https://cejsr.academicjournal.io

Integrated Stem Education Curriculum and Pupils Learning in Tubah Sub Division, Mezam Division, North West Region, Cameroon

Chongwain Lilly Oyoma Jehovah
University of Bamenda, Cameroon

ABSTRACT

Integrated STEM education approach combines the subject matter of two or more STEM subjects into a joint learning experience. This approach recognises that each STEM subject has overlapping, shared skills to offer. This work seeks to assess the impact of implementation of an integrated STEM education on pupils learning in the North West Region of Cameroon. The specific objective of the study was to find out the effect of content, teaching methods, teaching materials and evaluation strategies of integrated STEM education curriculum on pupils learning. The research methodology was a survey research design. The data was obtained from a 4-point Likert scale questionnaire and analysed using the statistical package for social sciences (SPSS) and hypothesis was tested with the T-test. The results show that there is a strong positive relationship between integrated STEM education curriculum and pupils" learning. It was recommended that primary school teachers should endeavour to master integrated STEM education curriculum and implement it in their classroom.

KEYWORDS: *Integrated STEM Education Curriculum. Content, Teaching Methods, Teaching Materials and Evaluation Strategies.*

Introduction

STEM stands for Science, Technology, Engineering and Mathematics. Each subject is part of the greater whole of the lesson plan as the concepts work together. Integrated STEM education is an effort to combine science, technology, engineering, and mathematics into one class that is based on connections between the subjects and real world problems. It involves intentionally integrating the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education. Making crosscutting STEM connections is complex, and according to Kelley & Knowles (2016), requires that teachers teach STEM content in deliberate ways so that learners understand how STEM knowledge is applied to real-world problems.

Integrated STEM is an interdisciplinary approach to instruction that enables knowledge use in real life. In this approach to integration, teachers organize the curriculum around common learnings across disciplines which is about the important thing since it gives children the opportunity to improve the learning process (Debora, 2015). This approach recognizes that each STEM subject has overlapping, shared skills to offer. Making crosscutting STEM connections according to Kelley & Knowles (2016) is complex and requires that teachers teach STEM content in deliberate ways in order that learners understand how STEM knowledge is applied to real-world problems. Sanders, (2009) is of the view that, integrated STEM education is the key to making learning more connected and relevant for learners. It nurtures the interest that already exists which is important for learners at both early or basic and middle or secondary levels of the schooling process. It helps in the development of more effective, scientifically based, and technologically sound methods and solutions. According to Furner & Kumar (2007), integrated STEM education provides relevant opportunities that stimulating experiences for learners. It provides an integrated effort that removes the traditional barriers between the subjects. Jacobson- Lundeberg, (2016) is of the opinion that

pupils need to be equipped with content knowledge as well as soft skills. These "soft skills" can be acquired by learner when they are exposed to integrated STEM education (Jacobson- Lundeberg, 2016). Soft skills are also known as 21st century learning skills that have been defined as adaptability, complex communication/social skills, non-routine problem-solving skills, self-management self-development, and systems thinking (Hilton, 2010).

Statement of the Problem

Integrated STEM education puts together the common learnings embedded in its disciplines to emphasize interdisciplinary skills and concepts. Children need to be exposed to STEM education at an early level, since it prepares and makes them to understand STEM concepts better in their latter academic career. The understanding and a liking for a particular subject matter that learners have at an early age, helps to develop their brains. (Kennedy and Odell,2014); (Kelley & Knowles, 2016). It is important to introduce children early to STEM process when their brains are young and able to take in new information. Hence, the earlier educators put integrated STEM lessons into their curriculum, the easier it is for pupils to develop an interest for future STEM related jobs. Hardy, Jonen, & Moller, (2006) are of the view that STEM subjects maybe difficult for learners at the lower level to understand because the content may be abstract, coupled with teaching methods and activities that are not commensurate to the age group concerned. Teaching pupils STEM subjects increases the tendency that they will continue to be interested in the subjects and build a career in a STEM area (DeJarnette, 2012). Pupils may not be able to fully grasp abstract concepts however, when they are allowed to experiment using concrete materials and interesting activities, the concepts become familiar and interesting to them Hardy, Jonen, & Moller, (2006). Integrated STEM education is one way of teaching related concept in primary school science subjects, such that related topics are taught in an integrated manner which enables the pupils to have a better understanding of the knowledge, skills and attitude embedded in the lesson. This study therefore intends to find out the impact of integrated STEM curriculum on pupils learning.

