The Eurasia Proceedings of
Educational & Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2016

Volume 4, Pages 313-319

ICEMST 2016: International Conference on Education in Mathematics, Science & Technology

USING STEM INTEGRATED APPROACH TO NURTURE STUDENTS' INTEREST AND 21ST CENTURY SKILLS

Mohamad Sattar Rasul

Faculty of Education, The national University of Malaysia

Lilia Halim
Faculty of Education, The national University of Malaysia

Zanaton Iksan
Faculty of Education, The national University of Malaysia

ABSTRACT: This study aimed to identify the changes of 21st century skills among students after participating in integrated Science, Technology, Engineering and Mathematic (STEM) education programme. The learning activities in this programme applying Project Oriented Problem Based Learning approached as a fundamental pedagogy. A total of 125 secondary school students age 13-14 from four different zone of FELDA regions were involved as respondents. This study employed one group quasi-experimental and survey design to identify student's 21st century skills before and after the programme. The data were analyzed using SPSS 21.0 for descriptive analysis, which later followed by inferential analysis to compare the means (t-test) between pre and post groups. The findings from this study revealed that, the level of 21st century skills among students significantly increase. Interestingly, one of the 21st century skills components namely 'high productivity skills' shows positive changes, from moderate to high level skills. The outcome of this study provide evidence that the application of Po- PBL in STEM education could help students to enhance their 21st century skills by learning how to solve the real world problems based on the authentic and real life experience through project work.

Keywords: 21st century skills, Po-PBL, STEM education, project based learning, problem based learning.digital age literacy, ınventive thinking, effective communication, high productivity, spiritual values

INTRODUCTION

The most important asset to achieve a high income developed nation status is through quality human resource which can face challenges in applying 21st century skills. To spur a world class nation, human resource which is competitive, knowledgeable, creative and possessing positive ethics plays an important role. North Central Regional Educational Laboratory (NCREL) and Metiri Group has created a 21st century education model which is known as enGauge 21st Century Skills [1]. With this model, there are four main criterias which need to be weighed to produce a generation which is capable of handling 21st century challenges. The four criterias are Digital age literacy, Inventive thinking, Effective Communication and High productivity. Another criteria to accommodate the Malaysian context, which is spiritual norms and values was added [2]. This research will study on five aspects of 21st century skills.

The first 21st century skill is Digital age literacy which encompasses communications competency, the analysing and interpretation of data, the understanding and assessment of models, task management and task prioritization, involvement in problem solving, and ensuring wellbeing and safety [3]. Digital age literacy needs to be developed in a student's mind to ensure students maximize technology usage in this 21st century learning. The second skill is Inventive thinking. Inventive thinking is a cognitive activity which helps creative thinking application in a creative and critical manner with skills in problem solving through innovative or specifically designed activities. A few elements or 'life skills' in inventive thought ability was defined by

- Selection and peer-review under responsibility of the Organizing Committee of the conference

*Corresponding author: Mohamad Sattar Rasul-icemstoffice@gmail.com

others researcher groups [1, 4], which is adapting and managing complexities, self regulation, curiosity, the willingness to take risks and high level thinking. The next skill is Effective Communication. Effective Communication is a skill which needs to be developed by each individual in this 21st century. It encompasses information delivery, teamwork, interpersonal skills, social responsibilities, interactive communication and communication towards the environment [1]. The learning process becomes much more exciting and valuable when communication activities use ICT as a medium to obtain information, to communicate faster, and as a supporting medium which assists in the learning process. The fourth skill is High productivity, it is defined as a student who is able to produce relevant products, high in quality, intellectual, currently information and original [1]. The student is also skilled in delegating and structuring tasks in terms of importance and priority, and skilled in planning and producing high quality products. The final skill is Spiritual values. This skill emphasizes on the practice of religious knowledge and beliefs, attitude and values.

In dealing with the challenges of the 21st century, the working sector requires workers who possess marketability which encompasses problem solving skills, critical and innovative thinking and the ability to work in a team. To achieve that, students can no longer be assessed based on academic achievements only, but they also need to master 21st century skills. Nowadays, there are many student-centered teaching and learning processes and PoPBL is one of them, which is project centered and orientated. The PoPBL approach which was developed by Aalborg University, Dermark [5], has steps with experiences that activate students and ensure the connection between teaching of science and everyday life. The PoPBL approach is a teaching method in the teaching pedagogy model which was first used in Problem Based Learning (PBL) [6].The basic principles of POPBL can be summarized as (i) Student-centered and able to motivate and gain commitment among students; (ii) focus is more on learning process in finding solution; (iii) Project-Based which has goal and action for change; (iv) Exemplarity; (v) Promote group work/team work, social and communication skills [7]. PoPBL tries to cultivate students' ability, to think critically to learn actively and to solve problems through project based activities. It also develops skill on communication when students have to conduct group discussions. An implementation of POPBL in STEM Programmes therefore had given a great opportunity for the students in self-directed learning and enhanced their soft skills.

