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DESIGNING STEM LEARNING ACTIVITIES IN BASIC SECONDARY SCHOOLS MATHEMATICS CLASSROOMS IN NIGERIA

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Abstract

Many stakeholders in education believe that Science, Technology, Engineering, and Mathematics (STEM) strategy is an effective pedagogy that provides the learners with creativity, innovative and higher-order thinking skills needed in designing STEM learning activities. The STEM learning activities provide opportunities for the learners to have the exposure that requires them to become scientists, technicians, engineers, and mathematicians in solving real-world problems. Therefore, the purpose of this study is to provide STEM stakeholders in basic secondary education with valuable information for designing STEM learning activities in Nigeria and to determine the participants excitement and interest in STEM activities. The participants were purposively chosen as an intact class with a view to engage them in STEM learning activities and also the STEM challenges. This study was based on the construction of paper planes, bridges, the making of towers, and catapults. At the end of the activities, the opinion form was used to gather the participants' views about the activities using an open-ended STEM Activities Evaluation Questionnaire (STEMAEQ). The data were analyzed using the descriptive analysis method. The results of the study show that the participants found the activities interesting, exciting and fun, as well as conducive to learning STEM fields and higher-order thinking skills. It is believed that this study will provide practical and theoretical contributions to the fields of STEM activities.

Keywords: STEM, STEM Learning Activities, Mathematics Classroom

Introduction

Science, Technology, Engineering, and Mathematics (STEM) is a field which empowers future generations to grow dynamic and innovative ideas in fostering creativity and teamwork. STEM is also a new strategy that emphasizes connections among Science, Technology, Engineering, and Mathematics that increase students' interest and prepare them to face the challenges of the changing world. Nowadays, Science, Technology, Engineering, and Mathematics (STEM) emphasises transdisciplinary among STEM disciplines and devise a solution with multiple disciplines in mind for solving real-life problems (Dan & Gary, 2018).

STEM has been adopted by some research institutes, as part of their corporate social responsibility through creativity, digital literacy, collaboration, teamwork and communications. Hence, today the understanding of STEM fields is unachievable without a solid mathematics and science foundation (Fredricks et al., 2016). STEM is considered as connected concepts and content from multiple STEM disciplines in the curriculum through an increasing focus on students' persistence in STEM (Skinner et al., 2017; Struyf et al., 2019). Relatively, STEM is better understood as a connected discipline by eliminating disciplinary boundaries and teaching them as a single distinct entity (Galadima et al., 2019b; Nadelson & Seifert, 2017).

Thus, this connection between the STEM disciplines increases preparation and careers in developing the STEM-capable workforce that improves STEM literacy needs. The need for more engineers, technicians, scientists, and mathematicians (such as Software developers, Information security analysts, Architects, Actuarial Scientists, Cost estimators, Statisticians, Web Developers, etc.). This necessitates for more innovative and creative workforce needed to compete and spar in a global marketplace (Morrison & Bartlett, 2009; National Research Council, 2011). The emphasis of STEM strategy focuses on the stakeholders being aware of what and how to design and apply knowledge and practices of STEM disciplines (Nadelson & Seifert, 2017). The application of knowledge allows the learners to develop a deep understanding of STEM concepts, processes, and how they are interrelated. In supporting the statement, Nadelson and Seifert (2017) indicated that teaching STEM could be more efficient than teaching independent STEM subject.

Taken together, this rationale supports the continually growing demand for the required STEM skills to meet the present and future global economic and social challenges. The emphasis of STEM strategy focuses on the stakeholders being aware of what and how to design and apply knowledge and practices of STEM disciplines (Nadelson & Seifert, 2017). The application of knowledge allows the learners to develop a deep understanding of STEM concepts, process, and how they are interrelated. In supporting the statement, Nadelson and Seifert (2017) indicated that teaching STEM could be more efficient than teaching segregated STEM subjects. Additionally, STEM-focused on the student-centered pedagogies, science and mathematics content, technology integration, and the use of engineering design process that enables to develop of teamwork and communication skills (Stohlmann et al., 2013).

