive in today's industry. These skills are a critical part for country's financial accomplishment and learning of these skills should be a part of education system at every level starting from very basic as agreed by a number of primary education scholars, such as Sir Ken Robinson, Daniel Pink, Howard Gardner (Harvard), Richard Murnane (Harvard) and Edgar Morin (UNESCO).

Figure 1.1 Employers need according to U.S workforce



Hence, we should not forget that there is a challenge to train our students with basic skills that they need to survive on their own in today's world. And to meet this challenge, there Is a critical need of transforming schools in such a way that they are able to promote creative thinking, problem solving, communication, collaboration and innovation, because these are the skills that are needed to be successful in work and life.

1.3. Study Overview:

This research will examine the relationship of STEM education with developing 21st century skills in primary school children. The purpose of this study was to see that how using STEM in the classroom beside using conventional methods will help in developing critical thinking and creativity in primary children. The research problem was to see that how does the integration of STEM education in classroom help in developing the critical thinking and creativity skills of primary school children of Pakistan?

Pretest and post-test were conducted among experimental group and the results were interpreted by comparing students' performance before and after the experiment.

2. Literature Review:

All over the world Science, Technology, Engineering and Mathematics (STEM) education is emerging as latest means for the integration of these four major subjects into the education. It is necessary to introduce STEM at school level so that a child can get interested in the field before going to college. In order to prepare our children for the modern industry we have to build 21st century skills like critical thinking, problem solving, using STEM education. Here we are going to look into 21st century skills, STEM education and integration of these two into the curriculum.

2.1. 21st century skills:

According to Bell (2010) students need to gain a set of skills that not only help them master in academics but also prepare them for college, careers and socialization. They must become creative thinkers who are able to solve complex problems in our fast paced world. The trend is changing and old ways of teaching which were considered good in the past are no longer enough in 21st century for success in career, college or citizenship (Darling-Hammond, 2006).

The skills that are essential for students to flourish in this era's global economy has been developed by the Partnership for 21st century skills (2001). The framework for these skills can be categories as follows: high productivity, creative thinking, effective communication and digital age learning. According to Kaufman (2013) for today's economy these skills are very important especially creativity and innovation and these will also have an impact on society and its economic future. Therefore schools need to be "learner centered" where children are able to teach themselves with the guidance of teacher. (Pearlman, Creating Learner-Centered Schoolplaces/Workplaces for a New Culture of Students at Work, 2009).

As the framework was implemented it became clear to the educators that it was too long and complicated and so they determined that out of all, four basic skills were more important which are creativity, critical thinking, communication and collaboration. (Darling-Hammond, 2006). Creativity can be defined as a skill

where students are able to produce and expand on ideas and are able to work creatively with others (Bell, 2010).

Research by Darling-Hammond (2006) illustrated that in the past, creativity and innovation were thought as secondary by America's national curriculum. While today, the crucial factors of global economy are creativity and innovation. Critical thinking can be described as the ability which enables students to think reasonably about what to do or believe. Through technology there is a lot of information available in 21st century. Students should be able to reflect through the information and not just reflexively accept it. They need to apply critical thinking skills efficiently to their academic studies and intricate problems that will come their way as a result of rapidly technological changing information. (Oliver & Utermohlen, 1995).

The significance of education for civilization is facilitated fundamentally through individuals affected by education and become deeper as the facilitating organizations gain joint opportunities. Thus education is in its deepest core is an activity of the human spirit which can only be understood in a civilization of the future (Singh, 1991). It is essential for teachers to target 21st century skills as skills that need to be integrated with the education system and not see it as an additional subject (Larson & Miller, 2012). If the schools focus on integrating 21st century skills they can create an environment that can motivate students, and sparks the creativity. If students leave schools with these skills than the job is done by them (Kaufman, 2013).

Problem-based learning is a form of project-based learning that uses a case study approach which allows students to concentrate, on complex, real-world problems. By working in small groups in order to do research and solve problems, a collaborative and multidimensional environment is created (21st century skills for students and teachers, 2010). Educating a child about critical thinking and problem solving efficiently in the classroom is crucial for students. By learning critical thinking, it helps students to improve other skills, such as a concentration, reasoning skills, and enhanced understanding (Darling-Hammond, 2006).

Many school activities involve students to learn and replicate data they are provided. So it became essentially important for students to master the significant content of a domain. But only by memorizing they will not be able to excel in the skills that they need to achieve for successful higher education and employment industry. Critical thinking activities require students to produce ideas and understandings that are new. Students can do this through a process of

interpretation, analysis, synthesis, or evaluation (21CLD Learning Activity Rubrics).

2.2. STEM Education:

The huge difference in educational quality in the United States have resulted in gaps in math and science performance and it has extended significantly over the past 20 years along national, cultural, verbal, and socioeconomic lines (Freeman, et al., 2014). For the secure future of students Science, Technology, Engineering, and Mathematics (STEM) education is crucial because it is a trans-disciplinary approach that eradicates customary barriers between these fields and incorporates them into one interconnected learning and teaching model (Stohlmann, Moore, & Roehrig, 2012).

It consists of a curriculum that is based on the idea of educating students in four disciplines so that rather than understanding the world in bits they can make sense of it entirely (Hays Blaine Lantz, 2009). According to the U. S. Department of Commerce, STEM occupations are growing at 17%, while others are growing at 9.8% and are earning 26% more than non-STEM workers (STEM: Good Jobs Now and For the Future, n.d.).

