The Preliminary Study of an Integrated STEM Education with Design Thinking Module for Preschoolers

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Abstract. There has been a growing emphasis by educators, academicians, and policy makers on the importance of foundational scientific literacy and Science, Technology, Engineering and Mathematics (STEM) skills. Many studies have shown positive learning outcomes when STEM education was implemented in the preschool context. The preschoolers have demonstrated the capabilities in performing higher order thinking skills and engineering practices. However, most preschool teachers lack skills and competencies to plan and facilitate integrated STEM learning. In order to help these teachers, an integrated STEM with Design Thinking (iSTEM-DT) module was developed to develop the preschoolers' science process skills and engineering practices. This preliminary study aimed to evaluate the research procedures, the usability of the iSTEM-DT module and identify modifications needed prior to module implementation. A preschool teacher, six preschoolers and two parents from a private preschool were selected based on purposive sampling, and informed consent was obtained from the participants. This preliminary study was conducted over two different Saturdays, lasting about 5 h each. Classroom observation was carried out, with video recordings, photos and field notes captured. Interviews with the preschoolers were conducted. Data collection tools, namely the ECE STEM Classroom Observation Protocol (COP), guides for interview with teachers and parents, were tested. This study managed to identify instructional tasks that are not practical to implement in the classrooms, and more effective use of the tools to collect rich and useful data. It ascertained aspects that could be improved to develop the preschoolers' science process skills and engineering practices through the iSTEM-DT module.

Keywords: STEM education · integrated STEM · design thinking · problem-based learning · preschool · preschoolers · teaching and learning module · science process skills · engineering practices

1 Introduction

Critical thinking and problem-solving skills are the top two skills emerged consistently in World Economic Forum's 'Top 10 Skills' reports, but the graduates lack these essential skills needed by the workforce [1, 2]. Insights from OECD [3], World Economic Forum and McKinsey and Company further show that there is an acute shortage of Science,

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Technology, Engineering and Mathematics (STEM) graduates to meet the demand of STEM professionals globally, and COVID-19 has forced many to adapt and operate in a digital environment [4, 5]. Thus, there is an urgent need to prepare our students for the future jobs and technologies that may yet to exist, solve problems that have yet been anticipated, and prepare the workforce with twenty-first century skills for fourth industrial revolution.

With the growing emphasis on STEM education, it has gradually cascaded down to early childhood education (ECE). According to Katz on STEM education in ECE, a suitable STEM curriculum is one that motivates preschoolers to master the basic academic skills in their intellectual pursuits, which include the acquisition of knowledge, understanding, skills, and dispositions related to STEM [6]. Many studies have shown positive learning outcomes when STEM education was implemented in the ECE context and few other studies revealed that preschoolers have the capabilities in performing higher order thinking skills and engineering practices [7–14]. In Forbes et al.'s study on five to seven years old students using Design Thinking to learn STEM conceptual knowledge, skills and practices, it was found that the students demonstrated capabilities in problem solving, creativity, collaboration, communication, critical thinking and reflective thinking [11].

However, studies in STEM education have also shown that educators lack understanding in integrating the various disciplines in STEM; they struggled to effectively facilitate the teaching and learning in the classrooms and some studies have identified the challenges teachers faced in implementing integrated STEM education [15–23]. A literature review of 25 articles by Margot and Kettler [24] further indicates that even though teachers were aware of the importance of STEM education, they cited challenges in curriculum design, instructional practice, assessment, and availability of resources and support system.

Campbell, Speldewinde, Howitt and MacDonald investigated the preschool teachers STEM practices and found no evident of teachers planning and implementing STEM education as an integrated approach [9]. They planned the children's exploration based on a discipline (either Mathematics or Science) and there was a lack of understanding to plan the STEM activities across multiple disciplines. Evangelou and her team of researchers noticed preschool teachers tend to emphasize on linguistic development and less on engineering practices and call for educators to build on the basic structures in ECE and enhance it with desirable engineering practices in the preschoolers [25]. Thus, many researchers and academicians have called for preschool teachers to be equipped with pedagogical content knowledge in order to foster children's STEM skills and practices, and ensure high quality STEM experiences for these young children [8, 26].

