Science, Technology, Engineering, and Mathematics (STEM) as a Learning Approach to Improve 21st Century Skills: A Review

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Suci Fajrina (✉), Lufri Lufri, Yuni Ahda
Universitas Negeri Padang, Padang, Indonesia
sucifajrina20@yahoo.com

Abstract—Science, Technology, Engineering, and Mathematic (STEM) is an interdisciplinary approach where academic concept coupled with a lesson or problems that exist in the real world so that students can apply science, technology, engineering, and mathematics in a context that makes the relationship between the school, community, work, and global companies that will emerge the ability to compete in the 21st century integration of STEM in the classroom Form comprise of three, including: integrated content, supporting an integrated content, or integrated context, STEM in its application aims to develop thinking, reasoning, teamwork, investigation, and 21st century skills that can be used by students in all areas in their life,21st century skills to learn and innovate include critical thinking, creativity, communication, and collaboration known as the "Four Cs". This paper provides a comprehensive review of STEM as a learning approach to improve their skills, especially the skills of the 21st century "Four Cs" of the students. Skills "Four Cs" becomes one key to success is to be competitive in entering the era of information and knowledge.

Keywords—STEM, Learning Approach, 21st Century skills.

1 Introduction

US federal agencies to develop science, the National Science Foundation, states that 80% of workers will require human resources with competence Science, Technology, Engineering and Math (STEM). The US Bureau of Labor Statistics in 2011 explained that in the global scope in the next decade employment structure STEM will increase by 17%, while non-STEM jobs only increased by 10%. Therefore, STEM-based education is believed to create a young generation successor of the nation more competitive on a global scale [1]. STEM approach is that the teaching and learning content and practice of interdisciplinary knowledge covering science and mathematics through integrating engineering and design practices using the relevant technology engineering [2]. Using of information and communication technology in learning and train student can Enhance science process skills [3]. Integrating shape STEM classes comprise three, including: integrated content, supporting an integrated content, or integrated contexts [2].

Next Generation Science Standards identify learning science as issues related to the principles of the STEM. STEM, it is an approach to learning that is used to integrate elements of Science, Technology, Engineering and Mathematics in the learning process [2]. STEM education apply problem-solving based learning accidently put scientific investigation and application of mathematics in designing technology as problem solving. Scientific investigations are rare in technology education and technology design activity is rare in science classes. But in everyday life, design and scientific investigations are routinely applied simultaneously as a technical solution to real-world problems [4].

The United'm strated initiated education that develops STEM learning models. Besides American, STEM education widely adopted by several countries. In Taiwan, the learning curriculum was integrated with the STEM curriculum and make students as learning centers. Malaysia cooperated with the Americans by engaging students in the STEM fields to compete in the economy in the 21st century addition to the State, there are some countries that also have implemented STEM education, including Finland, Australia, Vietnam, China, and Philippines [5]. STEM has been developed in several countries and increasingly significant in recent years.

STEM in its application aims to develop thinking, reasoning, teamwork, investigation, and 21st century skills that can be used by students in all areas in their life, 21st century skills to learn and innovate include critical thinking, creativity, communication, and collaboration known as the "Four Cs". Skills "Four Cs" becomes key to success is to be competitive in the 21st century, so that every person should have the skills "Four Cs" in entering the era of information and knowledge [6]. Director-General of UNESCO conference in 2006 with the theme Building Creative Competencies for the 21st Century stated that the skills of the "Four Cs" be a way to provide solutions to global problems. Fisher stated that the skills of the "Four Cs" are essential for success in learning and success in life [7].

2 STEM Learning Approach

Next Generation Science Standards identify lessons biology as issues related to the principles of science, technology, engineering, and mathematics (STEM). STEM It is an approach to learning that is used to integrate elements of Science, Technology, Engineering and Mathematics in the learning process [2]. STEM education apply problem-solving based learning accidently put scientific investigation and application of mathematics in designing technology as a problem solving. Scientific investigations are rare in technology education and technology design activity is rare in science classes. But in everyday life, design and scientific investigations are routinely applied simultaneously as a technical solution to real-world problems [4].

How to support the implementation of activities in the form of habituation STEM, STEM approach in the classroom and give the task a project to learners [8]. Give the project to the students could make learners more quickly understand and address real-world problems. It bases this on critical thinking will support learners or people in the face of various problems it faces today through systematic thinking process [9].