Literature bound that STEM activities develop students to be self-reliant, logical thinkers, innovators, problem solvers, and technologically literate (Galadima, 2020; Stohlmann et al., 2012). However, developing students' skills in STEM activities require careful selection of materials and designing appropriate STEM learning modules and activities. Substantial literature, indicates STEM approach develops students' interest, and performance using different approaches. For example, the use of technology in STEM activities improves interest and performance in STEM and fostering abilities for innovation and invention (Abdioglu et al., 2021; Siregar et al., 2023; Sivaraj et al., 2019). Consequently, Hassan et al. (2020, 2023) affirmed that the use of engineering design with the van Hiele model develops students' geometric thinking skills at basic secondary school. Also develop hearing-impaired students' geometric thinking skills (Binji et al., 2022).

Moreover, Galadima (2023), indicates that STEM learning activities develop pre-service teachers' interest towards STEM activities. In addition, STEM activities allow the learners to focus on big ideas that are interrelated between the STEM subjects, make STEM experience more fun and provide opportunities for the learners to have necessary skills in hands-on challenges (Ibid). In spite of the importance of STEM in the 21st century, there is limited research conducted on STEM activities in Nigeria such as the construction of paper planes, bridges, making towers, and catapults (Galadima, 2020).

According to English and King (2019), these types of activities are designed to scaffold the development of the learners' foundation of STEM knowledge. Paper planes have been recognised as flying toys. In the construction of paper planes, the learners work in development teams for designing, making, and testing the paper planes (Frydenberg et al., 2018). The construction of bridges is a learning idea that enhances 2ist-century STEM initiative that promotes problem-solving skills. By learning how to build bridges, the learners would learn how engineers make designs and structures that people use every day in all parts of the world (English & King, 2019). The STEM activities used in this study potentially helped learners in other areas, increasing a better understanding of STEM experience and new pedagogies in their future classroom practice.

Likewise, Galadima (2023); Galadima et al. (2019b) affirmed that STEM activities improve the attention, and interest of the learners in mathematics classrooms. The present study adopted a STEM learning activities module for Basic Secondary Schools with the hope to develop basic secondary school students' interest and develop them with 2ist-century skills through STEM learning activities. See Table 1 below for the STEM learning module.

Table 1: Example of STEM Learning Activities Module for Basic Secondary Schools

Week	STEM Activities/Challenges
1	**Making a Paper Plane:** Engaging the learners in the group to make a paper plane for making the class fun and as an introduction to STEM activities. 1. **Situation** What makes an aeroplane fly farthest and highest? 2. **Challenge** Construct a paper plane and find the distance of flight trials. 3. **Constraints** 15minutes time limit; must use only the material provided, but not all resources should be used. 4. **Resources** Sheet of A4 paper; ruler; scissors; measuring tape. 5. **Evaluation** To find the farthest paper plane by throwing the object and measuring the distance that it hit the ground with measuring tape.
2	**Construction of Bridge with Straws:** Engaging the learners in a group to build a bridge using straws and making the class fun. 1. **Situation** How to make a strong Bridge? 2. **Challenge** Build a strong bridge and test the strength contest that can span a gap of at least 20cm and support 4000g of weight coins as possible. 3. **Constraints** 25minute time limit; must use only the material provided, but not all resources should be used. 4. **Resources** 30 pieces of straws; ruler; scissors; 1 roll tape; weight coins; and books. 5. **Evaluation** Test of strength contest of bridges using straws in testing how strong enough that the bridge can support a suitable weight/load placed on it to collapse.
3	**Free-Standing Spaghetti Tower:** Engaging the learners in a group to make a free-standing Spaghetti tower for making the class fun 1. **Situation** How to make a free-standing spaghetti tower? 2. **Challenge** Build the tallest free-standing tower using not more than 30 sticks of spaghetti. One marshmallow must be on top of the tower. Also, the tower has to stand firmly on its own. 3. **Constraints** 20minutes time limit; must use only the material provided, but not all resources should be used.