In Malaysia ECE context, fostering preschoolers' science process skills is an important aim in preschool education and is listed as part of the National Preschool Curriculum Standards (NPCS) [27]. In addition, converging evidence also indicates that an early exposure to engineering promotes both the application of mathematics and science concepts and the science process skills and children can perform better when they have attempted an engineering design challenge before [28–30]. Nevertheless, there is little opportunities for the students to experience engineering in the normal classroom [31].

In fact, many of the engineering education programmes were conducted as an extra curriculum and tend to be based on a 'competition model' which ended with more losers than winners and likely to appeal to boys [28]. Thus, it is imperative to develop an integrated STEM module that could be implemented in the classroom with clear learning intentions to develop preschoolers' science process skills and engineering practices.

In order to support the preschool teachers in embracing the pedagogical transformation in integrated STEM teaching and learning, many researchers opine that having an exemplar integrated STEM module would be helpful [32, 33].

Considering the above issues on the preschool teachers' skills and competencies, and the urgent need to focus on developing the preschoolers' science process skills and engineering practices, a study aimed to design and develop an exemplar integrated STEM with Design Thinking (iSTEM-DT) module to nurture preschoolers' science process skills and engineering practices was conducted. This is a preliminary study which forms part of the above-mentioned larger study which aimed to evaluate the research methodology, the usability of the iSTEM-DT module and identify modifications needed prior to module implementation. It is guided by these research questions, namely:

- How is the usability of the iSTEM-DT module for teacher?
- How is the usability of the iSTEM-DT module for preschoolers?
- How are the usability of the data collection tools for the study?

2 iSTEM-DT Module

The instructional design used in iSTEM-DT module is grounded in constructivist theories of Piaget and Vygotsky, SOLO Taxonomy and Design Thinking [34–37]. In designing the iSTEM-DT module, the constructivist's theories can be applied together with the SOLO taxonomy in order to operationalize the instructional design. It consists of five distinct levels of Pre-structural, Unistructural, Multi-structural, Relational, and Extended Abstract, allowing teachers to evaluate the success of the classroom instructions [36, 38].

The module is designed based on an interdisciplinary model which uses Design Thinking as the engineering design process to integrate STEM disciplines to solve real-world problems. The Design Thinking process, from Empathize, Define, Ideate, Prototype and Test stages, forms the core structure of the iSTEM-DT module; guiding the students in the inquiry process [19, 39]. This five stages DT process is deemed age-appropriate for young children as teachers shared that engineering design processes with 7-step or 10-step are more suitable for high school or middle school students [40].

The preschoolers were given real-life problems to solve using Design Thinking through hands-on, child-centered, experiential learning. The module aims to develop six years old preschoolers' science process skills and engineering practices through the two exemplar problems to be solved using the Design Thinking process. These two problems are 'River Crossing Challenge' and 'River Clean-up Challenge'. In this study, each real-life problem was completed within five hours.

3 Methodology

This study adopts a case study evaluation design with an intention to capture the complexity of a case and address the contextual conditions fully. Compared to other evaluation methods (i.e., experiments, quasi-experiments), case study evaluation allows the researchers to include the views and responses from broader stakeholders that interact with the case [41]. Evaluation is a systematic application of social research procedures for assessing the conceptualization, design, implementation and utility of programs [42]. Throughout this evaluation process, one can assess the need for the program, the quality of its instructional design and theory, and the effectiveness of the final product.

This study holds a social constructivists worldview as the researchers believe that teacher-students and inter-student interactions can influence one another; and they are complex, dynamic and mutually shaping rather than linear causation of one element on another. Thus, the researchers attempt to look holistically and in natural setting, for varied and multiple meaning of integrated STEM education in ECE, embracing the complexity of views rather than focusing on a narrow meaning of the subject [43].

This is a single case study evaluation design with an exploratory approach in a private preschool in Klang Valley, Malaysia; involving a preschool teacher, six preschoolers and two parents, whom were selected based on purposive sampling [41]. It provides an opportunity to focus on the study of the iSTEM-DT module's preliminary implementation and elicit qualitative data from classroom observations, fieldnotes, students' artifacts and interviews from various stakeholders for an understanding of the iSTEM-DT module usability in ECE context, the research methodology and the usability of the data collection tools [41, 44]. Listed below are the four data collection tools being used in this study and its corresponding purpose(s). These tools were developed by adapting from past studies except for the ECE STEM Classroom Observation Protocol (COP) which was adopted entirely from Milford and Tippett [45] (Table 1).