In line with STEM's education objective to develop inter-disciplinary thinking, the PoPBL approach is one of the methods that is suitable in STEM's education. PoPBL is seen as an approach that has potential in creating students which will learn better through meaningful teaching which is associated with real life situations and the students can experience the situation themselves. PoPBL is also an alternative teaching method where students are immersed in an environment which focuses on teaching through project work and not solely on oral teaching [8]. The inability of students to apply concepts and skills in the field of STEM which has been taught to solve STEM-based problems and also in everyday life becomes more worrying each day. As a result, students have difficulty in understanding abstract concepts. This problem causes students being unable to apply those concepts in solving STEM-based problem because they do not understand the underlying theory of each given subject.

PoPBL is a pedagogy model which is most favoured in structuring teaching methods [6]. PoPBL incorporates the development of students' personal skills and also encourages creativity [9]. Therefore, through PoPBL, the teaching and learning processes in STEM-based education is hoped to achieve its objective to cater to the needs of the 21st century generation. This is because PoPBL needs to start with research problems analysis followed by project designed to solve problems through activity execution which has already been planned to solve problems which are being analysed [7]. This matter is important because students need a sound basis in STEM to face challenges in their career and go through life in this 21st century [10].

Some researcher [11, 12] proved that the PoPBL approach can elevate students' interest towards science. PoPBL has the ability to develop students' sense of importance for science subjects by making it easy for students to learn science and therefore increases their interest in science [11]. This approach also has an ability to develop new knowledge when it is regarding the issue of low percentage of recycling practices in campus for what has been taught in class [12]. The PoPBL approach able to elevate students' achievements and this statement is proven through the research [8, 9]. Finding show that through the PoPBL approach, students can have a high level of achievement in their work and highly motivated in their learning processes [9]. Through teamwork, PoPBL can elevate students' humanity skills (communication between team members and planning) [9, 13]. Studies of application of PoPBL among students from the Faculty of Electric and Electronics, found that the processes of teaching and learning which employs the PoPBL approach has increased students' ability to analyse and create analog circuits using various types of transistors and diodes.[8].

Science education objectives in Malaysia are to develop competitive human resource at a global level and also

become a contributor to the development of the science and technology civilization, resistant, and able to master scientific knowledge and technological craftsmanship [14]. Even so, the decline in students' interests towards science in Malaysia especially [15, 16], will become a challenge in achieving that objective.The average score for Malaysian students in the *Trends in International Mathematics and Sciences Study* (TIMSS) examination clears indicates a downward trend, starting from ranking 510 in 2003, 471 in 2007 and 426 in 2011 [17-19]. PISA 2009 results indicate Malaysia is located at the bottom third out of 74 participating countries and also below the international and OECD average [20]. In 2011, only 45% of student graduates were from the Science stream, including technical and vocational programmes [21]. This scenario cannot be ignored because it will affect Malaysia's efforts in achieving developed nation status in 2020 where Malaysia needs a 33% workforce in the field of science and technology. Steps need to be taken to achieve the targeted number of graduates in STEM-related fields to increase future students' achievements.
In line with that, programmes that incorporate the various disciplines of science such as Science, Technology, Engineering and Mathematics (STEM) conducted outside schooling hours are seen as an alternative that positively affects the efforts to increase interest and involvement in STEM-related careers. Also, the integration of these STEM subjects will spur the minds of students to be creative, critical, innovative, and this in turn contributes to the advancement of technology. STEM education is an approach that explores the processes of teaching and learning between any two or more STEM components or, between any one STEM components with another field of knowledge [22]. The Malaysian education system is already equipped with science, mathematics and engineering which is taught as a stand-alone subject, but the integration of science and mathematics with engineering concepts can be a better practice as compared to the traditional method. In fact, STEM education is the integration of technology and engineering design concepts in the teaching and learning processes of science and mathematics [23]. The Education Ministry (KPM) and PPPM has clearly stated that they will strengthen the delivery of STEM across all education systems. "This new discipline was meant to transform traditional classrooms from teacher- centered instruction into inquiry-based, problem solving, discovery zones where children engage with content to find solutions to problems" [24].

