ASM Sc. J., 18, 2023

https://doi.org/10.32802/asmscj.2023.1430

Maker-centred Learning Approach to Craft STEM Education in Primary Schools: A Systematic Literature Review

V. Balakrisnan*, N. Kamarudin, A.M. Ma'rof and A. Hassan

Faculty of Educational Studies, UPM, Serdang, Malaysia

The implementation of STEM (Science, Technology, Engineering and Mathematics) in primary schools is a new avenue for researchers and educators. Several studies have reported the needs, barriers and threats and tested instructional methods in general. In Malaysian primary schools, it is still a work in progress and a great challenge to deal with existing issues in teaching and learning primary science. Hence, education futurists have redirected science learning by commercialising the student-centred learning model of makerspace with STEM elements, which combines high-tech tools and materials. Besides, in the Scopus database, the number of researches on the STEM education infused maker concept shows notable figures. Therefore, this study presents a systematic literature review on implementations of the STEM-Maker concept in primary schools for in-depth understanding and application. A checklist of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is referred to and applied. Eight STEM-Maker concept implementations and six STEM-Maker concept practices were identified from 13 shortlisted articles. The citation, purpose and primary results of each shortlisted study are also discussed in this paper. To establish a solid foundation in science with transversal competencies in primary education, the bridging concept of the Maker with STEM education would be a tremendous opportunity to instil future skills under one roof.

Keywords: Maker spaces; Maker-centred learning; STEM; Primary Schools; Systematic Literature Review

I. INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) for primary schools has been addressed as a complex matter for teachers to deliver and students to understand. A good understanding of STEM principles and purpose is necessary (Robertson, 2020). In primary schools, STEM is essential to understand and be aware of the surrounding development through primary science and not to measure the potential of teachers and students in STEM (Rauf *et al.,* 2017).

Since integrated education of primary schooling enhances mastery of reading, writing, arithmetic and reasoning skills with additional elements of creativity, innovation and entrepreneurship (MoE,2013), more inputs from researchers and educationists are required to study the ways to implement STEM in primary schools and to ensure there is earlier exposure on education revolution.

Hence, the classroom-based assessments that emphasise students' skills have made it possible. Ramli (2017) identifies inquiry-based learning (IBL), problem-based learning (PBL), project-based learning (PjBL), peer-led, module-based and modelling or model-based learning as common instructional techniques in STEM disciplines. Recently, one of the model-based learning known as makerspace has risen globally for preschoolers to adults, from schools and businesses. The makerspace has acquired major recognition for hands-on learning and learning through the evolution of digital modelling and fabrication (Alley, 2018).

Makerspace is not just a space to engage students to handle high-tech tools and materials. It is a place where students can learn by thinking and making through their joyful exploration

*Corresponding author's e-mail: vijaya.balakrisnan@gmail.com

and collaboration. Many commentators have welcomed the possible transfer of these tools and technologies into formal school settings as addressing several current educational imperatives (Godhe *et al.,* 2019). Although many of the activities often associated with makerspaces are already conducted in schools' computers or science labs and workshops, makerspaces are distinguished from more structured, formal learning environments for creating or tinkering or making three dimensions (3D) models with effective collaboration and communication (Hatch, 2014). In this case, there are intense arguments and studies on infusing STEM with the maker concept in the classrooms since the usage of science laboratory or computer lab or workshops in schools is questionable (Bevan, 2017).

Lilia (2017) reports that science laboratory activities in Malaysian schools are mostly used to clarify theories as in ordinary classrooms. Besides, the condition and frequency of usage of science laboratories in Malaysian primary schools need to be studied for a better understanding of the effectiveness of learning science in the laboratory. Even though the primary science syllabus has no dangerous chemical substances (DSKP, 2017), primary schools students are undergoing the same laboratory learning environment as in secondary and tertiary education.

In this regard, the idea of setting up the classroom or laboratory as a design-based makerspace with maker-centred learning can support STEM implementation and practices in schools. There is a need to extract valuable information from previous studies to design our unique concept with affordable scales (Balakrisnan *et al.,* 2021). The unique maker concept that can be created in a typical Malaysian classroom or laboratory is a room with appropriate Information and Communications Technology (ICT) tools and materials for creativity and innovation activities yet safe storage with space for students to move around to collaborate and communicate under a teacher as a facilitator which can be used for all the subjects' teaching and learning in primary schools. Owing to this, tested and recommended STEM-infused maker concept implementations for primary schools in Scopus were analysed and presented in a systematic literature review. This study collectively reflects the voices of researchers and educationists on teaching and learning STEM-Maker-rich activities.