Review of Literature

Integrated STEM education fosters creativity and divergent thinking. It motivates and inspires children to generate new technologies and ideas. With a focus on practice and innovation, students are able to learn from inquiry-based assignments. Integrated STEM education gives an understanding of concepts and encourages knowledge application. Students are free to exercise what they learn and embrace mistakes which equips them to respond to real-world problems. According to Ramnarain (2014), integrated STEM curriculum is linked to inquiry-based learning and teachers need a strong level of knowledge of both the subject and pedagogy of inquiry-learning to successfully teach their pupils during the elementary years as they are driven by curiosity, a belief in their abilities, a thirst for knowledge, and a passion to grow.

Constructivism Learning Theory

Constructivism and cognitive learning theories form the basis of pupils learning of STEM has roots in, and research by Holmlund et al. (2018) use the idea of construction of knowledge as their basis. Jean Piaget, Lev Vygotsky, and John Dewey are major proponents of constructivism camp. STEM education research clearly points to effective pedagogical approaches that are part of constructivist pedagogy (Brau, 2018; Kelly & Knowles,2016; Ramirez-Montoya,2017; Rosicka,2016; Holmlund et al and Hamdi, 2018). They are of the view that teachers who put constructivism as a learning theory into practice solve real-world problem, by helping learners through their own acquired knowledge and personal experience. Bell (2016) discovered, that teachers will be able to provide integrated STEM education when learners are better able to construct knowledge by their self and for themselves.

Piaget's cognitive theory explores how children create knowledge through the interaction between

their experiences and ideas (Mayer 2008; Schunk, 2012; Ibrahim, 2017). He identified the processes of accommodation and assimilation which focuses on how learning occurs. Dewey's work proclaims that learners who engage in real world activities will be able to demonstrate higher levels of knowledge through creativity and collaboration (Behling & Hart, 2008). Vygotsky focused on the social aspects of acquiring knowledge. He suggests that one learns best through interacting with peers. Social constructivism has a great impact on instruction and curriculum design because of its relevance in curriculum integration approaches (Schunk, 2012; Ibrahim, 2017). This will include employing problem solving methods which leads to high student active learning, and learner centred teaching in appropriate environments. Kelly & Knowles (2016) supports situated cognition theory as an important aspect of student learning. Learning environments whether physical or social, promote the development of knowledge, skills and attitude in learners. Chongwain (2020) is of the view that school authorities should initiate programmes that will encourage and motivate learners as they study together in groups by introducing hands on and outdoor activities. Strawhacker & Bers (2019), focused their research on Piaget's constructivism where learners are expected to use both their senses, and real objects, to construct knowledge.

STEM Education Curriculum

Teaching STEM subjects in the most effective way can require non-traditional approaches to learning. STEM education curriculum involves strengthening discipline-based content learning, enhancing discipline-based integration, and preparing for the innovation-driven integration (Zhi Hong Wan, Yushan Jiang & Ying Zhan, 2020). Integrated STEM de-emphasizes the teacher learning content just to teach, and more about providing an environment that encourages creativity. Ramírez-Montoya (2017), says that integrative instruction allows learners to explore greater depths of the STEM subjects by utilizing the skills learned. This enables them to master the facts, principles and theories. Integrative STEM education is meant to engage all students in learning by promoting, investigative hands-on activities and transfer of learning to several subjects and contexts since the learners are able to explore and have their own experience. (Pedaste et al., 2015). Children's STEM learning opportunities can be enhanced and developed by engaging them in critical thinking skills, using learner-centred methods and teacher-learner interactive method which are very useful in teaching children. According to Endeley & Zama (2021), these methods enhances the needs and interest of learners. These teaching methods include the play way method which according to Jamison (2021), consists of pleasure and satisfaction, small group instruction, student-centred / constructivist approach, project-based learning, Montessori, inquiry-based learning, flipped classroom, and cooperative learning. The integrative STEM approach to education motivates and inspires learners to generate new ideas by participating in class discussions, answering questions, and sharing ideas. It focusses on practice, learning from inquiry-based assignments, teaches critical thinking skills, builds creativity, and instils a passion for divergent thinking which leads to innovation.