4 Result

In order not to disturb the preschool's operation and their classes for a long period of time, the preliminary study was conducted over two different Saturdays, lasting about 5 h for each real-world problem. This arrangement allowed the teacher and the researcher to work collaboratively on the instructional design using the Stringer's Action Research model; implementing the 'Look, Think, Act' cycle on the first Saturday and repeat the cycle on the second Saturday [46]. The participating teacher holds a Diploma in ECE and a degree in Education (Teaching English as a Second Language). She has been a preschool teacher for five years and have vast experience teaching hands-on science activities with young children. Only six preschoolers (all six years old) enrolled in this preschool teacher's classroom and parents of these children were able to participate.

To ensure this study is being conducted ethically, as it involved young children, the informed-consent process was conducted in two rounds prior to the data collection process. First round of explanation was carried out with the adults (the teacher and six parents) followed by another round of meeting involving the children and their parents. During the first meeting, parents were informed of their right to decline their child's

Table 1. Data Collection Tool and Its Purpose

Data Collection Tool	**Purpose(s)**
ECE STEM Classroom Observation Protocol (COP)	To assess on 1. Students' science process skills and engineering practices, 2. Teachers STEM practices in the classroom, and 3. Usability of the iSTEM-DT module through classroom observation.
Guide for Interview with Teachers	To assess the usability of the iSTEM-DT module for the teacher and students. To evaluate the effects of the iSTEM-DT module on students' science process skills and their engineering practices. To explore teachers' classroom practices.
Guide for Interview with Preschoolers	1. To assess the usability of the iSTEM-DT module for the students. 2. To evaluate the effects of the iSTEM-DT module of students' science process skills and their engineering practices.
Guide for Interview with Parents	To evaluate the effects of the iSTEM-DT module on students' science process skills and engineering practices.

participation, and they were assured that there would not be any negative outcomes of their child's participation; it would be kept confidential and anonymous, i.e., no real names would be used, and faces on photos and in videos would be blurred. In the second meeting with the parents and children, the principal researcher explained to the children in simpler language with photos about the purpose of the research, what would they be doing, who would be doing it together with them, how long it will take and how we would be collecting the data. The children were told that during the process, they can stop if they want to or when they feel that they are not comfortable when photos or videos are being taken or they are being interviewed. This additional meeting of explaining to the children was to ensure that they understand that they have a choice in their participation and not to participate unwillingly due to the power relations between adults and children [47]. With the parents present in the meeting with their children, it allowed parents to elaborate and explain further on the discussion points to enhance their understanding. In addition, examples of photos, videos, artefacts such as sketches and prototype built were shared so that they are aware that the researchers would be taking photos and videos during the study, and their artefacts would be taken away after the classes. Consent was obtained from the teacher, parents (for both their participation and their child's participation), as well as from the children (by showing of a thumbs-up sign at the end of the meeting and the beginning of each session during the study). During the study, the principal researcher had consciously look out for children's visual, verbal and non-verbal cues for their response to the research participation.

Once the consent was obtained from all participants, materials and presentation slides needed for the training were prepared. A training session was held with the teacher to introduce the iSTEM-DT module and how it can be implemented in her classroom. Two Saturdays were identified with a gap of two weeks to allow initial data analysis, reflection and minor modifications on the instructional design of the second project. The implementation of the two projects in the iSTEM-DT module lasted about five hours each. During the module implementation, classroom observation was carried out using the ECE STEM COP instrument, with video recordings, photos and field notes captured. Upon completion of the study on the second Saturday, semi-structured, face to face interviews were conducted with the teacher, two parents, and two children. Selection of the children and parents were done based on purposive sampling. Interview with the two children was carried out as a focus group as they were collaborating as a group during the study, and they shared the artefacts produced. During the interviews, the Guides for the Interview were referred to.

The interview with the teacher strived to collect data about her experiences of teaching the module, providing feedback on the content, activities and resources of the module, and its effects on the students as well as teachers' classroom practices. The principal researcher guided the discussion to ensure the discussion topics were relevant to the study's aims. The interview conversations were audio recorded.