A. Literature Review

To make the connection or build the foundation in science is scope for primary schools as highlighted in the conceptual framework for developing Malaysia STEM education in Southeast Asian Ministers of Education Organisation Regional Center for Education in Science and Mathematics (SEAMEO RECSAM, 2014). STEM challenges can be readily introduced to children in primary schools with their communities to gain information from simple data analysis and experts in related fields (English *et. al.,* 2015; MacDonald *et al.,* 2020).

The interconnections between the four fields and how they complement and strengthen one another are where the real value in STEM education lies (Vasquez, 2013). The findings of Ramli and Talib (2017) indicate that teachers' understanding of how to incorporate STEM is inadequate. The motivation, curriculum, time limits, lack of training, insufficient facilities, students' involvement and school community response are some of the hurdles that this study highlights. However, STEM education can still be effective in budget-constrained school contexts provided it is reinforced with the appropriate resources and support (Yunus, 2020). Innovation in curriculum, pedagogical and assessment can help to strengthen STEM education efforts (Lilia *et al.,* 2016). One of the innovations in learning is makerspace or maker concept learning for STEM education (Jaatinen & Lindfors, 2019). It provides joyful learning with freedom for students to organise their thinking to build useful products or process (Martin, 2015).

The maker concept aims to cultivate students' 21st-century skills with sufficient knowledge of STEM. Maker-centred learning is centred on the learner's context and knowledge is built through producing and engaging with physical objects, following the 'Learning by Doing' ideas of Jean Piaget and Seymour Papert (Gonzale *et al.,* 2018). In this matter, high-tech tools such as 3D pens, 3D printers, coding, robotics and web-based 3D modelling are studied and applied (Sheffield *et al.,* 2017).

However, Gracia (2019) states that a makerspace does not need all high-tech machines. It is more of the maker mindset of creating something out of nothing and exploring students' interests. The maker-centred learning system allowed students to think and learn by making (Vongkulluksn *et al.,* 2018). The findings of the Vongkulluksn (2018) study indicate that design-based makerspaces can help elementary children's learning in STEM with appropriate scaffolding for efficacy and emotion. It encourages students to bring their own learning experiences, technical expertise and communication skill set as student independence is the necessary component of the makers' class. In this study, the application of the STEM-Maker concept in any significant form such as a policy, curriculum, pedagogy, project, afterschool program or other modes in an educational setting is known as implementation. This study defines the practice as the process of teaching and learning through tinkering, planning, knowledge acquisition, making or building, and reflection within the framework of a field experience (Eckman *et al.,* 2016).

B. Purpose of the Study

The research aims to discover STEM-Maker concept implementations in primary schools and find relevant practices in teaching and learning. The following research questions lead our review and analysis:

RQ1: What are the STEM-Maker concept implementations in primary schools?

RQ2: What are the STEM-Maker concept practices in teaching and learning?

II. METHODS AND ANALYSIS

A. Literature Search Strategy

The systematic literature review was carefully designed to extract information on STEM-Maker concept implementations in primary schools. This analysis employed only Scopus journals because it has the largest abstract and citation database of peer-reviewed literature (Zhu,2020). The searches have been reported by protocol entries describing the year, research strings, database and quantity of things identified to locate eligible studies.

The search results have been confined to 2017- 2022 to ensure the manageability and relevant current cohort of articles. Since we have a different term to describe the school of children at age 6-12, the primary, elementary and middle schools used in search strings to ensure a sufficient number of studies reviewed in this study. "Upper primary" or "lower secondary" are terms used to describe middle school. It varies throughout several nations. However, this systematic literature review has included studies that applied to students between the ages of 7 and 12 as their sample population.

The selection of articles has undergone three stages as illustrated in Figure 1. The identified records' titles, abstracts, keywords, authors' names and affiliations, journal names, and publication years were exported to an MS Excel spreadsheet. Articles that were obviously outside the scope of the investigation, such as conceptual papers and critical literature reviews were removed after evaluated the titles and abstracts of the records. After that, we independently and thoroughly read the full contents of the remaining papers to determine the papers' eligibility. Disagreements among us were discussed during this stage, and we were then resolved by consensus. The opinions of us would have been taken into account if an agreement could not be achieved.