	4.	**Resources**	20 sticks of spaghetti; ruler; and 1 yard of masking tape; one marshmallow; measuring tape to measure the height after the challenge; video Clip, projector, sound system; and stopwatch.
		Evaluation	Identify the winning team and ensure they get applause and a prize; Measure the height of the free-standing tower
4	**Making Catapult using Popsicles:** Engaging the learners in a group to build a catapult using popsicles and rubber bands		
	1.	**Situation**	Focussed on finding a way to propel objects at long distances
	2.	**Challenge**	Engaging learners in a group to make a catapult that can be used to throw marshmallows to the longest distance possible.
	3.	**Constraints**	20minutes time limit; must use only the material provided, and throw marshmallows accurately to hit the targets.
	4.	**Resources**	popsicle sticks, safety goggles, and 1 yard of masking tape; a bag of marshmallows; measuring tape; rubber bands;
	5.	**Evaluation**	Use tape to measure and record the accurate distance that it hit the target

Source: Galadima (2020)

Problem Statement

In an attempt for tackling the societal issues of learning STEM activities, there is a need for fostering scientific, technological, engineering and mathematical innovations. In line with this, the developed nations are calling for interconnected nature of STEM in which the learners get to explore the connection between the STEM disciplines (Stohlmann et al., 2012). The reality in Nigeria is that, despite all the calls for nationwide development in learning STEM education, the STEM disciplines are still taught separately (Galadima et al., 2019b; Okpala, 2012) and the design of STEM learning activities is, however, still limited. Adversely, if STEM learning activities are not designed in the teaching and learning STEM education in Nigeria, it will affect the learners' awareness and interest in STEM, which is tantamount to the stagnation of knowledge in the midst of global scientific and technological advancements.

In recent years, several studies have highlighted the need for providing STEM learning activities (Akcay Malcok & Ceylan, 2022; Buber & Unal Coban, 2023; Daher & Shahbari, 2020; Dilek et al., 2020; Galadima, 2023; Gazibeyoglu & Aydin, 2019; Hiğde & Aktamış, 2022; Kahraman & Doğan, 2020; Karakaya et al., 2020; Pekbay, 2022; Silk et al., 2010; Yalçın & Erden, 2021; Yıldırım, 2021) to meet contemporary global demands, social and technological challenges like efficient healthcare, technological development as well as sufficient and sustainable energy (English, 2016; Thibaut et al., 2018). The importance of providing strong learning activities in science, technology, engineering and mathematics (Hiğde & Aktamış, 2022) has been stressed (Galadima et al., 2019a; Okpala, 2012). To achieve this in Nigeria, designing STEM learning activities are required particularly at the basic level of education. In view of these, the present research used STEM learning activities to develop students' interest, problem solving skills and other 21st century skills needed for the development of our society.

Learning STEM Activities in Mathematics Classroom

Aligning teaching mathematics with STEM is important as mathematics is one of the components of STEM disciplines available for explaining an observation, formulating theories and helping in making engineering designs process (Galadima et al., 2019b;

Okpala, 2012; Shahali et al., 2016). The mathematics in the STEM classroom focuses on content that builds skills in developing hands-on activities using problem-based learning, project-based learning and inquiry-based learning in the context of STEM (Milaturrahmah et al., 2017). The practice of teaching mathematics with a STEM approach involves preparing materials and tools for students to explore and solve a real-world problem through designing, expressing, testing, and revising their ideas (Galadima, 2023; Milaturrahmah et al., 2017; Stohlmann et al., 2012).

The materials and tools needed in the teaching of mathematics with STEM comprise cardboard or construction paper, Styrofoam, glue, wood, scissors, ruler, straws, spaghetti, marshmallow, rubber bands, sew, harmers, and measuring devices. Likewise, electronic materials needed in STEM classroom comprises calculators, laptops, projectors, robotics kits, and other materials for designing which makes the students a better understanding of technology and engineering design challenges (Stohlmann et al., 2012).

Objectives of the Study

The purpose of this research was to provide information for designing STEM learning activities. Specifically, the study has the following objectives:

I. To Investigate the change in the response of Basic secondary school students' interest before and after using STEM learning activities in their mathematics classroom;

II. To find out if gender has any significant effect on the student's interest before using STEM learning activities in their mathematics classroom,

III. To find out if gender has any significant effect on the student's interest after using STEM learning activities in their mathematics classroom.

Research Questions

This study was guided by the following research questions, based on the research objectives in carrying out the study:

I. Is there any significant change in the response of Basic secondary school students' interest before and after using STEM learning activities in their mathematics classroom?