In addition, direct classroom observations (using the ECE STEM COP instrument) were conducted on both Saturdays, and were video recorded to ensure the entire process of how teacher implements the module was captured. In the ECE STEM COP, there are indicators within the various dimensions of this instrument to capture evidence of the characteristics of questions teacher asked, her interactions with students and the instructions she used. During the classroom observations, fieldnotes were taken for triangulation and to validate the research findings [44].

This direct classroom observation was also used to evaluate the module usability for students as it enables the principal researcher to collect first-hand data at the actual surrounding [48]. Furthermore, it is suitable to apply in preschool setting because these young children are yet to possess verbal communication skills to express themselves and sufficient cognitive ability to share their thoughts. It was guided by the ECE STEM COP to collect evidence on the preschoolers' engagement during the learning tasks and their interactions with others.

Two cameras were used to capture the classroom activities, including the interactions of the teacher and the students or a focus group of students. Having two cameras allowed the researcher to study events that happen simultaneously in the highly mobile or active classroom as iSTEM-DT module is mostly hands-on and highly engaging [49, 50]. The use of video recordings enabled the researcher to identify and analyse preschoolers' body language (i.e. gaze, expression, body posture, gesture) and verbal expressions during the engagement of the activities [50]. It enables the researcher to examine the participants behaviour and actions rigorously and systematically, reducing the risk of researcher missing out capturing important evidence during the classroom observation. In addition, the video recording allows the researcher to review the recordings multiple time with different focus [49].

One of the main objectives of a usability evaluation is to inform programme development potential usability problems before any large-scale implementation [51]. In the context of this study, besides evaluating the research methodology, the instructional design of the iSTEM-DT module was evaluated for its usability among the preschoolers and the teachers. As this study serves as a part of a larger study, the scope of the usability of the module limits to the implementation of the module by the teacher and its suitability for the preschoolers and not to ascertain to what extent has the module achieved its intended outcomes.

As this study holds a social constructivists worldview, which aims to offer insights to the practices of the teachers and preschoolers, it is important to ensure the trustworthiness of the study by deliberately planning the rigour needed in this case study evaluation. The criteria to ensure the rigor of this study include credibility, dependability, confirmability and transferability [52–54]. To ensure credibility of the study, it triangulates the data by using multiple sources of data using multiple methods; namely data from direct classroom observation using ECE STEM COP, photos, video records, fieldnotes and student artefacts from classroom observation, and interview data from three stakeholders (teacher, students, and parents). To ensure the dependability of this study, the procedure to ignore the video recordings of the first hour of the study on both Saturdays due to Hawthrone effect is added during the data collection stage. In addition, multiple viewings of the video recordings and multiple listening of the audio recordings were carried out.

Qualitative data collected from various sources and methods (i.e. classroom observations data via ECE STEM COP, video recordings, fieldnotes, students' artefacts and interviews data from different stakeholders) was analysed inductively through thematic analysis process. It was carried out in these four steps, which are (1) familiarizing with the data, (2) generating codes, (3) reviewing codes and combine into initial themes, and (4) generating final themes. As the principal researcher was the person collecting and transcribing the data, she was immersed in the data from the beginning of this study, which is an excellent way to familiarize with the magnitude of the content [55].

During the data analysis, the trustworthiness of the interpretations is another important aspect. The principles that this study adhere to include how the views and findings are presented, making judgement about typicality, and the researcher's perspective to the interpretation. This principal researcher has linked the findings to the data with detailed description on the participants actions and experiences, so that they are visible and comprehensible to the readers. Furthermore, she has strived to collect rich information and evidence about the contextual settings and provide thick description (descriptive data) for future engagement in purposeful sampling or future judgements on transferability [53]. This study only involved the six year-old children and not the younger ones because of their cognitive ability and their ability to communicate and express their thoughts and ideas, thus enhancing the interpretive validity and transferability of this study [44]. The principal researcher was the participant-observer, defined by Johnson and Christensen as "the researcher spends extended time with the group as an insider and tells members they are being studied (p.868)" [44]. As a participant-observer, it allowed the teacher to implement the iSTEM-DT module comfortably, even with the presence of the researcher. The teacher was able to focus on her even though she was being observed. Thus, enhancing the authenticity and trustworthiness of the data collected.

5 Findings and Discussion

Overall, the teacher was able to implement the iSTEM-DT module, with the six preschoolers successfully built their prototypes to solve the two problems presented. Below are the changes made on the instructional designs during the implementation.