Children love to experiment, they love to pour and mix liquids, put things together, build, scatter, collect, and play while learning. They most often carry out STEM activities both at school and at home without knowing it. Teachers only need to look for additional opportunities to build STEM activities into their daily school work routine in an organized way. Satchakett & Thana (2019), are of the view that STEM activities are great because they can be adjusted to suit different age ranges, abilities, group sizes and interests. When children are deeply vested in a topic, they are more engaged and willing to experiment. STEM learning activities brings benefits to all learners, at all levels of ability, creating truly inclusive and effective learning opportunities Margot, & Kettler, (2019). Their adaptability is part of what makes them so great to use in teaching and learning environments. There are also many possibilities with STEM activities, and their practical nature makes the pupils to feel like they are playing games. Hence they are more engaged in the learning environment and therefore, will not get bored easily.

Assessment of learners in STEM lessons, is challenging since traditional methods such as examinations and short tests do not generally apply in practical approach to learning (Daud, et al. 2012). There are many types of assessment strategies that are used within STEM inquiry classrooms, and the focus is on observing, developing, and improving inquiry competencies. Grangeat, et al. (2021). Formative assessment checks learners progress, it provides ongoing feedback which is designed to improve teaching and learning, helps learners to identify their strengths and weaknesses, thereby improving the learning process. It also helps teachers to recognise common areas where they have difficulties which can easily be corrected (Yakob, et al. 2021). Hence, formative assessment is very useful for STEM learning because it's closer to how real-world scenarios play out, it encourages active engagement in lessons. Summative assessments, such as examinations, discourage learners who are slow. This can be the case particularly in science subjects where written tests can be very difficult. Practical examinations in laboratory/workshop, school agricultural gardens, geographical gardens, as well as portfolios should be encouraged. Yakob, et al. (2021), is of the view that integrative STEM-based science performance assessment result in the improvement of learning. Integrative STEM education needs to focus more on practical, creative and problem-solving content, teaching methods, learning activities and assessment process.

Research Questions

- What is the effect of the content of integrated STEM education on pupils learning?
- What is the effect of teaching methods of integrated STEM education on pupils learning?
- What is the effect of teaching materials of integrated STEM education on pupils learning?
- What is the effect of evaluation strategies of integrated STEM education on pupils learning?

Research Hypotheses

Ha_1: The content of integrated STEM education has significant effect on pupils learning.

Ha_2: Teaching methods of integrated STEM education has significant effect on pupils learning.

Ha_3: Teaching materials of integrated STEM education has significant effect on pupils learning.

Ha_4: Evaluation strategies of integrated STEM education has significant effect on pupils learning.

Methodology

The research methodology is a survey research design. The study was carried out using a sample of 40 pupils. The data was collected using a 4-point Likert scale questionnaire and analysed using the statistical package for social sciences (SPSS). The data was collected from class five pupils of four primary institutions in Bambili. The results and findings obtained from this research was guided by the four hypotheses. The data was subjected to t- test for comparisons of two means. When the level of significance was less than 0.05, the null hypothesis was rejected in favour of the research hypothesis.

Hypothesis Testing:

Hypothesis 1: The content of integrated STEM education has an effect on pupils learning.