II. Does gender have any significant effect on the student's interest before using STEM learning activities in their mathematics classroom?

III. Does gender have any significant effect on the student's interest after using STEM learning activities in their mathematics classroom?

Methodology

Research Design

The research design employed in this study is a one-group experimental design with pre-test and post-test. In this design, the pre-test survey was conducted at the beginning of the STEM learning activities to determine the prior knowledge of the participants before conducting the intervention. Then after the intervention, the same instrument for the Post-test was administered to the participants to determine their interest towards STEM learning activities. A visual representation of the design of this study is shown in Table 1 below.

Table 2: One-group Pre-test and Post-test Design

Pre-test	Intervention	Post-test
O_1	X	O_2

Where, O1 indicates the Pre-test, X is the intervention and O2 indicated Post-test.

Participants of the Study

The participants of this study were purposively chosen from one of the science intact classes of forty students (26 Male and 14 Female) in upper basic secondary school during Mathematics period in the class. The age of the students ranges between 14-17 years.

Evaluation of Students' STEM Learning Activity

In evaluating the students' STEM learning activities, a questionnaire developed by the researchers titled STEM Activity Evaluation Questionnaire (STEMAEQ) was submitted for comments and suggestions to check the content coverage, wording, and general editorial exercise of the instruments. The data were collected using the same questionnaire before and after STEM activities based on 3 Likert scales. After the expert's validation, the reliability index of 0.83 was obtained using Cronbach's alpha. There are 8 items in the questionnaire and it was distributed during the STEM learning activities.

Data Analysis

The data obtained were analyzed using descriptive statistics to describe the views of the participants about their interest in the activities conducted.

Results

Table 3: Is there any Significant Change in the Response of Basic Secondary School Students' Interest Before and After using STEM Learning Activities in their Mathematics Classroom

Group	N	Mean	Std. Deviation	Median	p-value	Decision
Before	40	1.44	0.26	1.56	0.000	Rejected
After	40	2.71	0.26	2.75		

ά = 0.05 level of significance

Table 2 the result of the Wilcoxon signed rank test indicates a mean of 1.44 and median of 1.56 describing student interest before using STEM learning activities in a Mathematics classroom and also a mean of 2.71 and median of 2.75 describing students' interest after using STEM learning activities in Mathematics classroom with a calculated p-value of 0.000 which is less than 0.05 level of significance. This indicated that there is a significant change in the response of Basic Secondary School students' interest before and after using STEM learning activities in their Mathematics Classroom.

Table 4: Does gender have any significant effect on the students' interest before using STEM learning activities in their Mathematics classroom?

Gender	N	Mean	Std. Deviation	Median	p-value	Decision
Boys	26	1.46	0.26	1.62	0.477	Retained
Girls	14	1.41	0.27	1.50		

ά = 0.05 level of significance

Table 4 the result of the Wilcoxon signed rank test indicates a mean of 1.46 and a median of 1.62 describing Boys students' interest before using STEM learning activities in Mathematics classrooms and a also mean of 1.41 and a median of 1.50 describing Girls students' interest before using STEM learning activities in Mathematics classroom with a p-value of 0.477 which is greater than 0.05 level of significant. This indicated that Gender does not have any significant effect on the students' interest before using STEM learning activities in their Mathematics classroom.

Table 5: Does gender have any significant effect on the students' interest after using STEM learning activities in their Mathematics classroom?

Gender	N	Mean	Std. Deviation	Median	p-value	Decision
Boys	26	2.69	0.28	2.75	0.904	Retained
Girls	14	2.74	0.24	2.75		

ά = 0.05 level of significance

Table 5 the result of the Wilcoxon signed rank test indicates a mean of 2.69 and median of 2.75 describing Boys students' interest after using STEM learning activities in Mathematics classrooms and a mean of 2.74 and a median of 2.75 describing Girls students' interest after using STEM learning activities in Mathematics classroom with p-value of 0.904 which is greater than 0.05 level of significance. This indicated that Gender does not have any significant effect on the student's interest after using STEM learning activities in their Mathematics classroom.