Hays Blaine Lantz (2009) argued that the implementation of STEM requires a method where science, mathematics, and technology teachers plan and teach cooperatively. The implementation should accomplish students who are problem-solvers, innovators, inventers, self-reliant, logical thinkers, technologically literate. The implementation does not only require changes in the content and teaching strategy it also require changing in assessing students and it will not be possible if we continue to use traditional regular institutionalized tests, integrated STEM can never gain the required results until institutes and student success is assessed differently (Ostler, 2012).

To integrate STEM into curriculum different researchers uses different approaches like (Moundridou & Kalinoglou, 2008) used LEGO Mindstorms as an instructional aid. They used a pre made robotic car which was utilized in teaching Mechanical Engineering students. They made a lesson plan to carry out the process as well as they measured student engagement, motivation and usefulness of method.

In another research by Sheldon (2017) Jeannette Wing devised a new term computational thinking stating that it is very important to incorporate it among school students. She defined the term as the skill where students are able to solve every day human behaviors, problems just as the computers do. By using the concept of computer science we can incorporate the logic among students and get them to use the skills in every aspect of life.

According to (DEVANEY, 2016) STEM 2026 is a report generated by U.S STEM Education the intent of which is to reform the system according to what is already known, what is yet to be discovered, and what needs to be developed in order to incorporate STEM learning among all youth with equality. STEM education that is readily available to everyone is really important because in today's era every individual need all the teaching and learning experiences so that they have the enough confidence and skills to shape the world through STEM.

(Mayo, 2009) Discussed the use of video games to integrate STEM within students. The author argued that video games consists of pedagogical approaches that are known to be effective. A recent research on elementary school students success later in life suggest that to achieve success in early school children need to have learning related skills like self-regulation and social competence. The children who lake these skills in early school remain poor in learning throughout elementary school in reading and math skills. While the children who had high learning curve were quite fast in both math and reading throughout elementary till sixth grade. (McClelland, Acock, & Morrison, 2006).

(Brophy, Klein, Portsmore, & Rogers, 2008) Article explores how we can increase knowledge and skills associated with STEM education to tackle real world problems and problem solving by implementing engineering education in our system. The researchers presents many instructional models to teach engineering education in k-12 classrooms. By introducing engineering education in k-12 classrooms it increase the opportunities for STEM learning.

In another research, researchers uses robot to teach STEM to primary level students. By using robots it provides them with ease to teach technology. Use of robotics also helps creativity and team building among students. This program also involves college freshman of electrical and computer engineering program as paid mentors so it also help improve retention rate among, and it also targets at getting young students excited about engineering (karp & etal, 2010). (Stohlmann, Moore, & Roehrig, Considerations for Teaching Integrated STEM

Education, 2012) Provides a model that can be used as starting point for teachers to use in STEM integrated classrooms.

(Jaakkola & Nurmi, 2008) Conducted an experiment in elementary school to substitute traditional teaching method of teaching science with computer simulations and lab experiments. The main purpose was to see if the combination of lab activity and computer simulation would produce better learning than to use them separately. The results showed that the combination of both produced more learning than using each of them alone. It also stimulates student conceptual understanding because it involves hands on experiments in the lab.

2.3. Integration of 21st century skills through stem education:

To make learning more related and appropriate for students, one technique is Integrated STEM education (Stohlmann, Moore, & Roehrig, Considerations for Teaching Integrated STEM Education, 2012). Many researchers argue that using integrated curriculum can increase the chances for proper, continuous, and motivating practices for learners (Furner & Kumar, 2007).

Project-based learning can increase student interest in science, technology, engineering, and math because it helps students to get hands on experience by solving problems and communicating with others. Research tells us that students learn best when they can reflect on their learning and integrated STEM approach encourages them to construct their own knowledge about the surrounding world (Laboy-Rush, Integrated STEM Education through Project-Based Learning).

By fostering 21st century skills in students through STEM we can make them able to take personal and social decisions, which in the 21st century progressively oblige scientific and technological understanding. (Gamoran & etal, 2011). For the blending of STEM and 21st century skills there is a need to change the traditional old school setup because integrated schools are schools where students are evaluated on 21st Century skills and STEM knowledge and master them for attainment. (Pearlman, Making 21st Century Scools, 2009).

The integration of STEM in curriculum can start with small steps like at first start with only half an hour where STEM can be practiced in class. Later design such activities that involves all your students and list learning outcomes of every activity (Schwartz, 2016). The integration of STEM stops the four subjects from being taught separately and individually in schools. All the four subjects are combined as one in STEM through interdisciplinary approach. This approach helps students to be more active while learning and their learning becomes relevant as compared to the curriculum that focuses on single subject (Khalil & Osman, 2017).

(Laboy-Rush, Integrated STEM Education through Project Based Learning, n.d.) States that the goal of integrated STEM education is to create opportunities for students so that they can construct knowledge and skills. It can be done by involving the students in a procedure where they can provide solutions for real world problems. Some scientists argue that problem solving does not mean that a problem is solved rather it means that a solution to solve the problem is optimized. The typical science and math curriculum do not provide this opportunity rather they already have only one solution and the purpose is to bring students to right answer and it does not involve solving any real world's problems.