The STEM programme in this research includes a partnership between Universiti Kebangsaan Malaysia (UKM) with FELDA authorities aimed to increase students' participation in the fields of *Science, Technology, Engineering and Mathematics* (STEM) and eventually become enabling to compete in this 21st century. This programme's approach is based on multi-disciplinary features, active learning through inquiry, application of 21st century skills, and exposing students to careers in the fields of contemporary science and technology. The learning theories underlying this research are the theories of Constructivism and Constructionism. The Constructivism theory is comprised of five phases, namely orientation phase, idea generation phase, idea restructuring phase, idea application phase, and reviewing phase. The *Constructionism* theory is applied during the idea application phase, throughout the processes of practical activities which involves real world problem solving in the STEM Bitara Module. According to the theory of *Constructionism*, the generation of new ideas will happen effectively if participants are involved in artifact designing processes [25]. This theory emphasizes participants towards artefact designing activities in the learning process [26]. The engineering design process, which is the TMI model [27], is applied by participants in their artefact designing process.

The STEM Bitara Module applies the TMI Model [27] through three main stages, namely, *Think* (T), *Make* (M), and *Improve* (I). During the *Think* stage, after participants have been given a situation or real world problem to solve, they will discuss and work in a group to identify the problem, give suggestions, and make plans. The facilitators will continue to support each participant to ensure they complete this stage effectively. During the *Make* stage, participants build, create, experiment, solve the issue, and any other issues arising during artefact design. After the artefact has been completed, testing is conducted to identify any problems that arise. Finally, at the final *Improve* stage, participants will improve the artefact that they have built by testing and rebuilding the artefact again with improvements to identify arising problems, or build a much better artefact following the guidelines which have been set.

Objective of Study

The purpose of this study was to assess the effect of the implementation of PO-PBL in STEM education programme in terms of students' 21st century skills by using a one group pre and post-test quasi-experimental design. This study was launched to investigate the following research questions:

1. Were there any significance changes in the students' 21st century skills in POPBL learning program?
2. Can PoPBL learning program increase students' 21st century skills?

Methodology of Research

Learning by doing is a way to help students to understand their learning especially the abstract content effectively. An alternative method to promote this way of learning is called PoPBL. Students learn how to solve the real world problems based on authentic and real life experience through project work that emphasizing the creation of artifact. The success of the project work come from the collaboration between students in a team work and teacher as a facilitator. Designing of PoPBL approach with integrated STEM is still new in learning environment. On 2 to 6 June, 2014, the programed called '*Bitara-STEM UKM-FELDA Camping program*' was held in MRSM FELDA Trolak, Perak. This program implemented POPBL with integrated STEM. The learning activities in this program is project based and multi-disciplinary activities that provide students with fun learning by applying students-centered approach. The theme for this program is "Science of Smart Communities". The learning activities in this program provide students with fun learning by applying students-centered approach which is project based and multi-disciplinary activities. Implementation of POPBL with integrated STEM in this program also in order to develop, 21st century skills, higher-order thinking and research skills. Four separated units of modules was introduced to the students for participate namely (i) Energy, (ii) Urban infrastructure, (iii) Transportation, and (iv) Wireless communication (Figure 1)

Figure 1. Units of intervention and activities

Unit	Modules	Example of Activities
Energy	Introduction of Newton's Law & Electrical Basics Worldly environment Power generation Power storage Biomimicry	Balloon rocket & parachute. Rain in the bottle. Potato battery Hydrogen fuel cell Fish tail
Transportation	Modes of transport Smart transportation Smart highways Intelligent transportation systems. Traffic engineering	Make a circut Robot programming
Wireless Communication	Smart electronics basics Real time communication Space based wireless communication Internet and communication network. Smart wireless communication	Flash LED Cell antenna
Urban Infrastructure	Environmental engineering Soil and land development Building towards to the future Recycling and waste management Natural disasters	Pump It! Water turbine Earthquake Town

Samples

The sample in this study was participants who are participated in 'Bitara-STEM UKM-FELDA Camping program'. A total of 125 lower secondary school students from four different zone of FELDA regions were involved in this study. Majority of participants have an excellent result in their past standard Primary school evaluation test (UPSR), both subject science and mathematic with 'A' score were 60.7% and 77.9% of the participants.