Discussion

The result of this study indicated that there is a significant change in the response of Basic Secondary School students' interest before and after using STEM learning activities in their Mathematics Classroom. This clearly shows that STEM learning activities in Mathematics Classrooms enhance students' interest. And this finding is in line with that of Galadima (2023), who found that STEM learning activities develop pre-service teachers' interest towards STEM activities. In addition, STEM activities allow the learners to focus on big ideas that are interrelated between the STEM subjects, make STEM experience more fun and provide opportunities for the learners to have necessary skills in hands-on challenges (Ibid). Consequently, Galadima (2023); Galadima et al. (2019b); Hiğde and Aktamış (2022) affirmed that STEM activities improve the attention, and interest of the learners in mathematics classroom.

The result also indicated that Gender does not have any significant effect on the student's interest before using STEM learning activities in their Mathematics classrooms. Likewise, gender does not have any significant effect on the student's interest after using STEM learning activities in their Mathematics classroom. That means STEM learning activities in Mathematics classroom improve both male and female students' interest. That is why many researchers concluded that the practice of teaching mathematics with a STEM approach involves preparing materials and tools for students to explore and solve a real-world problem through designing, expressing, testing, and revising their ideas (Galadima, 2023; Milaturrahmah et al., 2017; Stohlmann et al., 2012).

References

Abdioglu, C., Çevik, M., & Kosar, H. (2021). Investigating STEM Awareness of University Teacher Educators. *European Journal of STEM Education, 6*(1), 1-18. doi:https://doi.org/10.20897/ejsteme/9559

Akcay Malcok, B., & Ceylan, R. (2022). The effects of STEM activities on the problem-solving skills of 6-year-old preschool children. *European Early Childhood Education Research Journal, 30*(3), 423-436.

Binji, B., Hassan, M. N., Aliyu, B. S., & Galadima, U. (2022). Investigating Attitude of Hearing-Impairment Students Towards Learning Multiplication among Lower Basic Students in A. A. Raji Special School Sokoto, Sokoto State, Nigeria. *Rima International Journal of Education, 1*(1), 119-125.

Buber, A., & Unal Coban, G. (2023). STEM project-based activity: bio-efficacy of microalgae. *Science Activities*, 1-19.

Daher, W., & Shahbari, J. A. (2020). Design of STEM activities: Experiences and perceptions of prospective secondary school teachers. *International Journal of Emerging Technologies in Learning (iJET), 15*(4), 112-128.

Dan, Z. S., & Gary, W. K. (2018). *Teachers' perceptions of professional development in integrated STEM education in primary schools.* Paper presented at the 2018 IEEE Global Engineering Education Conference (EDUCON).

Dilek, H., TAŞDEMİR, A., Konca, A. S., & Baltaci, S. (2020). Preschool children's science motivation and process skills during inquiry-based STEM activities. *Journal of Education in Science Environment and Health, 6*(2), 92-104.

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(1), 1-8.

English, L. D., & King, D. (2019). STEM integration in sixth grade: desligning and constructing paper bridges. *International Journal of Science and Mathematics Education, 17*(5), 863-884.

Fredricks, J. A., Wang, M.-T., Linn, J. S., Hofkens, T. L., Sung, H., Parr, A., & Allerton, J. (2016). Using qualitative methods to develop a survey measure of math and science engagement. *Learning and Instruction, 43*, 5-15.

Frydenberg, M., Yates, D., & Kukesh, J. (2018). Sprint, then Fly: Teaching Agile Methodologies with Paper Airplanes. *Information Systems Education Journal, 16*(5), 22.

Galadima, U. (2020). *Pedagogical Content Knowledge of Pre-service Mathematics Teachers in an Integrated Science, Technology, Engineering, and Mathematics*

Course in Sokoto State, Nigeria. (Unpublished Doctoral Thesis), Universiti Teknologi Malaysia, Johor.

Galadima, U. (2023). Design and Development of Integrated STEM Teaching Module for Pre-service Teachers in Nigeria. *Journal of Science, Technology and Mathematics Pedagogy, 1*(1), 268-277.

Galadima, U., Ismail, Z., & Ismail, N. (2019a). A need analysis for developing integrated STEM course training module for pre-service mathematics teachers. *International Journal of Engineering and Advanced Technology (IJEAT), 8*(5C), 47-52.

Galadima, U., Ismail, Z., & Ismail, N. (2019b). A preliminary study for the need of developing integrated stem course training module. *Asia Proceedings of Social Sciences, 4*(3), 62-65.