- Children were supposed to work in a group of three but due to their nature, it was a challenge for the children to brainstorm and share ideas especially during the Ideate Stage. The module was then modified to let the children work in pairs instead of three and it was found to be more effective when it was tested in the second challenge (River Clean Up Challenge), they were able to communicate more, took turns to share their ideas and managed to collaborate better in building a workable prototype.
- In the original module, there was no constrain on the cost and during the study on the River Crossing Challenge. Almost all the materials prepared at the material store was used up. Therefore, in the second challenge (River Clean Up Challenge), cost constrain was added. Each group was given twenty RM1 notes to 'buy' the materials needed from the material store. This has caused the children to evaluate the function of each item in their design - do they really need it and for what purpose. They even need to justify or reason with their partner the need of this item in their design.
- During the Prototype Stage in the first challenge, children were allowed to test their prototype with water, which made them tend to build and test via trial and error, without going back to think critically where went wrong, what should be modified and why, and sketch again their improved design. Thus, in the second challenge, the storage containers (representing the river) were not filled with water. They can see the river model but they can only test their prototype in the water during the Testing Stage.
- River Crossing criteria were too difficult, the three bottles filled with water representing three persons were too heavy. Thus, the amount of water in the bottles were reduced to half.
- One of the rubbish used in the River Clean Up Challenge was a baby diaper. It absorbed so much water and became too huge and heavy to be scooped out. Thus, this item was removed from the list of rubbish.

In evaluating the research methodology and the instruments involved in the study, below are the findings.

- ECE STEM COP: This instrument was found to be effective in detecting the teacher and students' classroom practices. However, it was quite impossible to identify and label the observation according to the aspects and dimensions listed in the instrument during the lesson. Analysis of the video recordings for identifying the elements in the instrument had to be carried out after the lesson. The video recordings revealed that the teacher lacks the ability to ask good questions, resulting not achieving the learning outcomes intended. The questions tend to be too open ended, i.e. "Why is it so?" The teacher also loved to compliment the children's work, i.e. "Well done!"

but she did not observe carefully to ask questions to elicit deeper thinking among the children. It may be needed to print out the modules and let the teacher highlight those questions listed on the lesson plan so that she would ask these questions to scaffold the children's learning during the activities. Another challenge noticed in regard to using the video recording to extract evidence of teacher and children's interactions and practices was that quality of audio in the video recording. Thus, the technical aspect of the video recording would be looked into or improved.

- Guide to Interview the Teacher and Parents: This data collection tool was found to be sufficient to elicit information about the usability of the module as well as to collect additional information about the observation of the teacher and parents on the children's science process skills and engineering practices. Teacher was able to reflect and share about the challenges she faced in implementing the lessons in the module, allowing the researcher to work collaboratively with the teacher in evaluating the instructional designs and improving them.
- Interviewing of Preschoolers: During the first project in the study, it was found that the children were either too engrossed in the activities or the teacher was too focus in getting the children to execute the tasks, resulting less opportunity for the teacher or the researcher to ask questions to the children to assess their science process skills and engineering practices. Thus, in the second project, interviews were conducted by the researcher after the lessons on two children as a focus group. The interview questions were guided by the lesson's intended learning outcomes (which focus on science process skills and engineering practices) and questions listed in the lesson plan as part of the instructional designs. By interviewing the preschoolers after the lessons, this additional information can be used as additional evidence to the research as well as be used for triangulation purpose.

However, it was found that it was very challenging to get good response from the preschoolers. Their reply to the open-ended questions tends to be short, usually one or two words. According to Ponizovsky-Bergelson, Dayan, Wahle & Roer-Strier, when asking open-ended questions to young children, the interviewers must use facial expressions to encourage the response from them [56]. In addition, interviewers are encouraged to ask more "request" type of question, such as "Please tell teacher about your sketch or prototype here." Upon reflection, the principal researcher feels the lack of skills in conducting interviews with preschoolers because during the interviews, not much encouragement was given to the children, and often, a few questions were asked at one time (hoping that they may be able to response to at least one of them.), in which Ponizovsky-Bergelson et al. ask researchers to avoid doing [56].