Table 1: Effect of Integrated STEM Education Content on Pupil Learning

One-Sample T-Test						
	Test Value = 2.55					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
We are taught Health Education as a subject	-61.000	39	.000	-1.52500	-1.5756	-1.4744
We are taught Environmental Science	-13.372	39	.000	-1.40000	-1.6118	-1.1882

My teacher teaches Home Economics as a subject	-34.972	39	.000	-1.47500	-1.5603	-1.3897
Mathematics is an important subject	-18.484	39	.000	-1.45000	-1.6087	-1.2913
The teacher sometimes mixes Home Economics with Environmental Science	5.792	39	.000	.85000	.5532	1.1468
The Health Education lessons are sometimes mixed with E. Science lessons	7.054	37	.000	.95000	.6771	1.2229

From table 1 above, it can be seen that all values of the sig. (2-tailed) are smaller than the p value (0.05) hence the null hypothesis is rejected. This implies that the content of integrated STEM education has an effect on pupils learning ability.

Hypothesis 2: Teaching methods of integrated STEM education has an effect on pupils learning

From the table 2 below, it can be seen that "teachers ask students to solve mathematics on the board" has a higher p value than the standard p value which means, the teaching method of mathematics has no effect on the integrated STEM learning ability of the pupils. Table 2 shows that the rest of the variables have a positive effect on the learning ability of the pupils. The other factors such as visual displays, explaining, asking pupils' questions and letting pupils ask question all seem to reject the null hypothesis from their p values which are all lower than 0.05. Finally looking at how well the teacher draws diagrams, it can be seen that it has no effect on the learning ability of the pupils. From table 2 below, the teaching methods of integrated STEM education has an effect on pupils learning.

Table 2: Effect of Integrated STEM Education Teaching Method on Pupil Learning

One-Sample T-Test						
	Test Value = 2.55					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
My teacher explains Mathematics very well	-15.142	39	.000	-1.35000	-1.5303	-1.1697
The teacher asks us to solve Mathematics on the blackboard	-2.527	39	.016	-.40000	-.7202	-.0798
My teacher explains a lot when teaching	-26.660	39	.000	-1.47500	-1.5869	-1.3631
My teacher always asks us if we have questions	-61.000	39	.000	-1.52500	-1.5756	-1.4744
My teacher asks a lot of questions in class when teaching	-7.585	39	.000	-.97500	-1.2350	-.7150
The teacher draws very beautiful diagrams when teaching	-9.905	39	.000	-1.00000	-1.2042	-.7958

Table 3 below shows the effects of the teachings materials of integrated STEM education has on the learning ability of pupils. The p values of the variables materials used by teachers for teaching, diagrammatic representations, charts, food items and practical work is below 0.05 which means the null hypothesis of the testing has been rejected. Therefore, the teaching materials of integrated STEM education has an effect on pupils learning. The other variables like teacher using physical objects and charts of the various body parts have a p value above the standard p value of 0.05 which means that these variables don't affect the pupils learning ability.

https://cejsr.academicjournal.io

Hypothesis 3: Teaching materials of integrated STEM education has an effect on pupils learning.

Table 3: Effect of Integrated STEM Education Teaching Methods on Pupil Learning

One-Sample T - Test						
	Test Value = 2.55					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
The teacher uses different materials when teaching	-6.161	39	.000	-.82500	-1.0959	-.5541
The teacher draws very beautiful diagrams when teaching	-9.905	39	.000	-1.00000	-1.2042	-.7958
My teacher uses real things in teaching ES and Mathematics	-.992	38	.328	-.16538	-.5030	.1723
The teacher uses pictures of the parts of the body to teach us	-1.797	39	.080	-.30000	-.6378	.0378
Charts showing different types of food are used for teaching in my class	3.797	38	.001	.57821	.2700	.8864
My teacher sometimes brings food stuff to explain the lesson	6.068	38	.000	.88590	.5903	1.1815
We are sometimes asked to make dust bins and other things as assignments for ES	3.547	39	.001	.65000	.2793	1.0207

Hypothesis 4 examines the evaluation strategies used by teachers and how it affects the learning ability of the pupils. From the variables, assignments, pop quizzes and examination we can see that all their p values are below 0.05 which means we reject the null hypothesis for these variables. The variables with a p value greater than 0.05 are pop quizzes, practical works. Overall the hypothesis tested concludes that evaluation strategies of integrated STEM education have an effect on pupils learning.