Instrument and Procedures

The instrument used in this research is a set of questionnaires which employ the Likert Scale with five degrees of agreement (1=does not agree at all to 5=agrees very much). This instrument is comprised of two main sections, which are (i) students' interest towards STEM, and (ii) 21st century skills. The instrument used to gauge students' interest towards STEM is an instrument which is adapted from STEM Semantics Survey [28] and this instrument to gauge students' interest toward STEM will gauge (i) students' interest towards STEM content, and (ii) a career in any STEM field. Next, the instrument to gauge 21st century skills is an instrument used was adapted from Arsad et al. (2011) [29], which takes into consideration skill components from *Engauge 21st century skills*, which are (i) Digital age literacy, (ii) Inventive thinking, (iii) Effective Communication, and (iv) High productivity, whereas the additional component of Spiritual values is a component which is adapted to suit the Malaysian Education Philosophy (Figure 2). This instrument has been checked dan verified by experts (construct validation, content and language). The credibility of this instrument

is high with both all main contructs achieving a high Cronbach Alpha value for each item in the pilot study which was conducted before at a value of between 0.78-0.86.

Figure 2. Example of Items of 21st Century Skills Elements

Element	Item	Number of items
Digital age literacy	I can understand the concept of science and mathematic that the teacher teach in English I am able to evaluate the information regarding science.	7
Inventive thinking	I can be positive towards the problem with the level of difficulty which is beyond my expectation I am interested to find out new and unusual things that I can find from surrounding	12
Effective Communication	I act as a leader and follower at the same time in completing the assignment. I collaborate with team members in any circumstances	8
High productivity	I plan the time provided to complete each assignment. I created product from my project or practical science	8
Spiritual values	I thankful because I am able to learn science and mathematics. I always associated the science knowledge needed in the world or hereafter	5

RESULT and DISCUSSION

Findings from pre- and post tests were used to study the effects of PoPBL approach in STEM programmes on 21st century skills. The mean score from pre-tests were compared with the mean score from post-tests using a paired sample t-test. 21st century skills were tested in five aspects, which are (i) Digital age literacy, (ii) Inventive thinking (iii) Effective Communication, (iv) High productivity, and the added component, (v) Spiritual values. Table 3 shows the comparison for mean score from both pre- and post-tests for all aspects tested to gauge students' 21st century skills. Table 3 below also shows the mean score value and the standard deviation (SD) value from both pre- and post-tests for aspects under 21st century skill.

Figure 3. T-test table table for the mean score of students 21st century skills

Skill	Test	Mean	Std. Deviation	t-value	Sig (2- tailed)
Digital age literacy	Pre-test	3.774	0.419	3.424	0.001
	Post-test	3.916	0.498		
Inventive thinking	Pre-test	4.015	0.412	1.377	0.171
	Post-test	4.082	0.601		
Effective Communication	Pre-test	4.088	0.426	1.942	0.055
	Post-test	4.173	0.598		
High productivity	Pre-test	3.851	0.401	5.878	0.000
	Post-test	4.121	0.481		
Spiritual values	Pre-test	4.550	0.414	0.994	0.322
	Post-test	4.511	0.525		
21st Century Skills	Pre-test	4.055	0.331	2.996	0.003
	Post-test	4.145	0.451		

Based on Figure 3 above, its ~~is evident~~ shows that there is a rise in the mean score values for all aspects of 21st century skill except for *Spiritual values* aspect, which shows a decrease in mean score of 0.039 and there is no significant difference (125)=0.994. As a whole, the findings show that the increase in mean score for 21st century skills happened after students were exposed to the Bitara STEM programme with a t value of (125)=2.996. The findings also show that there is a significant difference for the aspect *Digital age literacy* with a t value of (125)=3.424 and *High productivity* with a t value of (125)=5.878. However, there are two aspects of 21st century skill which do not show any significant difference, which are *Inventive Thinking* with a t value of (125)=1.377 and *Effective Communication* with a t value of (125)=1.942. As a whole, the level of 21st century skills for the majority of students is at a high level. After attending this programme, the percentage of students who exhibit a high level of 21st century skills increased by 4.9%. Figure 4 shows the analysis findings of the percentage of students based on 21st century skills which has been divided into 3 stages, namely low, medium and high.