STEM is an interdisciplinary approach where academic concept coupled with a lesson or problems that exist in the real world so that students can apply science, technology, engineering, and mathematics in a context that makes the relationship between the school, community, work, and global companies that will emerge the ability to compete in the new economy [10]. STEM in its application aims to develop thinking, reasoning, teamwork, investigative and creative skills students in all areas can use that in their life [11].

Science (S) explains the existence of objects and events, laws and principles of objects and events, and the relationship between them [12]. Technology is an innovation and modification of the natural environment to produce things that are needed and desired by humans [13]. Technology (T) can be e-books, or online encyclopedia that gives students direct access to find information or resources; probes, sensors and experiment set that allows students to collect data; social networks or websites that allow students access or contact an expert through online communication tools; presentation or video editing software that facilitates the students in making presentations; and recording or analysis software that allows students to expand their capabilities [14]. Engineering (E) is a research and development based on science to produce specific products to solve the problem [12]. Math (M) refers to the application of the formula, put the details in the design.

STEM has six special characteristics that distinguish it from other approaches, namely: a. STEM lessons focus on the problems that exist in the real world and to find a solution to solve the problem; b. STEM lessons guided by the engineering design process where the design comes from the student's own thinking in developing solutions to overcome the problems; c. STEM lessons engage students in productive teamwork; d. STEM subjects bring students into direct inquiry and open exploration of meaning in STEM subjects learning activities are open and there are limits; e. STEM lessons integrate math and science content so that students realize that science and mathematics subjects are not isolated, but to work together to solve the problem [11].

In addition, the emphasis STEM learning aspects include: asking questions of science and define problems, plan and carry out investigations, using mathematics; information and computer technology; and computational thinking, and gain, test, and communicate information [15]. It is basically very supportive when using project based learning. How to support the implementation of activities in the form of habituation STEM, STEM approach in the classroom and assign tasks to the project in the form of learners [8]. It bases this on critical thinking will support learners or in dealing with various problems it faces today through the systematic thinking process [9].

3 21st Century Skills

The development challenges of the 21st century, especially in education, is to prepare the young generation of flexible, creative, and proactive. Trilling and Fadel stated that to face the challenges of the 21st century one must possess the following skills:(1) life skills and career, (2) the skills to learn and innovate, and (3) the skills of media and

technology.Learning and innovating skills include critical thinking, creativity, communication, and collaboration (critical thinking, creative thinking, communication, and collaboration), otherwise known as "Four Cs" [16].

Director-General of UNESCO conference in 2006 with the theme Building Creative Competencies for the 21st Century stated that skills "Four Cs" be a way to provide solutions to global problems. Fisher stated that the skills of the "Four Cs" are essential for success in learning and success in life. Skills "Four Cs" prepare them with flexible skills that they need to face an uncertain future [7].

Critical thinking skills are reflective and reasoned way of thinking that is focused on decision-making to solve the problem. Critical thinking skill gives advantages to students both in the classroom, at work and in everyday life [17]. Ennis classifying critical thinking in five aspects, namely: (1) Provide an explanation, (2) Developing basic skills, (3) Make the inference, (4) Make further explanation, and (5) Set the strategy and tactics. The learning process should make the students can think critically by linking learning with contextual issues that exist in everyday life.

Creative thinking is a mental activity to build the idea / ideas in dealing with problems. It improves self-confidence, academic achievements, and career success. The creative thinking is complex and its measurement involving many aspects of flexibility, originality, fluency, elaboration, sensitivity and imagination [18]. Skills of creative thinking is a skill to find something new that has not existed before, are original, developed a variety of new solutions to every problem, and involves the ability to generate ideas that are new, varied and unique [19]. Creative means also do different things with other people that have their own characteristics [20]. Creativity needs to be trained from an early age that the students got used to create original work and distinctively. Education should create an environment where students can create and innovate, rather than dictated and intimidated by teachers. Teachers always should be a facilitator in accommodating creativity and innovations developed by the students. Creativity refers to the creation of an appropriate response in the form of ideas, products, or solutions to the open task. Creativity is a tendency to self-actualization and the potential for development [21]. The tendency of the character of creative behavior is an adventure, to accept the challenge, curiosity, imagination, and the authorities themselves. Barron and Harrington suggested that the qualities of a creator include the authority, confidence and tolerance differences between themselves and others [22]. Lubart and Sternberg found people with high creativity shows persistence when faced with obstacles, will to take reasonable risks, willing to grow, can tolerate the situation is unclear, it can accept a new experience, and have the independence, self-confidence. Thus, education and promotion of creativity in education is a significant problem [23].