Using robotics in classrooms is a new trend in integrating STEM that is being used widely by instructors. One such example is Medibotics which uses LEGO MINDSTORMS in schools. Students can use robots to learn programing, building of robots, which will expose them to many science fields including biology, medicine, engineering, physics and information technology. (Meyrick, 2011)

The integration of STEM and 21st century skills require a process in which students in STEM environment should be able to understand the information they are provided with and be problem solver and provide solutions to problem based on data. Then they should be able to evaluate the unplanned results of their findings and communicate the information to their classmates. This procedure helps in the progress of critical thinking and problem solving skills. Through this approach, a STEM environment is created that supports the development of critical 21st Century skills (Moss, 2014).

3. Methodology:

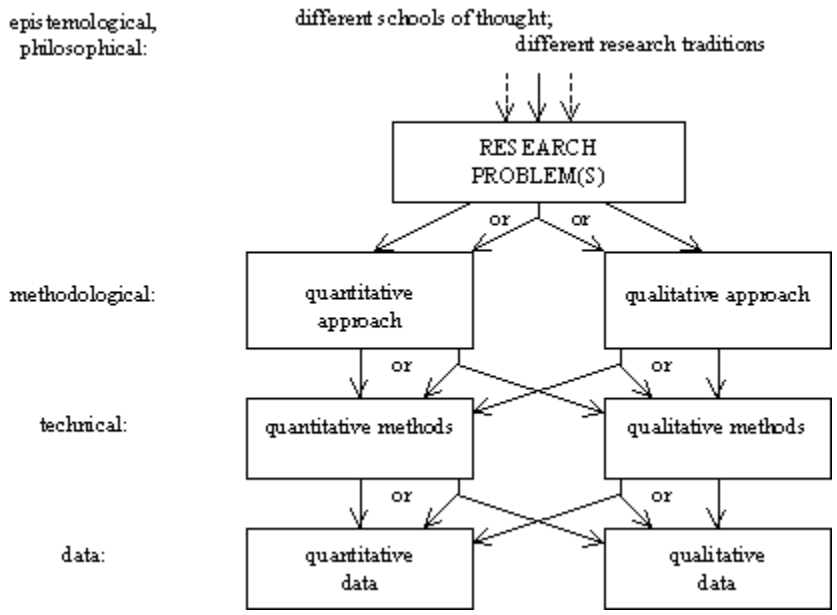
3.1. Types of Educational Research:

Research is a process of orderly analysis that helps to understand a particular phenomenon and variables related to that phenomena. It involves collection, analysis and interpretation of data to answer research questions. It is a systematic approach and has certain steps that need to be followed, finding a final answer is the vital goal of research process (Blessinger, 2015).

There are a number of types of educational research methodologies. They can be classified as:

- Descriptive
    - Survey: is a list of questions meant to extract data from a particular group of people. They are used in social research.
    - Historical: it involves dealing past events to conclude assumptions and make estimation about the future.
    - Content Analysis: the data of existing textual material is analyzed.
- Associational
    - Correlational: it is used to interpret the relationship between two variables.
    - Casual-comparitive: it involves two or more groups and one individual variable.
- Intervention
    - Experimental: data is collected by doing interventions on one individual or groups.
    - Quasi-Experimental: data is not randomized. It is a sub group of experimental study.
    - Action Research: it is a cyclic process in which after intervention you interpret the result and so specific changes and again the intervention is done until desired results are produced.
- Qualitative is mainly and exploratory research. Some common methods of research are interviews, focus group, and observation.
- Quantitative research produced data that can be statistically tested. The data is used to convey facts and uncover patterns in research.

Figure 3.1 Quantitative and Qualitative Research



3.2. Experimental Research:

It is a research in which there is a dependent variable and an independent variable. The dependent variable is measured by manipulating independent variable. The basic of aim of this method is to predict phenomenon (Blakstad, 2008).

Following are design and features of Experimental study:

- Pretest/Posttest Design:
- Control Group
- Randomized Control Trials
- Solomon- four Group design
- Between subjects design
- Within subject design
- Counterbalanced Measures Design
- Matched subjects Design
- Double-blind Experiment
- Bayesian Probability

3.2.1. Steps in Experimental Research:

While carrying out a research a researcher must follow the steps of scientific methods. By following basic steps, the experiment will generate valid results (Shuttleworth, 2008). Conducting an experiment involves number of steps which are described below:

1. Select a topic

   Identify an area of interest.

2. Identify/ Indicate research Problem

   After choosing area of interest now there must be a question or problem that researcher needs to identify in order to determine the scope of experiment.

3. Conduct Literature Review

   After identifying the problem it is advisable to know about the previous studies done in the field. This helps the researcher in knowing the types of experiment, research design used and how the study was conducted and will help in creating an experiment that compliments existing research.

4. Build Hypothesis

   It is a critical step as it is the basis of all the other findings and decisions of study. In this step research question is stated as hypothesis.

5. Define Research Design

   Depending on hypothesis the researcher identifies if experimental design is the right method to answer questions.

6. Decide Research Methods

   In this step the researcher identifies the other things used to carry out experiment like identifying variables, data collection techniques, and procedure for intervention.

7. Conduct intervention and test hypothesis

   The experiment is implemented in this step and results are calculated.