B. Eligibility Criteria

The recommendations of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement (Page *et al.,* 2020) followed the protocol in this study as in Figure 1. The following criteria were used to determine eligibility: (a) STEM-Maker concept practices had to be described as an interaction between teachers/educators and students in STEM teaching and learning practice in the primary, elementary or middle schools; (b) studies had to be focused on STEM-Maker concept implementations in the context of education; (c) studies had to be given a thorough and clear indication of STEM-Maker concept in teaching and learning; and (d) English journal articles and conference papers at the final stage. Figure 1 shows a summary of the search methodology.

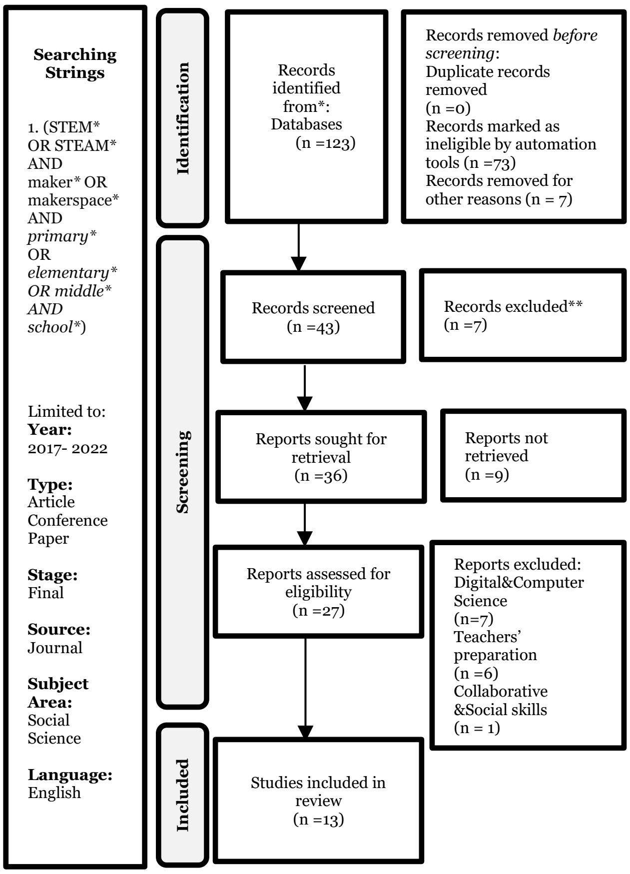


Figure 1. An overview of the search protocol based on the PRISMA statement

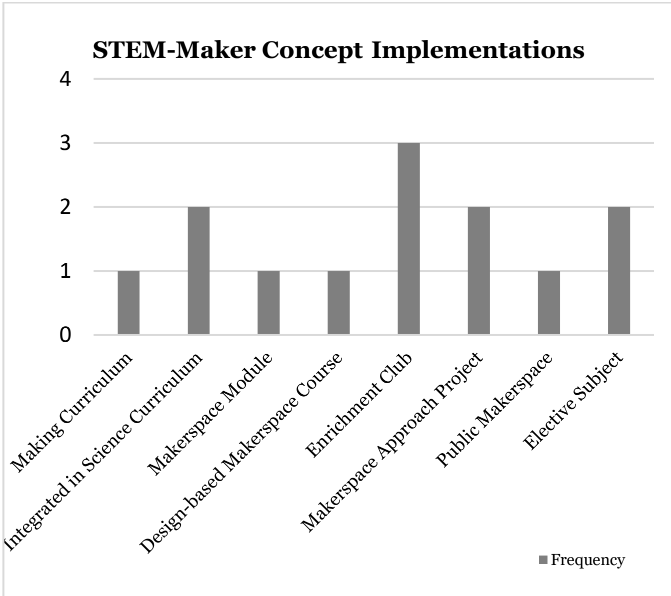
The following are the exclusion criteria: (a) STEM-Maker concept implementations and practices in higher and secondary education; (b) proceedings; (c) book (chapter) reviews; and (d) publications are written in languages other than English. These exclusions have been made because of irrelevant information for the study matter. STEM activities in some of the studies like computer science, high-tech robotics and many more are not suitable for students aged 7-12 in Malaysian primary schools. Besides, sources other than journal articles and conference papers are excluded because a systematic review article follows the same structure as that of an original research article, with a title, abstract, introduction, methods, results, discussion, and references. Following the inclusion and exclusion criteria, thirteen studies remained for analysis.