Creation is using creative thinking to solve the problem [24]. Wallas suggested that psychological creativity process is divided into stages of preparation, incubation stage, the stage of clarification and verification stage. Thus, creative thinking is a series of processes, including perceived problems, make conjectures and hypotheses about the problem, looking for answers, present evidence, and finally report the results [25]. Treffinger, Isaksen and Stead-Dorvad proposed that, to solve creative problems, one must first create opportunities, explore the facts, prepare questions, developing resolutions, and set the reception [26].

However, Wu found that, when schools organize knowledge about creativity, they deliver such subject matter knowledge, and rarely allows students to personally experience the process and creative invention. If students can truly experience and sense of creativity, it will give you the key to inspire personal creativity [27]. Treffinger argues that creativity can be enhanced through the actual activity of thought and creative action [26]. If the creative thinking skills can be put into learning, students can shape and develop creative ideas and enhance their imagination,

Communication is an activity to transfer an information both orally and in writing [28]. Collaboration is the use of communicative skills to achieve a common goal, working productively with others, create a synergy, respect for others, and teamwork while generating ideas together [29]. When the learning process teachers should create a situation where students can sit together / group (team work), that will create a democratic atmosphere where students can sit appreciate differences of opinion, realized the mistake he made, and can foster a sense of responsibility in work responsibilities which is given. In addition, the students will learn from this situation about teamwork, leadership, obedience to authority, and flexibility in the work environment.

Complex problems such as globalization, technology, migration, international competition, the world market, political upheavals, changes in the environment and climate change, a major challenge that must be faced by learners. Therefore, it is necessary to develop the creativity of learners by providing a learning experience. One approach to learning that is considered equipping students with the skills "Four Cs" is a STEM learning approach. STEM learning approach is under the demands of the 21st century because it stimulates students to conduct scientific activities, solve real-world problems by designing their own questions, planning lessons, organizing research, and apply a variety of learning strategies [30], [31]. Implementation of the meta-cognitive learning strategies in information retrieval processes could help students become autonomous learners [18].

4 The Development of STEM

STEM literacy development is difficult. Required at least a decade to develop STEM education in a State [32]. It requires the first two years to start the STEM educational reforms to designing, developing, and implementing models of STEM learning units. Six years later to enter STEM education into the curriculum [5]. It requires the next two years for STEM continue reform items, namely to build school capacity in making continuous improvement of STEM education program [33], [34], [35].

The early phases of the development of STEM education require the participation of academicians of universities, especially for designing models of STEM-based learning unit effective implementation in the school or outside the school setting [36]. We expect graduate theses and dissertations in science education to Contribute to the development of models of STEM-based science learning units and learning tools proven its effectiveness based on scientific research-based class [37]. The research includes two stages important items, namely the stages of development and field testing phase [38]. The development phase includes an analysis of subject content in the science curriculum in

force, then started learning innovations that content, integrating technology (T), engineering (E), and mathematics (M) in it, so the prospects for the younger generation to Realize the STEM literacy [39]. Testing stage designs involve; experimentation to test the effectiveness of science teaching units (including teaching equipment and materials) based STEM started in a variety of school settings [40].

Contributions college at a later stage may include involvement in a suggestion of this research were the importance of integrating STEM education in the policies of the national curriculum, and competence development of teachers to Ensure the effectiveness of the implemented a STEM education According the applicable curriculum [41], [42], [43], [44], [45]. It involves support scientific research universities In These phases Necessary to Investigate the effectiveness STEM education on a wider scale in the school's development's capacity to manage STEM education.

The United'm excited that develops STEM education started learning models. Besides to the American, STEM education Widely Adopted by Several countries. In Taiwan, the learning curriculum was integrated with the STEM curriculum and the make students as learning centers. Malaysia cooperated with the Americans by engaging students in the STEM fields to Compete in the economy in the 21st century addition to the State, there are some countries that Also have implemented a STEM education, Including Finland, Australia, Vietnam, China, and Philippines [5]. It has developed STEM in Several countries during and increasingly significant in recent years.

It has STEM research carried out by the Researchers. STEM approach should stress the project design process by integrating elements of STEM to get the solution of real problems in life [12]. STEM approach Also Provides a good impact on the creativity of the students Because It requires students to integrate the various disciplines on the real problems in life [46]. To resolve problems related to learning, can we expect learners to identify, implement, and integrate STEM concepts to solve complex problems and make-creative problem solving and innovative.