The graph that appear above further illustrated the hypothesis of the study. This graph (figure 4) shows that the observed cumulative probability of the outcome or expected results are similar to the expected probability which means all the hypotheses of the study were verified as correct.

Hypothesis 4: Evaluation strategies of integrated STEM education has an effect on pupils learning

Table 4: Effect of Integrated STEM Education Evaluation Strategies on Pupil Learning

One-Sample Test						
	Test Value = 2.55					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
My teacher always gives Mathematics assignments	-11.222	39	.000	-.97500	-1.1507	-.7993
I do my Mathematics homework easily	-6.667	38	.000	-.72949	-.9510	-.5080
I never know when the teacher will give a test	.553	39	.584	.10000	-.2661	.4661
My teacher gives practical work in Home Economics as assignment	-.264	39	.793	-.05000	-.4332	.3332
The teacher always tells us when we will write examination	-13.042	39	.000	-1.30000	-1.5016	-1.0984
My teacher ask us to do practical work in Environmental Science, Health Education and Home Economics for examinations	-.246	38	.807	-.03718	-.3426	.2683

Summary of Findings

- The content of integrated STEM education has an effect on pupils learning ability.
- The teaching methods of integrated STEM education has an effect on pupils learning.
- The teaching materials of integrated STEM education has an effect on pupils learning.
- Evaluation strategies of integrated STEM education have an effect on pupils learning.

Discussions

From table 1, the content of integrated STEM education has an effect on pupils learning ability. Jacobson- Lundeberg, (2016) and Furner & Kumar (2007), are of the view that pupils need to be equipped with content that are less fragmented which is what integrated STEM education provides for learners.

Mathematics teaching method of has no effect on the integrated STEM learning ability of the pupils in science. Table 2 shows that factors such as explaining, asking pupils' questions and letting pupils ask question has a positive effect on the learning ability of pupils. This is confirmed by Jamison (2021), who says that teaching methods such as play way method which consists of pleasure and satisfaction inspires learners to generate new ideas. Small group instruction, project-based learning, Montessori method are teaching methods that suit the ages of the learners (Endeley & Zama 2021).

From hypothesis three, teaching materials used by teachers for teaching, such as diagrammatic representations, charts, food items and practical work has an effect on pupils learning. Hardy, Jonen, & Moller, (2006) supports this finding. He is of the view that pupils may not be able to fully grasp abstract concepts but when they are allowed to experiment using concrete materials and interesting activities, the concepts become familiar and interesting to them. Therefore, the use of teaching materials will promote integrated STEM education.

From table 4, evaluation strategies of integrated STEM education have an effect on pupils learning. Yakob, et al. (2021), is of the view that integrative STEM-based science performance assessment result in the improvement of learning. This include practical examinations in laboratory/workshop, school agricultural gardens, geographical gardens, as well as portfolios assessment.

Conclusion

This study investigated the impact of integrated STEM curriculum on pupils learning. It was aimed at equipping teachers who have low self-efficacy in science instruction with the knowledge required so that may have positive experiences of other teachers who have used the integrated STEM curriculum in teaching their pupils. This will increase the primary school teachers' willingness to try to use the STEM curriculum (Holzberger, Philipp, & Mareike, 2013). Integrative STEM education needs to focus more on practical, creative and problem-solving content, teaching methods, learning activities and assessment process.

Recommendations

- Inspectors, delegates, and directors of Education need to come together to revise primary school Science syllabuses and schemes of work for teachers to use in order to design integrated STEM specific lesson objectives.
- SMART objectives must be laid out to guide the teaching and learning process of integrated science at the primary school level.
- Well developed and useful teacher in-service training needs to be conducted to train educators how to design an integrated STEM curriculum.
- Individual schools need to provide resources and materials and storage area for equipment and materials.