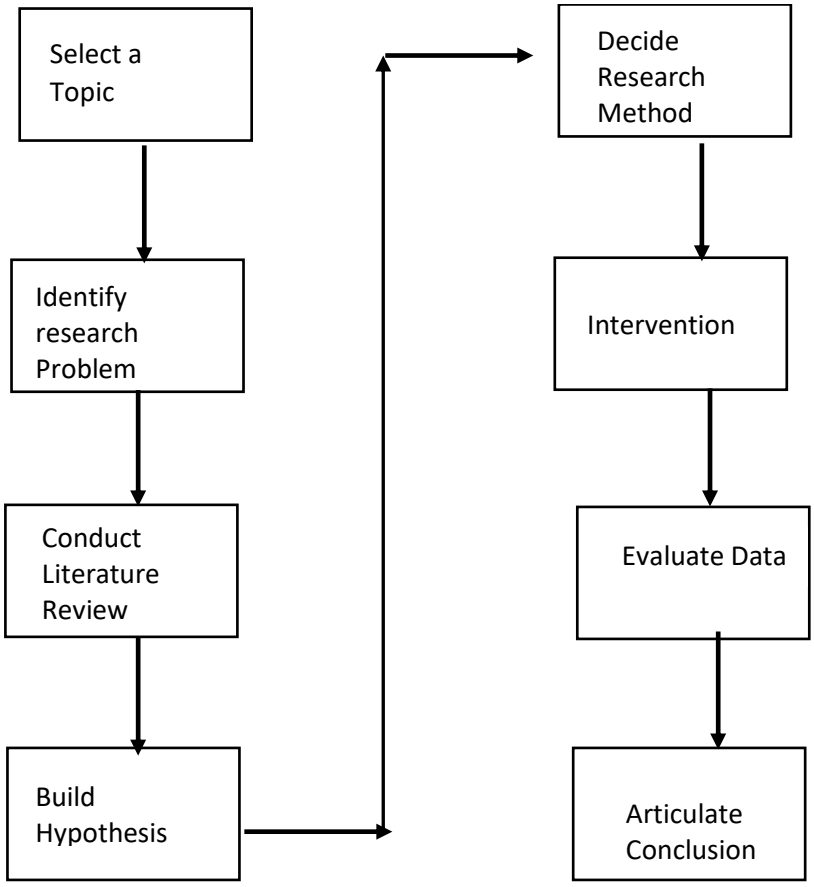
8. Evaluate Data

   Data is analyzed according to its type and the hypothesis that needs to be proved.

9. Articulate Conclusion

   Interpret the data and see if it proves or disproves the hypothesis.

Figure 3.2 Procedure of Experimental Research



3.2.2. Advantages and Disadvantages of Experimental Research:

It is a basic type of research that can be implemented in various field. It is the most suitable method for drawing conclusions. It has a controlled environment due to which better results are achieved. Due to many variations of experimental research, it can provide different benefits depending on what is being explored. Depending on unique circumstances researcher can modify the experiment while still keeping the validity of the experimental research design (Fjermestad & Hiltz, 2015).

On the other hand there are also some disadvantages. The results can alter due to human error which can occur during experiment. It can also create fake situations because variables are deeply controlled by the researcher. In order to fully research all the variable many individual experiments have to be done which can result in a long time period conducting the experiment. Many external factors can affect the study like health, mood, and environmental factors and it may not be possible to control these variables. (Campbell & Stanley, 2015)

3.3. Research Design:

Choosing a research design is important because it expresses what data is necessary, which methods are going to be used to gather and analyze data, and how this will help us in answering our research question. Data and methods need to be very effective in giving answers to research question (Wyk).

3.3.1. Guideline for Quantitative Data Collection:

We need an experimental research design to collect data so that we can find answers to our research question. There are two types of experimental research designs one is group experiment another is single subject research design (McLeod, 2007). In group comparison two groups i.e., treatment and control group are involved. No intervention is done on control group while all the research is carried out on treatment group. The results are interpreted by matching the variables from treatment and control group. On the other hand single subject research design involves only one group on which intervention happens and results are measured using one variable before and after the experiment.

3.3.2. Single Subject Research:

The research design chosen was single subject research design. This design is used when a researcher is trying to change the behavior a subject or group of

subject and desires to document the change (Del Siegle, 2015). Here are some characteristics of this design:

- Only one group i.e., treatment
- No control group for comparison
- Students are their own controls
- There are two phases involved:
    - Baseline phase with no changes
    - Intervention phase

During first phase A there was no implementation of 21st century skills or stem education while both were implemented in second phase. Critical thinking skills were measured using bloom's taxonomy at first and second phase. Data was collected through pre and post tests and analyzed using t tests.

This section will explain how the data was collected and how it was analyzed. There are three types of data collection used in educational research quantitative, qualitative analysis and mixed method design.

Our research begins by collecting data before and after the implementation and then there is implementation phase and at the end results are collected and analyzed

3.3.3. Data Collection Tools:

Pre-test at the start of the first phase was conducted. While at the end of phase two post tests were conducted.

3.3.4. Assessment of Creativity:

Pretest and Post Test include 4 Questions to assess creativity skills. The questions are based on Torrance Tests of Creative Thinking (Figural & Verbal). Figural Questions Consists of three Activities:

- Picture Construction

    In this activity a person must build/draw something meaningful from a pear/jelly shape, the shape must be primary part of drawing. By doing this activity a person puts a meaning to

something that is initially useless and by elaborating it a real purpose appears.

- Picture Completion

  This activity requires the completion of incomplete figures into a complete picture. By doing this activity a person's skills of building, analyzing and presenting a scene are assessed.

- Lines and Circles

  In this activity a person uses only lines and circles, again and again to build different pictures. In this way he is able to revisit the same figures but with different perception each time to build something new.

Verbal Questions are based on following activities

- Product Improvement Activity

  A person tries to come up with as many different ways as possible to make changes to a toy so that it became more fun to play with. In this way he is able to present and play with different ideas.