Researchers have done some innovations of STEM in answering the shortage of STEM approach. Birney and McNamara developed a model of STEM + learning Career to create employment through community-based projects [47]. Ward developed a model of STEM + Education Outreach emphasizing the importance of goal-oriented learning or assessment [48]. Utami develop STEM + Animation based on local wisdom in learning physics [49]. Wu-Rorrer developed the STEAM program through community collaboration [50]. Innovations in STEM continues to grow today.

5 Conclusion

This paper provides a comprehensive review of STEM learning approach we can summarize: as a learning approach to enhance 21st century skills, especially skills "Four Cs" of the students.

a). STEM learning approach is a global movement of educational practice in which integrate with different patterns of integration to improve 21st century skills, especially skills "Four Cs" of the students.

b). STEM is not only used to describe an educational experience that integrates four disciplines, but also used to communicate the results of the teaching of science, technology, engineering and math. Thus, integrating the four disciplines, the role of engineering are frequently highlighted, while integrating it usually means connecting with the real context and to technology, the most widely used is usually associated with a virtual context.

c). Based on the debate surrounding the STEM approach, Researchers have brought together the vision of STEM approach to avoid a different angle than the actual essence. So that STEM is defined as "a learning approach that integrates content and skills for science, technology, engineering, and mathematics"

6 References

[1] National Science Foundation, *STEM Education Data and Trends*. Virginia: Eisenhower Avenue, 2012.

[2] Johnson, C.E. Carla, Erin, P. Burto, and Moore, J. Tamara, *STEM Road Map: A Framework for Integrated STEM Education*. New York: Routledge, 2016. https://doi.org/10.1080/00220671.2016.1253949

[3] Darmaji, Astalini, DA Kurniawan, H. Parasdila, Irdianti, "E-Module Based Problem Solving in Basic Physics Practicum for Science Process Skills," *International Journal of Online and Biomedical Engineering*, vol. 15, no. 15, pp 4-17, 2019. https://doi.org/10.3991/ijoe.v15i15.10942

[4] Sanders, Mark. "STEM, STEM Education, STEMmania," *Technology Teacher*, vol. 68, no. 4, pp 20-26, 2009.

[5] S. J. Lou, H. Y. Tsai, & K. H. Tseng, "STEM Online ProjectBased Collaborative Learning for Female High School Students," *Kaohsiung Normal University Journal*, vol. 30, pp 41–61, 2011.

[6] K. Labuske, J. Streb, "Technological creativity and cheap labour? Explaining the growing international competitiveness of German mechanical engineering before World War I," *German Economic Review*, vol.9, pp 65-86, 2008. https://doi.org/10.1111/j.1468-0475.2008.00422.x

[7] R. Fisher, *Teaching Children to Think (2nd ed.)*. Cheltenham, UK: Nelson Thornes Ltd, 2015.

[8] F.I Anggraini, S. Huzaifah, "Implementasi STEM dalam Pembelajaran IPA pada Sekolah Menengah Pertama," Seminar Nasional Pendidikan, vol. 1, no. 1, pp 722-731, 2017.

[9] C.P. Bhakti, A. N. G. Ghiffari, S. M. Regita, "Strategy of Core Curriculum to Improving Student's Critical Thinking Skill," *Teraputik: Jurnal Bimbingan dan Konseling*, vol. 1, no. 3, pp 176-182, 2018. https://doi.org/10.26539/1374

[10] N. Tsupros, R. Kohler, and J. Hallinen, *STEM education: A project to identify the missing components.* Pennsylvania: Intermediate Unit 1 and Carnegie Mellon, 2009.

[11] A. Jolly, Six Characteristics of a Great STEM Lesson. 2014. https://www.edweek.org/tm/articles/2 014/06/17/ctq_jolly_stem.html [Accessed 25 Aug 2019].

[12] R. Capraro, S. Slough, *Why PBL? Why STEM? Why now?*. Rotterdam: Sense Publisher, 2013.

[13] W. E. Dugger, "Evolution of STEM in the United States," *In 6th Biennial International Conference on Technology Education Research in Australia*. 2010. Retrieved from http://www.iteea.org/Resources/PressRoom/AustraliaPaper.pdf.