Gazibeyoglu, T., & Aydin, A. (2019). The effect of STEM-based activities on 7th grade students' academic achievement in force and energy unit and students' opinions about these activities. *Universal Journal of Educational Research, 7*(5), 1275-1285.

Hassan, M. N., Abdullah, A. H., & Ismail, N. (2020). Effects of VH-iSTEM Learning Strategy on Basic Secondary School Students' Degree of Acquisition of van Hiele Levels of Thinking in Sokoto State, Nigeria. *Universal Journal of Educational Research, 8*(9), 4213-4223.

Hassan, M. N., Abdullah, A. H., & Ismail, N. (2023). Rethinking Strategy on Developing Students' Levels of Geometric Thinking in Sokoto State, Nigeria. *International Journal of Evaluation and Research in Education, 12*(1), 444-450. doi:10.11591/ijere.v12i1.23531

Hiğde, E., & Aktamış, H. (2022). The effects of STEM activities on students' STEM career interests, motivation, science process skills, science achievement and views. *Thinking Skills and Creativity, 43*, 101000.

Kahraman, E., & Doğan, A. (2020). Opinions of middle school students about STEM activities. *Anatolian Journal of Teacher, 4*(1), 1-20.

Karakaya, F., Akpinar, A., Alabas, Z. E., & Yilmaz, M. (2020). Determination of Middle School Students' Views about STEM Activities. *International Online Journal of Education and Teaching, 7*(2), 537-551.

Milaturrahmah, N., Mardiyana, & Pramudya, I. (2017). *Science, technology, engineering, mathematics (STEM) as mathematics learning approach in 21st century*. Paper presented at the AIP Conference Proceedings.

Morrison, S. J., & Bartlett, R. (2009). STEM as curriculum. *Education Week, 23*, 28-31.

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *The Journal of Educational Research, 110*(3), 221-223. doi:10.1080/00220671.2017.1289775

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.

Okpala, P. N. (2012). *Reforms In Science, Technology, Engineering And Mathematics (Stem) Education*. Paper presented at the Keynote Address 54th Science Teachers Association of Nigeria (STAN).

Pekbay, C. (2022). A sample STEM activity based on the engineering design process: A study on prospective preschool teachers' views. *Participatory Educational Research*, *10*(1), 86-105.

Shahali, M. H. E., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2016). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(5), 1189-1211. doi:10.12973/eurasia.2017.00667a

Silk, E. M., Higashi, R., Shoop, R., & Schunn, C. D. (2010). Designing technology activities that teach mathematics. *The Technology Teacher*, *69*(4), 21-27.

Siregar, N. C., Rosli, R., & Nite, S. (2023). Students' interest in Science, Technology, Engineering, and Mathematics (STEM) based on parental education and gender factors. *International Electronic Journal of Mathematics Education, 18*(2), em0736.

Sivaraj, R., Ellis, J., & Roehrig, G. (2019). *Conceptualizing the T in STEM: A Systematic Review*. Paper presented at the Society for Information Technology & Teacher Education International Conference.

Skinner, E., Saxton, E., Currie, C., & Shusterman, G. (2017). A motivational account of the undergraduate experience in science: brief measures of students' self-system appraisals, engagement in coursework, and identity as a scientist. *International Journal of Science Education, 39*(17), 2433-2459.

Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research, 2*(1), 28-34. doi:Doi.og/105703/1288284314653

Stohlmann, M., Moore, T. J., & Cramer, K. (2013). Preservice elementary teachers' mathematical content knowledge from an integrated STEM modelling activity. *Journal of Mathematical Modelling and Application, 1*(8), 18-31.

Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: integrated STEM education as promising practice? *International Journal of Science Education, 41*(10), 1387-1407.

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., . . . De Cock, M. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education, 3*(1), 1-12.

Yalçın, V., & Erden, Ş. (2021). The effect of STEM activities prepared according to the design thinking model on preschool children's creativity and problem-solving skills. *Thinking Skills and Creativity, 41*, 100864.

Yıldırım, B. (2021). Preschool STEM activities: Preschool teachers' preparation and views. *Early Childhood Education Journal, 49*(2), 149-162.