III. RESULTS AND DISCUSSION

A. RQ1: What are the STEM-Maker concept implementations in primary schools?

Based on the findings from the systematic review, we were able to identify the STEM-maker concept implementations for primary schools. Figure 2 provides an overview of the findings. Eight STEM-Maker concepts implementations were identified from the 13 chosen research publications. The frequency of each practice is illustrated in Figure 2.

Figure 2. STEM-Maker concept Implimentatons from 2017-2022



The enrichment club after school with experts' collaboration has recorded the highest frequency. Three shortlisted studies have implemented this concept as STEM-Maker concept learning. There are Shivley (2022), Ogle (2019) and Lang (2018). These studies are recommended for further in-depth study since it provides more gains and freedom for teachers to teach and for students to learn. Indirectly, the collaboration with experts for various factors has given the opportunity for teachers to strengthen their skills and knowledge on the STEM-Maker concept. However, it is not generalised as the best implementation since we do not analyse the efficacy of each implementation in this study.

The integration maker concept in the science curriculum, makerspace approach project and as an elective subjects have recorded the second highest frequency in the ways of implementing STEM-Maker. The idea of Flores (2018) and

Schlegel (2019) of integrating maker concept into the Science curriculum, the makerspace approach projects of Sheffield (2017) and Blackley (2018) and studies of Jasmiin (2019) Kajamaa (2020) as an elective subject for primary schools are another aspects that can be explored from these shortlisted articles.

The other types of implementation in STEM-Maker are making curriculum, makerspace module, design-based makerspace course and usage of public makerspace have recorded the lowest frequency in this study. The challenges of designing and testing making curriculum have been narrated clearly as guidance in Giusti's (2020) study. The Makerspace in STEM (MIS) project, which was studied by Sheffield (2017) and Blackley (2018) shows some unique approaches to STEM-infused maker concepts in the classroom. Their affordable materials and applicable approaches to impart STEM-rich Makers activities are great inputs which can be applied easily by teachers. Macanns' (2021) idea on the usage of public makerspace is an alternative teaching and learning environment to attract primary schoolers' interest in STEM. Thus, the adaptation of this concept in the classroom by Vongkulluksn (2018) as a design-based makerspace is an innovative idea for students' consistent learning.

The space of these implementations is also noted in this study to highlight the variations in designing makerspace. Most of the studies have implemented their intervention in common classrooms as their design-based makerspace. The finding from within the selected articles as summarised in Table 1.

Table 1. The summary of articles

Citation	Purpose	STEM-Maker concept Implementation	Practice and Primary Results
(Vongkulluksn *et al.,* 2018)	To study students' self-efficacy improved in a design-based makerspace class.	Design-based makerspace course (makerspace class with computer lab).	- Design a product or prototype with computer and 3D printers. - It has potential to boost primary students' STEM learning.
(Blackley *et al.,* 2018)	To study the learning experiences primary school students.	Project (classroom).	- The Wiggle Bot (3R concept). - Positive learning experiences of students were explained in details.
(Flores, 2018)	To design and test curriculum adapted by the tools and mindsets of maker movement in science courses.	Integrated in Science Curriculum (a self-directed learning space).	- Problem-based Science games by using digital and non-digital tools. - It allows the learners to exercise attitudes and practices of STEM fields.
(Giusti & Bombieri, 2020)	To design and test an integrated method for rethinking the role of Makerspace in an inclusive context.	An inclusive makerspace (maker) curriculum (a modified classroom).	- Tinkering workshop by using 3R concept. - It records positive findings and outcomes on makerspace curriculum.
(Sheffield *et al.,* 2017)	To find out how a Maker space approach can engage female primary school students.	MIS project, Makerspace approach to develop integrated STEM education (classroom).	- Makerspace bag (Design). - A positive finding which suggested more inputs apart from cognitive aspects of female students in STEM learning.
(Bower *et al.,* 2020)	To understand what supports and constrains learning and teaching in technology-oriented maker spaces.	A makerspace module of work involving 3D design and printing (classroom).	- 3D design & 3Dprinting with i-Pads. - Thematic analysis has revealed the 11 supports and 19 constraints learning factors.