- Unusual uses Activity

  In this activity a person tries to originate different uses of everyday objects like cans, pencils. By doing so a person taps into the ability of thinking originally and this improves the creativity skills.

- Just Suppose Activity

  In this activity a person tries to think of possible results and conclusions of impracticable scenario. This activity works as degree of imagination as a person taps into the world of imagination and prediction and has to play with ideas to come up with consequences.

3.3.5. Assessment of Critical Thinking:

Blooms Taxonomy provides a framework for teachers to access high order thinking (Bissell & Lemons, 2006). There are six levels in the framework and our questions in pretest and posttest are divided according to these levels.

Level I: Knowledge

It involves remembering previous knowledge based on basic facts, answers, concepts and terms. Keywords: Define, label, recall, select.

Level II: Comprehension

Comprehension involves representing understanding of facts and ideas by establishing, relating, interpreting, inferring, giving descriptions, and stating the main ideas. Keywords: classify, translate, rephrase, summarize.

Level III: Application

Providing solution of problems by applying previous knowledge, facts, and methods in new and different ways. Keywords: construct, develop, and make use of.

Level IV: Analysis

It involves the breakdown of information into different parts and analyzing those parts, how they relate to each other, making prediction. Keywords: discover, dissect, and divide, assumption.

Level V: Synthesis

It involves building a whole new information from different parts of information and providing alternative solutions. Keywords: develop, create, and propose.

Level VI: Evaluation

Evaluating involves giving thoughts built on a set of standards by making decisions about information, and strength of ideas. Keywords: conclude, deduct, and choose.

3.3.6. Location:

A Summer school was held in Gujranwala City for 10 days where children learned concepts of science and math's and teacher taught them using STEM. This location was feasible for researcher and so it was selected by researcher.

3.3.7. Sample:

Children of class 6 and 7 were selected for this study. There total number was 22.

3.3.8. Duration:

Duration of this study was 10 days during summers. Because students were having summer holidays they gave their entire time and energy to this project and were highly enthusiast by its unique activities.

3.3.9. Procedure:

Pre-Test:

At the first day of summer camp students were really nervous and to get acquainted with them I had planned ice breaking activities. These were fun and exciting and I gained there attention in no time. Then I distributed the pre-test and asked them to fill it with whatever knowledge they had gain. After taking pre-tests I generically told them about the activities and study material that we had to cover and get to know them by asking few questions about themselves and their knowledge of coming topics.

Activities:

Day2:

The topic for day 2 were force, gravity, mass, weight. For demonstration I used different balls of size and color. I also showed them simulations on projector about these topics. Then to clear the concept of mass and weight we also solve the problem of same mass different weight of an object on mars and earth. Students were really attentive the whole time and enjoyed learning through carrying balls and solving problems.

Day3:

Day3 topics were friction, mass, inertia. Again I used visual aids and used different objects to clear the concepts. For friction I used same object on different surfaces, and then I ask some of them at front so that they can

experience it on their own. By doing things on their own their understanding was clearer and their attention span was highest.

Day4:

For day4 the topic was types of machines. I used different videos and images to help them better understand the concepts and uses of different machines. I used examples from everyday life for types of machines which helps them differentiate between them more easily.

Day5:

At day5 I decided to test them by doing creating challenge tasks for each topic that we had covered. I made 4 stations for each topic. First was friction station where different objects were placed on different surfaces and they have to explain what was happening there. Second station was types of machines. I had set up different models of machines and they were to identify them according to the types. Third station was mass and weight. Fourth station was gravity station. The detail of this test can be found in appendix. The reason for conducting this test to evaluate their understating of the topics.

Day6:

Acceleration, work, greater than, less than concept. When I conducted the pretest it showed me that the students are weak in basic math concept of lesser greater number. So I added it in my lessons along with other topics because STEM is the integration of each topic into one lesson.

Day7:

Introduction of Lego kits. I told them the purpose of these kits and showed them the parts of each kit. I then showed them different images of robots made from that kit and ask each of them what robot they want to make and what task will it perform for them.

Day8:

Making of basic robot and going into high level of making a car from Lego kits. We did not have time to code it but students had fun making cars out of the small parts of kits and it also help build their communication and creativity skills and they enjoyed building something on their own.

Post-test:

I conducted the same test which was conducted on day1 so that I can check their progress. Then I asked them different questions that how much they liked

this type of camp and would they like their everyday classes to hold like these. Their responses were positive and they show enthusiasm of having daily demonstration in classes.

4. Data Analysis:

Data analysis is an important stage of any research because it gives meaning to previously meaningless data. It is a process of studying, converting, and demonstrating statistics with the aim of interpreting results, proposing conclusions. There are different tools and techniques of data analysis and if proper statistical test are used only then we can say that the results are accurate. This means that we have to choose the right test for our data (Ali & Bhaskar, 2016).