6 Conclusion

This study revealed that the research methodology for the implementation of iSTEM-DT module, the research methodology and its data collection tools require some fine-tuning. As the module involves two different projects and being conducted on two different Saturdays, it allowed the principal researcher and the teacher to reflect on the first implementation and take necessary actions for the subsequent project. This is aligned with the Stringer's action research cycle and the collaborative nature in the systematic inquiry in action research in education [46, 57, 58]. The implementation was refined by considering the point of view of the preschoolers. Instruction tasks were modified to make sure they are age appropriate for the preschoolers. It identified instructional tasks that are not practical to implement in the classrooms, and the use of the tools to collect rich and useful data. It ascertained aspects that could be improved to develop the preschoolers' science process skills and engineering practices through this iSTEM-DT module.

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References

1. World Economic Forum, "These are the Top 10 Job Skills of Tomorrow," 2020. Accessed: 5 November, 2020. [Online]. Available: https://www.weforum.org/agenda/2020/10/top-10-work-skills-of-tomorrow-how-long-it-takes-to-learn-them/
2. World Economic Forum, "Why Skills - Not Degrees - Will Shape the Future of Work," 2020. Accessed: 5 November 2020. [Online]. Available: https://www.weforum.org/agenda/2020/09/reckoning-for-skills
3. OECD, "The Future We Want. The Future of Education and Skills Education 2030.," Paris: OECD, 2018.
4. World Economic Forum, "A guide to thriving in the post-COVID-19 workplace," 2020. Accessed: 4 November, 2020. [Online]. Available: https://www.weforum.org/agenda/2020/05/workers-thrive-covid-19-skills/
5. McKinsey & Company, "Future of Work," Assessed: 4 November, 2020. [Online]. Available: https://www.mckinsey.com/featured-insights/future-of-work
6. L. G. Katz, "STEM in the Early Years Some Distinctions between Academic and Intellectual Goals for Young," Early Child. Res. Pract. Collect. Pap. from SEED (STEM Early Educ. Dev. Conf., pp. 2–7, 2010.
7. N. A. Aguilar, "Examining the integration of science, technology, engineering, and mathematics (STEM) in preschool and transitional kindergarten (TK) classrooms using a social-constructivist approach," ProQuest Diss. Theses, 2016.
8. J. Aldemir and H. Kermani, "Integrated STEM curriculum: improving educational outcomes for Head Start children," Early Child Dev. Care, vol. 187, no. 11, pp. 1694–1706, 2017, https://doi.org/10.1080/03004430.2016.1185102.
9. C. Campbell, C. Speldewinde, C. Howitt, and A. MacDonald, "STEM Practice in the Early Years," Creat. Educ., vol. 09, no. 01, pp. 11–25, 2018, https://doi.org/10.4236/ce.2018.91002.
10. C. D. Tippett and T. M. Milford, "Findings from a Pre-kindergarten Classroom: Making the Case for STEM in Early Childhood Education," Int. J. Sci. Math. Educ., vol. 15, pp. 67–86, 2017, https://doi.org/10.1007/s10763-017-9812-8.
11. A. Forbes, G. Falloon, M. Stevenson, M. Hatzigianni, and M. Bower, "An Analysis of the Nature of Young Students' STEM Learning in 3D Technology-Enhanced Makerspaces," Early Educ. Dev., vol. 32, no. 1, pp. 172–187, 2021, https://doi.org/10.1080/10409289.2020.1781325.
12. N. M. Siew, "Integrating STEM in an Engineering Design Process: The Learning Experience," Eurasia Proc. Educ. Soc. Sci., vol. 6, no. 4, pp. 128–141, 2017.