References

1. Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education, 26*(1), 61–79. https://doi.org/10.1007/s10798-015-9300-9
2. Brau, B. (2018). Constructivism. In R. Kimmons, The Students' Guide to Learning Design and Research. EdTech Books. Retrieved from https://edtechbooks.org/studentguide/constructivism
3. Chongwain, L. (2020). Teaching methods and materials influence on students' vocational orientation in general secondary education. *African Journal of Social Sciences* 2. Vol.11, Number 9.
4. Daud, A. M, Omar, J., Turiman, P., & Osman, K. (2012). Creativity in Science Education," *Procedia - Social and Behavioral Sciences,* Vol. 59, pp. 467–474.
5. Debora, D. (2015). Self-learning in teacher's performance. *Indonesian Journal of Educational Review*, 2, 2, 38-45
6. Drake, S. (1991). How Our Team Dissolved the Boundaries. *Educational Leadership*, vol. 49 (2).
7. Drake, S. & Burns, R. (2004). *Meeting Standards Through Integrated Curriculum*. U.S.: Alexandria, Va.
8. Drake, S. & Reid, J. (2010). What Works? Research into Practice. Available at: http://www.edu.gov.on.ca/eng/literacynimeracy/publications.html
9. Endeley, M. & Zama, M., (2021). *Perspectives in curriculum studies.* Spear Books. Denver CO. ISBN: 9781942876823
10. Furner, J., & Kumar, D. (2007). The mathematics and science integration argument: a stand for teacher education. *Eurasia Journal of Mathematics, Science &Technology*, 3(3), 185–189.
11. Hamdi, S. (2018). A Comparison of Teacher-Centred and Student-Centred Approaches in Educational Settings. *International Journal of Social Sciences & Educational Studies*. 5. 10.23918/ijsses.v5i1p164.
12. Hardy, I., Jonen, A., & Moller, K. (2006). Effects of instructional support within constructivist learning environments for elementary school students' understanding of floating and sinking. *Journal of Educational Psychology*, 98(2), 307–326. doi:10.1037/0022-0663.98.2.307
13. Holmlund T.D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International Journal of Stem Education, 5*(1), 32–51. https://doi.org/10.1186/s40594-018-0127-2
14. Holzberger, D., Philipp, A., & Mareike, K. (2013). How teachers' self-efficacy is related to instructional quality: A longitudinal analysis. *Journal of Educational Psychology,* 105(3), 774–786. doi:10.1037/a0032198
15. Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K–12education: Status, prospects, and an agenda for research.* Washington, DC: The National Academies Press. doi:10.17226/18612
16. Hilton, M. (2010). Exploring the intersection of science education and 21st century skills: A workshop summary. Washington, DC: The National Academies Press. doi:10.17226/12771
17. Ibrahim, A. (2017). Vygotsky's Social Constructivists Theory of Learning. https://mmls.mmu.edu.my/wordpress/1161403286/wpcontent/uploads/sites/35482/2017/09/Vygotsky%E2%80%99s-Social-Constructivists-Theory-of-Learning.pdf
18. Jacobson-Lundeberg, V. (2016). Pedagogical implementation of 21st century skills. *Educational*

Leadership and Administration: Teaching and Program Development, 27, 82–100.