(Schlegel *et al.,* 2019)	To investigate the effects of integrating Making into existing school curricula at a public elementary school.	Integrated Making in Science curriculum (classroom).	- Making kits (Intervention maker activities in science lesson). - Empirical data suggests that technology-infused learning can help students build self-efficacy and STEM potential.
(Macann *et al.,* 2021)	To explore perceptions of primary school teachers on use of public maker space for Computational thinking (CT) in alignment with STEM.	Public makerspace.	- Tool/robotics workshop with coding etc. - Problem-solving is important for developing CT skills and the teachers has shared uncertainties on designing CT learning tasks and assessments.
(Jasmiina *et al.,* 2019)	To examine how leadership emerges in students' group interactions in school-based makerspace.	Elective subject (FUSE) FUSE Studio (a digital game-like environment in computer lab).	- Open-ended STEAM project (challenges) with digital& materials. - It illustrates how the students' leadership moves in group interactions.
(Shivley *et al.,* 2022)	To examine first-year teacher candidates early field experience designing and implementing maker workshops for an afterschool program.	Afterschool Program (Enrichment club in a designed based classroom).	- Maker workshops (Collaborate and create educational games) with 3R materials. - Positive feedbacks from teachers to practice a maker-mind set while teaching and learning.
(Ogle *et al.,* 2019)	To explore self-confidence and self-esteem of participation in Fashion FUNdamentals (FF), a STEM summer enrichment program.	STEM- Summer Enrichment Program (collaboration) (university campus).	- Fashion software to design& 3D print Only for girls. - Analyses revealed that girls have deepen their confidence for STEM learning.
(Kajamaa *et al.,* 2020)	To enhance the educational potential of makerspaces in supporting students' knowledge creation and learning.	Elective subject FUSE Studio (computer lab).	- Digital and non-digital tools for 30 (pre-given) activities. - Four different types of multimodal knowledge practice—orienting, interpreting, concretising, and expanding knowledge were discovered.
(Lang *et al.,* 2018)	To increase student interest in STEM activities through a MakerSpace STEM club.	MakerSpace STEM Club (collaboration) (classroom).	- Digital & non-digital materials for activities. - An excellent opportunity to boost student participation in STEM courses is provided by joint efforts between schools and institutions to develop STEM pathways.

RQ2: What are the STEM-Maker concept practices in teaching and learning?

The STEM-infused maker concept practices in teaching and learning is another important gist in this systematic literature review. Based on the above articles, the practices of maker concepts with STEM in teaching and learning are extracted and illustrated in Figure 3.

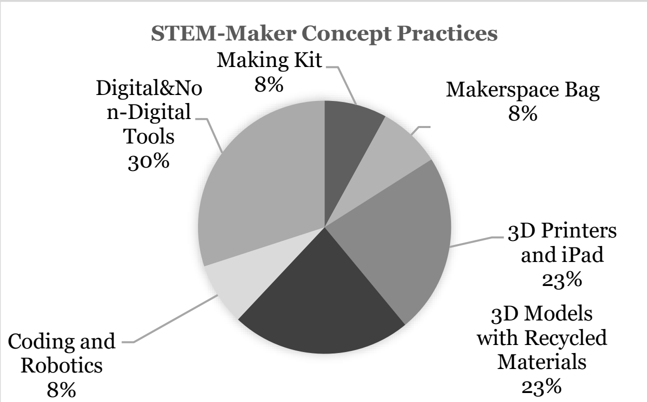


Figure 3. STEM-Maker concept practices in teaching & learning

Mainly, the maker concept practice needs a space known as a makerspace for students to work collaboratively with necessary tools and materials for learning by making. The regular classrooms were customised according to the requirements of the lessons as learning spaces in most of the above studies. Some researchers used existing rooms in the schools such as computer labs, shared rooms and public makerspace for their project or program or workshop, which involve many students.

Although makerspace is known for its high-tech tools and materials in a user-friendly environment, the creative practices with balance integration of STEM with digital and non-digital tools have been tested most, by Flores (2018), Jasmiina (2019), Kajamaa (2020) and Lang (2018) in teaching and learning. Access to low-cost and recycled materials in the classroom can support STEM practices like IBL, PBL and PjBL (Lee, 2014; Llewellyn *et al.,* 2016) and create a resource-rich environment, such as makerspaces (Sheffield *et al.,* 2017). Giusti (2020), Blackley (2018) and Shively (2022) report on the usage of recycling or reusing materials in the classroom to make 3D models, whereas Bower (2020), Ogle (2019) and Vongkulluksn (2018) explain the usage of the high-tech tools, 3D printers and other IT tools in the makerspace. The makerspace bag of Sheffield (2017) stimulates students' interest by providing materials and tools needed for specific learning activities in the common classroom.