Figure 4. Student Percentage Based on 21st Century Skills

		Lowest	Moderate	High
Student Percentage Based on 21st Century Skills (%)	Pre-test	0	11.5	88.5
	Post-test	0	6.6	93.4

There are a few important 21st century skills which have to be mastered by students. Through the analysis which has been conducted, it was found that the level of 21st century skills show an increase in every skill after students attended the STEM Bitara Programme with the exception of *Spiritual Values.* The highest increase occurred for *High Productivity* with a difference between pre- and post-tests mean score of 0.27, followed by *Digital Age Literacy* (0.142), *21st Century Skills* (0.09), *Effective Communication* (0.085), and *Inventive Thinking* (0.067). In the STEM Bitara Programme, the teaching and learning approach which was emphasized upon was the usage of PoPBL methods, which applied various *hands on-minds on* activities, starting with problem identification and ending with a solution to the said problem. Research findings show that through the activities of teaching and learning in the STEM Bitara Programme, it increased the level of inventive thought in students. This is because through activities in small groups, students needed to think together on how to solve the problems that they faced by applying their individual experiences. To achieve that, students needed to explore and make connections between the problem's situation and the situations that they have experienced themselves. Also, the students were required to design new artefacts. Artifact design which was formed based on ideas shared with other team members managed to increase students' inventiveness and this gave a positive effect towards *High Productivity.* This finding is in line with other researches [8, 9] which found that PoPBL can enable high achieving results in students' work.

The research findings also show that students possess *Digital Era Literacy Skill* which was elevated after attending the STEM Bitara Programme. The Internet was used during teaching and learning processes to enable students to find additional information to further strengthen their project or the design which they were developing. Through this PoPBL approach, *Digital Era Literacy Skill* level among students who attended the STEM Bitara Programme was at a high and encouraging level. However, the decrease in the value for *Spiritual Values* (-0.039) after students attended the STEM Bitara Programme needs further research aimed at increasing the value in the future. Therefore, the application of spiritual values during teaching and learning processes should be improved upon to ensure that students are not only inventive, can communicate efficiently, possess digital era literacy skills, possess high productivity levels, but also equipped with spiritual values which is much needed for the good of mankind. Further data analysis on student percentage based on 21st century skills found that no students were at the lowest level before and after the programme. A high increase in the 21st century skills level occurred after students attended the STEM Bitara Programme for the highest scale, an increase of 4.9%. This proves that the teaching and learning pattern of PoPBL which was applied in the STEM Bitara Programme was suitable and able to capture students' interests to be involved in the processes of teaching and learning and ultimately increased the quality of students' mastery in STEM-based education. Research findings also show that the effectiveness of PoPBL through STEM programmes succeeded in increasing the level of 21st century skills.

CONCLUSION

Based on the research findings, it can be concluded that the application of the PoPBL approach in teaching and learning processes as implemented in the STEM Bitara Programme can increase the level of five 21st century skill elements, which are Digital Age Literacy, Inventive Thinking, Effective Communication, High Productivity and Spiritual Value. Also, PoPBL as a collaborative teaching strategy can increase communication skills effectively. The implementation of group activities can help nurture attitude and interpersonal skills, such as interacting skills during project presentation, teamwork, hardworking and creative thinking. The model and teaching principle such as this is much needed in today's teaching situation with students who are active and creative to prepare them for challenges in this 21st century. Therefore, the teaching and learning processes need to be relevant and coherent with current times. The STEM Bitara Programme which involved the integration of STEM education was futuristic, flexible, and dynamic can develop human resource which are creative and innovative in the ongoing attempt to master 21st century skills. It can also develop human resource which is clever in planning the future and able to make choices between culture and current values in facing globalization and information boom.

REFERENCES

NCREL and M. Group, *EnGauge 21st century skills: Literacy in digital age*. Napierville, IL & Los Angeles, CA: NCREL & Metiri, 2003.

K. Osman and N. Marimuthu, "Setting new learning targets for the 21 st century science education in Malaysia," *Procedia-Social and Behavioral Sciences,* vol. 2, pp. 3737-3741, 2010.

K. Kay and M. Honey, *Beyond Technology Competency: A Vision of ICT Literacy to Prepare Students for the 21st Century*. Charleston, W.V: Evantia, 2005.

Committe Workforce Needs in Information Technology. (2001, 21 March 2011). Building a workforce for the information economy. Available: http://books.nap.edu/html/building_workforce.html

D. M. A. Hussain and T. Rosenørn, *Assessment of Student Competencies for a Second Year Operating System Course*. Rotterdam The Netherlands: Sense Publisher, 2008.