[14] B.C Bruce, J. A. Levin, "Educational Technology: Media for Inquiry, Communication, Construction, and Expression," *Journal of Educational Computing Research*, 17(1), 79–102, 1997. https://doi.org/10.2190/7hpq-4f3x-8m8y-tvca
[15] J. Afriana, A. Permanasari, A. Fitriani, "Penerapan Project Based Learning Terintegrasi STEM untuk Meningkatkan Literasi Sains Peserta Didik ditinjau dari Gender," *Jurnal Inovasi Pendidikan IPA*, 2(2): 202-212, 2016. https://doi.org/10.21831/jipi.v2i2.8561
[16] B. Trilling, C. Fadel, "21st Century Skills: Learning for Life in Our Times," *John Wiley & Sons*, 978-0-47-055362-6, 2009.
[17] R. H. Ennis, *Critical Thinking. University of Illinois.* Prentice Hall, Inc. Upper Saddle River, New Jersey, 1996.
[18] E. Mitsea, A. Drigas, "A Journey into the metacognitive Learning Strategies," *International Journal of Online and Biomedical Engineering*, vol. 15, no. 14, pp 4-20, 2019.
[19] C. C. Leen, H. Hong, F. F. H. Kwan, T. W. Ying, *Creative and Critical Thinking in Singapore Schools*. Singapore: National Institute of Education, Nanyang Technological University, 2014.
[20] E. Delen, F. Kaya, "Creativity in the primary classroom," *European Journal of Teacher Education*, vol. 36, no. 2, pp 233-235, 2013.
[21] C. R. Rogers, :A theory of therapy, personality, and interpersonal relationships, as developed in the client-centered framework," *Psychology: A Study of a Science*, vol. 3, pp 184-256, 1959.
[22] F. Barron, D. M. Harringtion, "Creativity, intelligence, and personality," Annual Review of Psychology, vol. 32, pp 439-476, 1981.
[23] T. Lubart, R. Sternberg, *Defying the crowd. Cultivating creativity in a culture of conformity.* New York: Free Press, 1995.
[24] J. Dewey, "The experimental theory of knowledge," Mind, vol. 15, pp 293- 307, 1906.
[25] G. Wallas, *The art of thought*. London: Cape, 1926
[26] D. J. Treffinger, S. G. Isaksen, K. B. Stead-Dorval, *Creative problem solving: An introduction.* Prufrock Pr, 2005.
[27] J. J. Wu, *Enticing the crouching tiger and awakening the hidden dragon: Recognizing and nurturing creativity in Chinese students*. Taipei: Development and Practice of Creativity, 2002.
[28] L. Breslow, "The pedagogy and pleasures of teaching a 21 st - Century Skill," *European Journal of Education*, vol. 50, no. 4, pp 420-439, 2015.
[29] S. Bell, "Project-based Learning for the 21 st Century: Skills for the Future," *Clearing House*, vol. 83, no. 2, pp 39-43, 2010.
[30] BIE. *Introduction To Project Basic*. USA: Buck Institude for Education, 2013.
[31] A. Patton, *Work that Matters The Teacher's Guide to Project Based Learning*, Paul Hamlin Foundation, U.K, 2012
[32] R. W. Bybee, "Advancing STEM education: A 2020 vision," *Technology and Engineering Teacher, vol. 70*, no. 1, pp 30-35, 2010.
[33] M. Barak, M. Assal, "Robotics and STEM learning: Students' achievements in assignments according to the P3 Task Taxonomy—practice, problem solving, and projects," *International Journal of Technology and Design Education*, vol. 28, no. 1, pp 121-144, 2018. https://doi.org/10.1007/s10798-016-9385-9
[34] M. Duran, M. Höft, D. B. Lawson, B. Medjahed, E. A. Orady, "Urban high school students' IT/STEM learning: Findings from a collaborative inquiry- and design-based afterschool program," *Journal of Science Education and Technology*, vol. 23, no. 1, pp 116–137, 2014. https://doi.org/10.1007/s10956-013-9457-5

[35] C. Kim, D. Kim, J. Yuan, R. B. Hill, P. Doshi, C. N. Thai, "Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teachin," *Computers and Education*, vol.91, pp 14–31, 2015. https://doi.org/10.1016/j.compedu.2015.08.005

[36] S. E. August, M. L. Hammers, D. B. Murphy, A. Neyer, P. Gueye, R. Q. Thames, "Virtual engineering sciences learning lab: Giving STEM education a second life," *IEEE Transactions on Learning Technologies*, vol. 9, no. 1, pp 18–30, 2016. https://doi.org/10.1109/tlt.2015.2419253