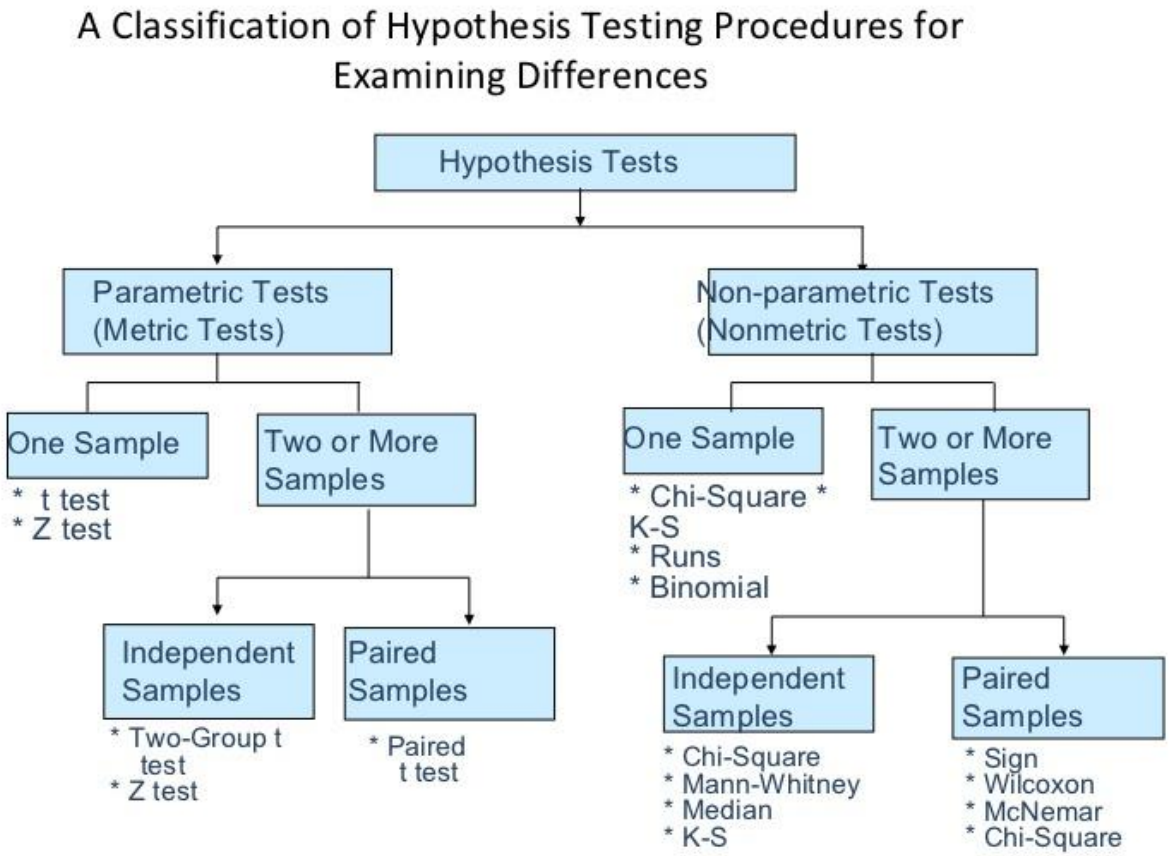
4.1. Choosing Right method for analysis:

There are two types of data. Tests are chosen according to data type (Ali & Bhaskar, 2016).

- Independent sample: two different groups are involved in such type of data and thus tests are done to compare their results
- Dependent sample: there is only one group but two sets of data.

According to the type of data a number of methods are available for statistical analysis as seen in figure below:

Figure 4.1 types of Statistical Test (Image from Hernandez, 2017)



4.1.1. Parametric VS non-Parametric Test:

Parametric Test: these tests assume that the data is normally disturbed.
Non-parametric test: these tests assume the equal variance of sample and their population.

4.1.2. Data Normality Test:

A data normality test is performed on the data to determine whether the sample is drawn from normally distributed population. A number of tests can be performed to determine the normality like W/S test, Jarque-Bera test, Shapiro-Wilks test, Kolmogorov-Smirnov test, D'Agostino test. We can also test the normality using graphical representation but this method is not very useful when the sample size is small. We will test the normality with Shapiro -Wilk test (David & L.Gunnik, 1997).

Table 4.1 Test of Normality

Test of Normality

Variable	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Statistic	df	Sig.	Statistic	df	Sig.
critcal_post	.124	18	.200*	.980	18	.955
creativty_post	.239	18	.008	.902	18	.062
creativity_pre	.149	18	.200*	.935	18	.242
Critical_Pre	.145	18	.200*	.904	18	.067

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

It is clear from the above table that sig $p > 0.05$ that means data is normally distributed. And we also don't need to apply Wilcoxon test as the assumption of data normality is fulfilled.

4.1.3. Choosing a t-test:

Since our data is dependent and normally distributed as seen from above table we can say that a paired t-test can be used to check our hypothesis (Refer to figure 4.1).

4.2. Paired t-test:

Paired t-test also called dependent sample t-test, is used to compare means between two entities and whether it is zero (EncHsu, Henry, & Lachenbruch., 2008). It is usually applied on a single subject design (Gotway & A, 1994). Each entity is measured twice, which results in pairs of observations. Before applying t-test to our data there are some assumptions we take. First the data should be normally distributed. Second there should not be any outliers. Outliers are exceptional data points which appear far away from majority of the data. Outliers should be removed because they can lead to incorrect conclusions. We can simply remove outliers from our data. However if they have a strong impact on data we can use Wilcoxon signed rank test for removing them (Blair & Higgins, 1985). We applied Shapiro-Wilk test to check the normality for data and it holds the normality so there is no need of Wilcoxon test and we can proceed with t-test.