The making kit, as discussed by Schlegel (2019) and Vongkulluksn (2018), is different from the makerspace bag. The maker kit consists only of tools which can be used throughout the project or program. However, the usage of 3D printers has highlighted most of the listed studies for primary schools. All of them have recorded positive gaining for STEM-maker concept teaching and learning. Gender aspects in learning STEM were also studied and tested by Ogle (2019) in fashion design and Sheffield (2017) in Science projects for girls. Collaboration with experts for tools, expertise and space is also strongly recommended by Ogle (2019) and Macann (2021) to have active learning of the STEM-Maker concept.

To have solid guidance for future research, the challenges in the above implementations and practices need to analyse critically. Besides, the finding from another database with more than articles such as thesis, dissertation, review and editorial can be applied through meta-analysis by showing some statistical methods with experts' consensus to further strengthen and refine the STEM-Maker concept implementations and practices in primary schools.

IV. CONCLUSION

Learning by doing as a maker-centred learning approach in the classroom is one of the ways to craft STEM in primary schools. This study has compiled and presented eight types of implementations and six ways of practising ideas on integrating STEM in primary schools through the maker concept. With great initiative from stakeholders, finding and filling up gaps in the STEM-Maker concept in primary schools to cultivate students' 21st -century skills other than basic skills is possible. For further studies, a critical meta-analysis on the effectiveness of this matter is a must to integrate STEM while tackling problems and challenges in teaching and learning primary science.

V. ACKNOWLEDGEMENT

This study was funded by Universiti Putra Malaysia Grant (#960940) and Bahagian Tajaan Pendidikan (BTP), Ministry of Education, Malaysia.

VI. REFERENCES

Alley, W 2018, 'Making English speakers: Maker spaces as constructivist language environments', Mextesol Journal, vol. 42, no. 4, pp. 1–8.

Balakrisnan, V, Kamarudin, N, Marina, A & Hassan, A 2021, 'Maker-centred in Classroom Learning : Metamorphosis of Primary Education', Journal of Bitara Education, UPSI, vol. 14, pp. 119–127.

Bevan, B 2017, 'The promise and the promises of Making in science education', Studies in Science Education, vol. 53, no. 1, pp. 75–103.

Blackley, S, Rahmawati, Y, Fitriani, E, Sheffield, R & Koul, R 2018, 'Using a maker space approach to engage Indonesian primary students with STEM', Issues in Educational Research, vol. 28, no. 1, pp. 18–42.

Bower, M, Stevenson, M, Forbes, A, Falloon, G & Hatzigianni, M 2020, 'Maker spaces pedagogy–supports and constraints during 3D design and 3D printing activities in primary schools', Educational Media International, vol. 57, no. 1, pp. 1–28.

Eckman, EW, Williams, MA & Silver-Thorn, MB 2016, 'An integrated model for STEAM teacher preparation: The value of a teaching cooperative educational experience', Journal of STEAM Teacher Education, vol. 51, no. 1, Article 8.

English, LD & Mousoulides, NG 2015, 'Bridging STEM in a real-world problem', Mathematics Teaching in the Middle School, vol. 20, no. 9, pp. 532–539.

English, LD 2016, 'STEM education K-12: Perspectives on integration', International Journal of STEM Education, vol. 3, no. 1, p. 3.

Flores, C 2018, 'Problem-based science, a constructionist approach to science literacy in middle school', International Journal of Child-Computer Interaction, vol. 16, pp. 25–30.

Garcia, PC & Fernandez, TG 2019, 'Influence of maker-centred classroom on the students' motivation towards science learning'', Cypriot Journal of Educational Sciences, vol. 14, no. 4, pp. 535–544.

Godhe, AL, Lilja, P & Selwyn, N 2019, 'Making sense of making: critical issues in the integration of maker education into schools', Technology, Pedagogy and Education, vol. 28, no. 3, pp. 317–328.

Gonzalez, CS & Arias, LGA 2018, 'Maker movement in education: maker mindset and maker spaces', Paper presented at IV Ibero-American Conference on Human Computer Interaction, Popayam, Colombia.

Giusti, T & Bombieri, L 2020, 'Learning inclusion through maker space: a curriculum approach in Italy to share powerful ideas in a meaningful context', International Journal of Information and Learning Technology, vol. 37, no. 3, pp. 73–86.