[37] D. L. Blustein, M. Barnett, S. Mark, M. Depot, M. Lovering, Y. Lee, D. DeBay, "Examining urban students' constructions of a STEM/career development intervention over time," *Journal of Career Development*, vol. 40, no. 1, pp 40–67, 2013. https://doi.org/10.1177/0894845312441680

[38] F. Caglar, S. Shekhar, A. Gokhale, S. Basu, T. Rafi, J. Kinnebrew, G. Biswas, G, "Cloud-hosted simulation-as-a-service for high school STEM education," *Simulation Modelling Practice and Theory*, vol. 58, pp 255–273, 2015. https://doi.org/10.1016/j.simpat.2015.06.006

[39] L. D. English, D. King, J. Smeed, "Advancing integrated STEM learning through engineering design: Sixth-grade students' design and construction of earthquake resistant buildings," *Journal of Educational Research*, vol. 110, no. 3, pp 255–271, 2017. https://doi.org/10.1080/00220671.2016.1264053

[40] M. A. Evans, M. Lopez, D. Maddox, T. Drape, R. Duke, "Interest-driven learning among middle school youth in an out-of-school STEM studio," *Journal of Science Education and Technology*, vol. 23, no. 5, pp 624–640, 2014. https://doi.org/10.1007/s10956-014-9490-z

[41] R. Lamb, T. Akmal, K. Petrie, "Development of a cognition-priming model describing learning in a STEM classroom," *Journal of Research in Science Teaching*, vol. 52, no. 3, pp 410–437, 2015. https://doi.org/10.1002/tea.21200

[42] P. D. Marle, L. Decker, V. Taylor, K. Fitzpatrick, D. Khaliqi, K. E. Owens, R. M. Henry, "CSI-chocolate science investigation and the case of the recipe rip-off: Using an extended problem-based scenario to enhance high school students' science engagement," *Journal of Chemical Education*, vol. 91, no. 3, pp 345–350, 2014. https://doi.org/10.1021/ed3001123

[43] J. McLurkin, J. Rykowski, M. John, Q. Kaseman, A. J. Lynch, "Using multi-robot systems for engineering education: Teaching and outreach with large numbers of an advanced, low-cost robot," *IEEE Transactions on Education*, 56(1), 24–33, 2013. https://doi.org/10.1109/te.2012.2222646

[44] R. B. Toma, I. M. Greca, "The effect of integrative STEM instruction on elementary students' attitudes toward science," *Eurasia Journal of Mathematics, Science and Technology Education*, 14(4), 1383–1395, 2018. https://doi.org/10.29333/ejmste/83676

[45] K. H. Tseng, C. C. Chang, S. J. Lou, W.P. Chen, "Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment," *International Journal of Technology and Design Education*, vol. 23, no. 1, pp 87–102, 2013. https://doi.org/10.1007/s10798-011-9160-x

[46] S. Hanif, "Enhancing Students' Creativity through *STEM* Project-Based Learning," *Journal of Science Learning*, vol. 2, no. 2, pp 50-57, 2019.

[47] L. Birney, D. McNamara, C. Sanders, H. Luintel, J. Penman, "Curriculum and Community Enterprise for Restoration Sciences: The Expansion and Future of the Model," *International Research in Higher Education*, vol. 3, no. 4, pp 1-11, 2018. https://doi.org/10.5430/irhe.v3n4p1

[48] A. Ward, "Promoting Strategic STEM Education Outreach Programming Using a Systems-based STEM-EO Model," *Research Management Review*, vol. 20, no. 2, 2018.

[49] S. I. Utami, R. R. Septiyanto, F. C. Wibowo, A. Suryana, "Pengembangan Stem-A (Science, Technology, Engineering, Mathematic And Animation) berbasis Kearifan Lokal dalam Pembelajaran Fisika," *Jurnal Ilmiah Pendidikan Fisika Al-BiRuNi*, vol. 06, no. 1, pp 67-73, 2017. https://doi.org/10.24042/jpifalbiruni.v6i1.1581

[50] W. Rorrer, "Developing STEAM Programs for Middle School Girls Through Community Collaborations," *Technology and Engineering Teacher*, vol. 79, no. 3, pp 8-13, 2019.

7 Authors

Suci Fajrina is student of doctoral program in education at State University of Padang, Padang - Indonesia. Email id: sucifajrina20@yahoo.com

Lufri Lufri is a professor of biology education, State University of Padang, Padang - Indonesia.

Yuni Ahda works at Department of Mathematics and Natural Sciences State University of Padang, Padang - Indonesia. Email id: yuniahda@yahoo.com

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