4.3. Results:

We are going to see the results of our data. A number of tests have been performed on data to check whether it supports our hypothesis that STEM education helps in developing critical thinking skills. Another hypothesis is that STEM education helps in creativity skills

4.3.1. CRITICAL Thinking:

Table 4.2 Statistics

Statistics

	Critical_Post	Creativity_post	Creativity_pre	Critical_pre
N Valid	18	18	18	18
Missing	0	0	0	0
Mean	53.9444	9.7778	10.0000	46.0000
Skewness	.205	.477	.281	.959
Std. Error of Skewness	.536	.536	.536	.536
Kurtosis	-.429	-.615	-.385	1.235

Std. Error of Kurtosis	1.038	1.038	1.038	1.038

Data is Normal, Groups are related, so all the assumption of Pair T-test holds

Table 4.3 Paired Samples Statistics

Paired Samples Statistics

Pair 1	Mean	N	Std. Deviation	Std. Error Mean
Critical Post	53.9444	18	12.45449	2.93555
Critical Pre	46.0000	18	10.20381	2.40506

Table 4.3 Paired Samples Correlations

Paired Samples Correlations

Pair 1	N	Correlation	Sig.
critcal_post & Critical_Pre	18	.784	.000

Table 4.4 Paired Samples Test

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 critcal_post - Critical_Pre	7.94444	7.74955	1.82659	4.09068	11.79821	4.349	17	.000

Paired sample t-test was conducted to compare the scores of critical thinking skills of students before and after the intervention. We hypothesized that

STEM education can increase the critical skills of students and this is supported as the value of $p < 0.05$.

4.3.2. CREATIVITY:

Table 4.5 Paired Samples Test

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 critcal_post - Critical_Pre	-.22222	.94281	.22222	-.69107	.24663	-1.000	17	.331

We also hypothesized that STEM education can help improve students' Creativity skills. We are failed to support this as the test indicates that the value of $p > 0.05$. It can be because of lot of reasons which are discussed in discussion part.

5. Discussion:

This approach has been widely used in schools and colleges all over the world to develop students' 21st century skills to improve their academic as well as cognitive abilities. we have also seen in the literature review section that STEM effects students many skills and prepare them for future where they have to face many challenges and be on their own. However, there is little to no research carried out in Pakistan for the development of these skills through STEM education. Therefore, the purpose of this study was to find out that whether using STEM has a significant impact on developing these skills in the Pakistani context.

5.1. Findings of Study:

5.1.1. 21st Century Skills:

After conducting this experiment we find out that there was a significant increase in critical thinking skills of students. We also found out that using STEM helps students to actively take part in class. They enjoyed different activities and learned quickly through those activities. There excitement level was hugely increased and through hands on activities they learned a lot. The school management was also impressed with the way activities were planned and carried out in a limited time slot. The use of LEGO MINDSTORMS was also a plus point as the schools in Gujranwala has never used this type of aid in classrooms. The school management was very happy with all the intervention and they promised to include some of the activities in daily class routines. They give remarks that they enjoyed these classes more than the regular classes.

5.1.2. Creativity:

However students' creativity skills were not improved much. There can be a lot of reasons for that. First that creativity is something you cannot develop in a limited time constraint. It takes time and also if it is introduced at the early ages of life it is likely to develop more in later ages. Second our education system does not promote creativity at any level. It only offer success to those who read and write books by heart and this is a great hindrance in the way of creative skills. In doing this experiment I find out that students; have zero to

no ability to create something on their own and they are not even interested to learn about creativity because it is not promoted at school level. All over the world the education departments are taking steps to include STEM at early level of schooling so that the skills are incorporated at earliest stage possible.

5.2. Limitations:

There are few limitations of this study:

- The sampling is from one school only and it has no variations in it. Therefore the results are subjected to a specific number of population.
- Time constraint was a big limitation. This is not something that should be introduced for a certain period of time. This process should be a crucial part of our education system at every level.
- Education department of Pakistan is not concerned about looking into the material taught in the schools. Every school has its own curriculum and own mindset of teaching which is a great hindrance in such of type of projects.
- There is no regular training of teachers carried out in various schools and teachers have no idea of new technologies and instructional models they think of such projects as a waste of time in completion of syllabus for final exams.

5.3. Future Directions:

It is recommended that in doing future research on this problem, the researchers should keep in mind limitation and findings of this study. This research has provided an understanding into developing 21st century skills through STEM education. However, a more rigorous study about developing other skills like creativity is required. There is also a need of teacher training about the constructivist approach and experimental approach in classrooms. Teachers have no idea how to pique students' interests in class and their only goal is completion of syllabus. I would recommend to explore this are as well in future because unless teachers are trained in new technologies the shape of schools and education system will remain same. We were unable to provide results about

creativity skills. It was affected due to a lot of reasons one of them being time constrained. So future researchers need to plan and execute according to the limitations stated above and including more skills in their study. Other than that communication, collaboration, can also be included in future researches. Another new concept of STEAM is being widely used instead of STEM and it can be used with the blend of 21st century skills.

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Appendices

Appendix A

Pre/Post test

Name: _____ **Age:** _____

Gender: Boy/Girl _____ **Date:** _____

School: _____

Q1. How many uses can you think of a pencil?

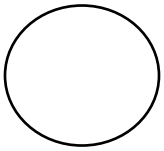
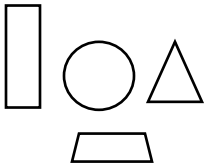
_____

_____

_____

_____

Q2. Use the following shapes given into your own drawing. Also give each of them a title.

Starting Shape	Your Drawing and its title
Use 	
Combine 	
Complete 	

Q3. Try to improve this stuffed toy rabbit so that it will be more fun to play with.

Q4. Just suppose that you are magician. Name some things that you would like to do with your magic?

_____

_____

_____

_____

Bloom's taxanomy(Level 1 Knowledge)

Q5. Can you tell why water from a waterfall flows downwards and not upwards?