19. Keith, K. (2018). Case Study: Exploring the Implementation of an Integrated STEM Curriculum Program in Elementary First Grade Classes (Thesis, Concordia University, St. Paul). Retrieved from https://digitalcommons.csp.edu/cup_commons_grad_edd/197
20. Kelley, T. R. & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. International *Journal of STEM Education* volume 3, Article number: 11 https://doi.org/10.1186/s40594-016-0046-z
21. Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International,* 25(3), 246–258. Google Scholar
22. Pedaste, M., Maeots, M., Siiman, L. A., de Jong, T., van Riesen, A. A.N., Kamp, E. T., Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47–61. doi: 10.1016/j.edurev.2015.02.003
23. Laksmiwati, Pasttita & Salmah, Ummy & Sri Padmi, Russasmita. (2017). F_M_4_PAL Investigating Mathematics Teachers' Knowledge and Beliefs of STEM Education.
24. Margot, K.C., Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *IJ STEM Ed* **6,** 2 https://doi.org/10.1186/s40594-018-0151-2
25. Mayer, S. J. (2008). Dewey's dynamic integration of Vygotsky and Piaget. *Education and Culture,* 24(2), 6-24.
26. Mustafa, N., Ismail, Z., Tasir, Z., Said, M. and Haruzuan, M. N. (2016). A meta-analysis on effective strategies for integrated STEM education. *Advanced Science Letters*, 22(12), 4225-4228. https://doi.org/10.1166/asl.2016.8111
27. Nadelson, L. S. & Seifert, A. L. (2017). Integrated STEM defined: Context, challenges, and the future. *Journal of Educational Research,* 110(3), 221-223. doi.org/10.1080/00220671.2017.1289775
28. Ramnarain, U. D. (2014). Teachers' perceptions of inquiry-based learning in urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in South Africa. Teaching and Teacher Education, 38, 65–75. DOI: 10.1016/j.tate.2013.11.003
29. Ramírez-Montoya, M.S. (2017). Training Educational Researchers in Science and Mathematics: A case study through a binational workshop Mexico-UK. En Ramírez Montoya, M.S. (Coord.). Handbook of Research on Driving STEM Learning with Educational Technologies (pp. 1- 21). EEUU: IGI Global. http://www.igiglobal.com/chapter/training-educational- researchers-in-science-and-mathematics/176993
30. Ramírez-Montoya, M.S.; Loaiza-Aguirre, M.I.; Zúñiga-Ojeda, A.; Portuguez-Castro, M. (2021). Characterization of the Teaching Profile within the Framework of Education. Future Internet 2021, 13, 91. DOI: 10.3390/fi13040091 (Problem solving in teaching environments)
31. Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, Dec/Jan*, 20-26
32. Schunk, D. (2012). Learning Theories an Educational Perspective (6th ed.). Boston: Pearson Education,
33. Sarkim, T. (2020). Developing teachers' PCK about STEM teaching approach through the implementation of design research. Journal of Physics: Conference Series. 1470. 012025. 10.1088/1742-6596/1470/1/012025.
34. Satchakett N. & Thana A. (2019). STEM Education Project-Based Learning Activities impacting on teamwork skills and Satisfaction of grade 11 Students in Khon Kaen Wittayayon School. IOP

Conf. Series: *Journal of Physics: Conf. Series.* 1340 (2019) 012037 doi:10.1088/1742-6596/1340/1/012037

35. Septiani, A. & Rustaman, N. Y., (2017). Implementation of Performance Assessment in STEM Education to Detect Science Process Skill. *J. Phys.: Conf. Ser.* 812 012052
36. Strawhacker, A., & Bers, M.U. (2019). What they learn when they learn coding: Investigating cognitive domains and computer programming knowledge in young children. *Educational Technology Research and Development*, *67*(3), 541–575. https://doi.org/10.1007/s11423-018-9622-x
37. Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P. and Depaepe, F. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. *European Jourrnal of STEM Education*, 3(1), 02. https://doi.org/10.20897/ejsteme/85525
38. Yakob, M. Hamdani, H. Sari, R. P., Haji, A. G., Nahadi, N. (2021). Implementation of performance assessment in STEM-based science learning to improve students' habits of mind. International Journal of Evaluation and Research in Education (IJERE). Vol. 10, No. 2, June 2021, pp. 624~631. ISSN: 2252-8822, DOI: 10.11591/ijere.v10i2.21084 624. Journal homepage: http://ijere.iaescore.com
39. Zhi Hong Wan, Yushan Jiang & Ying Zhan. (2020). STEM Education in Early Childhood: A Review of Empirical Studies. Pages 940-962. https://doi.org/10.1080/10409289.2020.1814986