J. Uziak, M. T. Oladiran, M. Eisenberg, and C. Scheffer, "International team approach to project-oriented problem-based learning in design," *World Transactions for Engineering & Technology Education,* vol. 8, pp. 137-144, 2010.

R. M. Yasin and S. Rahman, "Problem oriented project based learning (POPBL) in promoting education for sustainable development," *Procedia- Social and Behavioral Sciences,* vol. 15, pp. 289-293, 2011.

M. Mohamed, W. Mat Jubadi, and S. Wan Zaki, "An Implementation of POPBL for Analog Electronics (BEL10203) Course at the Faculty Of Electrical and Electronic Engineering, UTHM," *Journal of Technical Education and Training,* vol. 3, 2012.

N. Ibrahim and S. A. Halim, "Implementation of Project-Oriented Problem-Based Learning (POPBL) in Introduction to Programming Course", *International Research Symposium on Problem-based Learning,* vol. 4, pp. 279-288, 2013.

B. R. Jones-Kavalier and S. I. Flannigan, "Connecting the digital dots: Literacy of the 21st century," *Teacher Librarian,* vol. 35, p. 13, 2008.

K. B. Maria, *School science teaching by project orientation – improving the transition to university and labour market for the boys and girls.* .Germant: University of Applied Sciences, Germany, 2008.

S. Yusoff, C. Ng, Z. Keng, and Z. Mohamad, "Integrating sustainability in engineering curriculum through incorporation of problem-oriented project- based learning (POPBL) learning strategy," presented at the International Engineering Education Conference, Madinah al-Munawarah, Kingdom of Saudi Arabia, 2011.

L. P. Jensen, J. Helbo, M. Knudsen, and O. Rokkjær, "Project-organized problem-based learning in distance education," *International Journal Engineering Education,* vol. 19, pp. 696-700, 2003.

MOE, "Malaysian Science Curriculum," ed. Putrajaya: Curriculum Development Centre, Ministry of Education, 2011.

Kamisah.Osman, Zanaton.Hj.Iksan, and Lilia.Halim, "Sikap terhadap sains dan sikap saintifik di kalangan pelajar sains," *Jurnal Pendidikan,* vol. 32, pp. 39-60, 2007.

[Zanaton.Hj.Iksan, Lilia.Halim, and Kamisah.Osman, "Sikap terhadap sains dalam kalangan pelajar sains di peringkat menengah dan matrikulasi", *Pertanika Journal Social Sciences & Humanities,* vol. 14, pp. 131-147, 2006.

MOE, *TIMSS-2007 Trends In International Mathematics and Science Study - 2007*. Putrajaya: Ministry of Education, 2012. [18] IEA, *TIMSS (2007) International Science Report.* Chestnut Hill: IEA, 2008.

[IEA, *TIMSS (2011) International Science Report*. Chestnut Hill: IEA, 2012.

PISA, *Performance of U.S. 15-Year-Old Students in Reading, Mathematics, and Science Literacy in an International Context*. Washington, DC: U.S Department of Education, 2009.

MOE, "Strategies to Achieve the 60:40 Science/Technical:Arts Stream Policy Report," ed. Putrajaya: Ministry of Education, 2012.

K. Becker and K. Park, "Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis," *Journal of STEM Education: Innovations and Research,* vol. 12, pp. 23-37, 2011.

M. E. Sanders, "Integrative Stem Education as "Best Practice"," *Explorations of best practice in technology, design and engineering education,* vol. 2, pp. 102-117, 2012.

P. Fioriello. (2010, 18 January 2012). Understanding the basics of STEM education. Available: http://drpfconsults.com/understanding-the-basics-of- stem-education/

S. Papert, "Situating constructionism," in *Constructionism*, I. Harel and S. Papert, Eds., ed Norwood. NJ: Ablex, 1991.

Y. B. Kafai and M. Resnick, *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World*: Lawrence Erlbaum Associates, 1996.

S. L. Martinez and G. Stager, *Invent to Learn: Making, Tinkering, and Engineering in the Classroom*: Constructing Modern Knowledge Press, 2013. [28] T. Tyler-Wood, G. Knezek, and R. Christensen, "Instruments for assessing interest in STEM content and careers," *Journal of Technology and Teacher Education,* vol. 18, pp. 345-368, 2010.

N. M. Arsad, K. Osman, and T. M. T. Soh, "Instrument development for 21st century skills in Biology," *Procedia-Social and Behavioral Sciences,* vol. 15, pp. 1470-1474, 2011.