_____

_____

_____

Q6. George Washington was the first president of the United States and his wife, Martha, was the first, "First Lady."
Using the letters in the names of the first president and his wife, write smaller words that match the clues on the lines below. The letters will always be in order either from left to right or right to left, and may be separated by other letters.

GEORGE & MARTHA WASHINGTON

1._____ clean with soap and water

2. _____ a brief written message

3. _____ a wood-cutting tool

4. _____ a precious stone

5. _____ a bird needs this to fly

(Level 2 understanding)

Q7. How would you rephrase the meaning of friction?

_____

_____

_____

_____

Q8. What is the difference between mass and weight?

_____

_____

_____

_____

Q9. Can you distinguish the lowest and highest number from following?
10, 0, 20, 0.20, -18, 30, 0.05, -60, 27

Lowest:

Highest:

(Level 3 Applying)

Q10. Its winters and heavy snowfall outside. You are feeling cold. How can you solve this by using friction?

_____

_____

_____

_____

Q11. A tennis ball and a feather are dropped from same height. What do u think will happen to both? How would you show your understanding?

_____

_____

_____

_____

Q.12 How would you organize these numbers to show on a number line.

10, 0, 20, 0.20, -18, 30, 0.05, -60, 27

Q.13 What approach you would use to place a heavy box of sand on roof?

_____

_____

_____

_____

(Level 4 Analyzing)

Q14. How is +0 similar to -0?

_____

_____

_____

Q15. What is the function of Wheel?

_____

_____

_____

_____

Q.16 what evidence can you find for earth revolving around sun?

_____

_____

_____

_____

Q.17 What are the main features of a car?

_____

_____

_____

_____

(level 5 Evaluating)

Q.18 Do you think Friction is a good or bad thing?

_____

_____

_____

_____

Q19. How would you feel if there was no gravity on earth?

_____

_____

_____

_____

Q.20 What changes you would recommend in a cycle to make it better?

_____

_____

_____

_____

(level 6 Creating)

Q.21 Design a spaceship/rocket/car or anything that you would use to travel to space. What feature will it have?

_____

_____

Q22. Can you create new and unusual uses for inclined plan?

_____

_____

_____

_____

Q24. How many ways can you use a wedge?

_____

_____

_____

_____

Q25. If you had access to all resources how would you deal with friction?

_____

_____

_____

_____

Appendix B

Summary Test (Group test)

Name:_____ Name:_____

Name:_____ Name:_____

Name:_____

Date:_____

Q1. You are given a Styrofoam cup, water and a tub. You have to punch a hole in cup and see if water goes down from the hole. Then place your finger on thumb refill the water and now drop the cup. Will water still fall from the hole of cup? Write your observations with reasons.

Before Experiment:

_____

_____

_____

After Experiment:

_____

_____

_____

Q2. Select one group member for this. Write their weight on earth. Suppose they went on moon. Its gravity is 1/6 times lesser than earth, calculate their weight on moon? Then calculate weight on mars whose gravity is 2.53 times greater than that of earth.

	Mass	Weight
Earth		
Moon		
Jupiter		

Q3. You are given two surfaces to drive your cars on. On which surface do u think cars will move faster? Write your observations with reasons.

Before Experiment:

_____

_____

_____

After Experiment:

_____

_____

_____

Q4. You have been assigned to a simple machine station. At your station, there are the materials to demonstrate one of the six simple machines. Figure out which one it is and assemble it.
What your simple machine is?

_____

The uses of your simple machine

_____

_____

_____

Some examples of other machines that may use your simple machine.

_____

_____

_____

Appendix C
Workshop Lesson Plan

	Topic	Activities	Materials required	Mathematics concepts
Day1	Introduction, Ice breaking activity, Pre-Test	1. A pictorial version of consequences which helps students value one anothers artwork. • Get large A3 paper and fold into 5 sections, label each section head, shoulders, arms, legs, shoes/feet - photocopy enough for everyone in the class. • Then get each person to draw the relevant thing in the section, fold and pass it on. • At the end post the results on the board and discuss the outcomes. 2. Mirror activity Pair of two students will take part in activity, one student will become the shadow of other and he has to do exactly what his self is doing.		
Day2	Gravity, Force, mass, weight, acceleration	Most of the activities explained here will be followed http://www.thirteen.org/edonline/ntti/resources/lessons/gravity/b.html	Balls of different shape and size, charts, pencils, feather,	Calculating time of each falling object. Greater than, less than concept is required.
Day3	Friction, Inertia, Shadows(sundial clock)	For friction= http://www.discoveryeducation.com/teachers/free-lesson-plans/friction-in-our-lives.cfm Inertia = http://swift.sonoma.edu/education/newton/newton_1/html/newton1.html Sundial http://www.skyandtelescope.com/observing/how-to-make-a-sundial/	Projector for videos, balls, desk/chair, paper, pencil, geometry, tape, scissors	Angles, measuring longitude and latitude,

Day4	Types of machines	https://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_simple/cub_simple_lesson01.xml	N/A	
Day5	Summary test/ Challenge task			
Day 6	Introduction of Lego kits (very basic robot making)		Lego mindstroms kit	
Day7	Car robot following a certain path		Lego kits	Measurement of car distance, time to cover track, balancing car
Day8	Smart car avoiding obstacles, cliffs		Lego kits	
Day9	Revision of last 2 days.		Lego kits	
Day10	Challenge task, post-test		Lego kits	