13. . Bagiati and D. Evangelou, "Engineering curriculum in the preschool classroom: the teacher's experience," Eur. Early Child. Educ. Res. J., vol. 23, no. 1, pp. 112–128, 2015, https://doi.org/10.1080/1350293X.2014.991099.
14. B. L. Dorie, M. E. Cardella, and G. N. Svarovsky, "Capturing the engineering behaviors of young children interacting with a parent," ASEE Annu. Conf. Expo. Conf. Proc., 2014.
15. N. A. Adam and L. Halim, "Cabaran Pengintegrasian Pendidikan STEM Dalam Kurikulum Malaysia," Semin. Wacana Pendidik., no. September, pp. 1–10, 2019.
16. T. D. Holmlund, K. Lesseig, and D. Slavit, "Making sense of 'STEM education' in K-12 contexts," Int. J. STEM Educ., vol. 5, no. 1, pp. 1–18, 2018, https://doi.org/10.1186/s40594-018-0127-2.
17. S. L. Loh, V. Pang, and D. Lajium, "Evaluation of the implementation of a science project through the application of integrated STEM Education as an approach," Int. J. Educ. Psychol. Couns., vol. 4, no. 33, pp. 263–283, 2019, https://doi.org/10.35631/IJEPC.4330021.
18. E. R. McClure et al., "STEM starts early," Educ. Dig., no. December, pp. 43–52, 2017.
19. R. Tytler, G. Williams, L. Hobbs, and J. Anderson, "Challenges and opportunities for a STEM interdisciplinary agenda In B. Doig, J. Williams, D. Swanson, R. Borromeo Ferri, & P. Drake. (Eds.)," Interdiscip. Math. Educ., vol. Singapore:, pp. 51–84, 2019.
20. S. M. Drake and J. L. Reid, "Interdisciplinary assessment in the 21st century," Acad. Exch. Q., vol. 21, no. 1, 2017.
21. S. L. Loh, V. Pang, and D. Lajium, "A Case study of teachers ' pedagogical content knowledge in the implementation of integrated STEM education," J. Pendidik. Sains Mat. Malaysia, vol. 10, no. 1, pp. 49–64, 2020.
22. N. M. Siew, N. Amir, and C. L. Chong, "The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science," Springerplus, vol. 4, no. 1, pp. 1–20, 2015, https://doi.org/10.1186/2193-1801-4-8.
23. M. Stohlmann, T. Moore, and G. Roehrig, "Considerations for Teaching Integrated STEM Education," J. Pre-College Eng. Educ. Res., vol. 2, no. 1, pp. 28–34, 2012, https://doi.org/10.5703/1288284314653.
24. K. C. Margot and T. Kettler, "Teachers' perception of STEM integration and education: a systematic literature review," Int. J. STEM Educ., vol. 6, no. 2, 2019, https://doi.org/10.1186/s40594-018-0151-2.
25. D. Evangelou, S. Brophy, and J. Dobbs-oates, "Stem Module Develop," vol. 9, 2012.
26. Early Childhood STEM Working Group, "Early STEM Matters: Providing High-Quality STEM Experiences for All Young Learners. Policy Report.," vol. Chicago, I, 2017.
27. Kementerian Pendidikan Malaysia, Kurikulum Standard Prasekolah Kebangsaan. Putrajaya: Kementerian Pendidikan Malaysia, 2017.
28. R. Clark and J. Andrews, "Researching primary engineering education: UK perspectives, an exploratory study," Eur. J. Eng. Educ., vol. 35, no. 5, pp. 585–595, 2010, https://doi.org/10.1080/03043797.2010.497551.
29. K. B. Wendell, K. G. Connolly, C. G. Wright, L. Jarvin, and C. Rogers, "Children learning science through engineering: An investigation of four engineering-design-based curriculum modules," in ICLS 2010 Conference Proceedings - 9th International Conference of the Learning Sciences, 2010, vol. 2, pp. 390–391.
30. P. Tõugu, M. Marcus, C. A. Haden, and D. H. Uttal, "Connecting play experiences and engineering learning in a children's museum," J. Appl. Dev. Psychol., vol. 53, no. September, pp. 10–19, 2017, https://doi.org/10.1016/j.appdev.2017.09.001.
31. J. A. Ejiwale, "Barriers To Successful Implementation of STEM Education," J. Educ. Learn., vol. 7, no. 2, p. 63, 2013, https://doi.org/10.11591/edulearn.v7i2.220.
32. A. Ata Aktürk and O. Demircan, "A Review of Studies on STEM and STEAM Education in Early Childhood," J. Kırşehir Educ. Fac., vol. 18, no. 2, pp. 757–776, 2017.