Hatch, M 2014, The maker movement manifesto, New York: McGraw-Hill.

Jaatinen, J & Lindfors, E 2019, 'Makerspaces for Pedagogical Innovation Processes: How Finnish Comprehensive Schools Create Space for Makers', Design and Technology Education, vol. 24, no. 2, pp. 42–67.

Lilia, H 2017, 'Improving Science Literacy Through a Conductive Laboratory Learning Environment: A Proposed Model', Plenary Paper Presented at Third International Conference on Science and Mathematics Education (CoSMEd), 10th-12th November.

Lilia Halim & Mohamad Satar Rasul 2016, 'Transformasi STEM dalam Pendidikan Nasional', in Hussein Ahmad & Mohammed Sani Ibrahim (Eds), Transformasi Pendidikan Nasional Antara Aspirasi dan Anjakan, 1st edn, pp. 205-220, Kuala Lumpur.

Lee, MY 2014, 'iSTEM: Tinkering with buoyancy', Teaching Children Mathematics, vol. 20, no. 9, pp. 574– 578.

Llewellyn, D, Pray, S, DeRose, R & Ottman, W 2016, 'Engineering encounters: Building a spaghetti structure', Science and Children, vol. 54, no. 2, pp. 70–75.

MacDonald, A, Danaia, L & Murphy, S 2020, 'STEM education across the learning continuum: Early childhood to senior secondary', in STEM Education Across the Learning Continuum: Early Childhood to Senior Secondary.

Md. Yunus, AS 2020, 'Challenges of STEM Education', Icri 2018, pp. 45–52.

Macann, V & Carvalho, L 2021, 'Teachers use of public maker spaces to support students' development of digital technology competencies', New Zealand Journal of Educational Studies, vol. 56, pp. 125-142.

Malaysian Ministry of Education 2013, Malaysia Education Blueprint 2013-2025, Putrajaya: MOE.

Martin, L 2015, 'The promise of the maker movement for education', Journal of Pre-College Engineering Education Research, vol. 5, no. 1, pp. 30–39.

Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, BMJ 2021, 372, n71.

Ramli, NF, Talib, O & Manaf, UKA 2017, 'Instructional Approaches and Challenges of STEM Instructional Implementation: A Systematic Review', Graduate Research in Education Seminar (GREduc 17) Universiti Putra Malaysia, December 2017, pp. 1–12.

Ramli, N & Talib, O 2017, 'Can Education Institution Implement STEM? From Malaysian Teachers' View', International Journal of Academic Research in Business and Social Sciences, vol. 7, no. 3, pp. 721–732.

Rauf, RAA, Rasul, MS, Sathasivam, R & Rahim, SSA 2017, 'Training of trainers STEM build program for primary science teachers: An initiative towards STEM education in school', in International Conference New Perspectives in Science Education.

Robertson, L, Nivens, RA & Lange, A 2020, 'Tackling Integrated STEM in Elementary Education: A Collaborative Approach', International Association of Laboratory Schools (IALS), Volume X, no. 1.

Schlegel, RJ, Chu, SL, Chen, K, Deuermeyer, E, Christy, AG, & Quek, F 2019, 'Making in the classroom: Longitudinal evidence of increases in self-efficacy and STEM possible selves over time', Computers and Education, vol. 142, p. 103637.

Sheffield, R, Koul, R, Blackley, S & Maynard, N 2017, 'Maker space in STEM for girls: A physical space to develop twenty-first-century skills', Educational Media International, vol. 54, no. 2, pp. 148–164.

Shively, K, Hitchens, C & Hitchens, N 2021, 'Teaching Severe Weather: Examining Teacher Candidates' Early Field Experience in a Makerspace Environment', Journal of Education, vol. 201, no. 3, pp. 198–209.

Vasquez, JA, Sneider, CI & Comer, MW 2013, STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics, pp. 58-76, Portsmouth, NH: Heinemann.

Vongkulluksn, VW, Matewos, AM, Sinatra, GM & Marsh, JA 2018, 'Motivational factors in maker spaces: a mixed methods study of elementary school students' situational interest, self-efficacy, and achievement emotions', International Journal of STEM Education, vol. 5, no. 1.

Zhu J & Liu W 2020, 'A tale of two databases: the use of web of science and scopus in academic papers', Scientometrics, vol. 123, no. 1, pp. 321–35.