33. D. J. Shernoff, S. Sinha, D. M. Bressler, and L. Ginsburg, "Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education," Int. J. STEM Educ., vol. 4, no. 1, pp. 1–16, 2017, https://doi.org/10.1186/s40594-017-0068-1.
34. J. Piaget, The Origins of Intelligence in Children. New York: International Universities Press, 1952.
35. L. S. Vygotsky, Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press, 1978.
36. J. Biggs and K. Collis, Evaluating the Quality of Learning: The SOLO Taxonomy (Structure of the Observed Learning Outcome). New York: Academic Press, 1982.
37. Hasso Plattner Institute of Design, Design Thinking Process. Palo Alto, CA: Stanford University, 2007.
38. J. Biggs, "Enhancing Teaching through Constructive Alignment," High. Educ., vol. 32, no. 3, pp. 347–364, 1996.
39. A. Scheer and H. Plattner, "Transforming Constructivist Learning into Action: Design Thinking in education," Transform. Constr. Learn. into Action Des. Think. Educ., vol. 17, no. 3, pp. 8–19, 2012.
40. C. M. Cunningham and C. P. Lachapelle, "Designing Engineering Experiences to Engage All Students," Educ. Des., vol. 3, no. 9, pp. 1–26, 2016, https://doi.org/10.18260/1-2--21286.
41. R. K. Yin, Case Study Research: Design and Methods, 5th Ed. Thousand Oaks, CA: SAGE Publication, 2014.
42. P. H. Rossi, M. W. Lipsey, and G. T. Henry, Evaluation: A Systematic Approach. 2019.
43. J. W. Creswell and V. L. P. Clark, Designing and Conducting Mixed Methods Research, 3rd ed., vol. 3rd edition. Thousand Oaks, CA: SAGE Publication, 2018.
44. R. B. Johnson and L. Christensen, Educational Research Quantitative, Qualitative, and Mixed Approaches, 5th Ed. Thousand Oaks, CA: SAGE Publication, 2014.
45. T. Milford and C. Tippett, "The Design and Validation of an Early Childhood STEM Classroom Observational Protocol," vol. 6, no. 1, pp. 24–37, 2015.
46. E. T. Stringer, Action Research. Thousand Oaks, CA: SAGE Publications, 2007.
47. UNICEF, Ethical Research Involving Children. Florence: UNICEF Office of Research - Innocenti, 2013.
48. J. W. Creswell, Research Design: Qualitative, Quantitative and Mixed Methods Approaches, 4th ed. Thousand Oaks, CA: SAGE Publication, 2014.
49. M. Blikstad-Balas, "Key challenges of using video when investigating social practices in education: contextualization, magnification, and representation," Int. J. Res. Method Educ., vol. 40, no. 5, pp. 511–523, 2017, https://doi.org/10.1080/1743727X.2016.1181162.
50. C. Jewitt, "An Introduction to Using Video for Research," Natl. Cent. Res. Methods Work. Pap., vol. 3, no. 12, pp. 1–25, 2012.
51. J. Sandars and N. Lafferty, "Twelve Tips on usability testing to develop effective e-learning in medical education," Med. Teach., vol. 32, no. 12, pp. 956–960, 2010, https://doi.org/10.3109/0142159X.2010.507709.
52. L. M. Connelly, "Trustworthiness in qualitative research," MEDSURG Nurs., vol. 25, no. 6, pp. 435–436, 2016.
53. Y. S. Lincoln and E. G. Guba, Naturalistic Inquiry. London: SAGE Publications, 1985.
54. K. Manning, "Authenticity in constructivist inquiry: Methodological considerations without prescription," Qual. Inq., vol. 3, no. 1, pp. 93–115, 1997, https://doi.org/10.1177/107780049700300105.
55. V. Braun, V. Clarke, and G. Terry, Thematic Analysis. In: Rohleder P, Lyons A, editors. Qualitative Research in Clinical and Health Psychology. Basingstoke: Paqlgrave MacMillan, 2014.

56. Y. Ponizovsky-Bergelson, Y. Dayan, N. Wahle, and D. Roer-Strier, “A Qualitative Interview With Young Children: What Encourages or Inhibits Young Children’s Participation?,” Int. J. Qual. Methods, vol. 18, pp. 1–9, 2019, https://doi.org/10.1177/1609406919840516.
57. G. E. Mills, Action Research: A Guide for the Teacher Researcher, Sixth Edition. Upper Saddle River, NJ: Pearson Merrill Prentice Hall, 2011.
58. E. T. Stringer, L. M. F. Christensen, and S. C. Baldwin, Integrating Teaching, Learning, and Action Research: Enhancing Instruction in the K-12 Classroom. Thousand Oaks, CA: SAGE Publications, 2010.