Eurasia Journal of Mathematics, Science & Technology Education, 2014, **10**(3), 155-163

A Review of Science, Technology, Engineering & Mathematics (STEM) Education Research from 1999–2013: A Malaysian Perspective

Kamaleswaran Jayarajah, Rohaida Mohd Saat, & Rose Amnah Abdul Rauf
University of Malaya, MALAYSIA

Received 25 July 2013; accepted 19 January 2014

The purpose of this study is to explore the research base of STEM education in Malaysia through an analysis review of articles for a 14-year period, from 1999 to 2013. The research base review focuses on identifying four characteristics of STEM education: a) temporal distribution, b) the research areas involved in each discipline, c) the types of participants, and d) the methodological design employed. Published journals from web-based service providers were selected according to the original author's discussion of STEM education in the articles. The findings summarize the core consistencies of STEM education literature across the STEM disciplines throughout the years by identifying the STEM-related content addressed by professionals in their respective fields.

Keywords: Science, Technology, Engineering & Mathematics, STEM, education, review

INTRODUCTION

STEM is an acronym for the study of or professional practice in broad areas of science, technology, engineering, and mathematics. This educational concern is driven by a large majority of secondary school students who fail to reach proficiency in math and science (Hernandez et al., 2013). Meanwhile, Brown (2012) reveals that STEM education research is a field of wide variety and unclear parameters. The lack of agreement on what STEM education is can be seen in the many different definitions of STEM education (Brown, 2012). Apart from that, the United States (US) Department of Education (2007) defines STEM education as an educational program for those primarily intended to provide support for or to strengthen STEM education at the elementary and secondary through postgraduate levels, including adult education.

Correspondence to: Rohaida Mohd Saat,
Faculty of Education, University of Malaya,
Malaysia.
E-mail: rohaida@um.edu.my
doi: 10.12973/eurasia.2014.1072a

In line with the STEM education definition, risk and reassurance are also two key considerations of the activities of science, mathematics, engineering, invention, and technology, collectively often referred to simply as "science" or "science and technology" (Petroski, 2010) and they are now known as STEM education. Petroski (2010) added that STEM education plays a critical role in modern civilization, being essential for the advancement of society and the protection of our quality of life. The advantage of integrating STEM education into all content areas at all grade levels is that it provides students with informal practice in creatively solving problems long before they need to decide on a course of study for college (Meyrick, 2011).

Though Malaysia is directly comparable to the United States in S&T fields (MOSTI, 2008), Malaysia consistently registers lower numbers of citizens interested in S&T issues compared to the United States (MOSTI, 2008). According to MOSTI (2008), only 44.9% of Malaysians are interested in new science inventions or discoveries. In contrast, far more Americans (87.0%) and Europeans (78.0%) expressed an interest in these issues, exceeding Malaysians by

ISSN: 1305-8223

State of the literature

- Students and practitioners (teachers and lecturers) develop an understanding of the nature of STEM education so that it does not become lost in any integration process.
- Advanced interception between science and technology (S&T) is perceived through biotechnology and nanotechnology where both scientific and technological aspects are tightly interwoven.
- The resurgence of STEM education offers Malaysians, particularly the young, an opportunity to continue to define and include more contemporary components of engineering education.

Contribution of this paper to the literature

- Identifying the priorities and providing recommendations for future research and development in Malaysian STEM education using a combination of older research and recent papers to illustrate the advances of STEM education.
- Scoping the past research activities and presenting an agenda for moving forward through a reflection of interdisciplinary fields in STEM education.
- Recognizing the trends of method and design employed in the research studies over the past years in each STEM discipline.

42.1% and 33.1%, respectively. These percentages are based on a general sample collection following on the children's interest in S&T fields. As for the Malaysian population, this proves that more than one-third of the children clearly expressed a lack of interest in S&T. Parallel to this, according to Martin, Mullis, Foy and Stanco (2012), a total of 18% of Malaysian children have limited prerequisite knowledge and skills in science classrooms; meanwhile, 55% of them had limited prior knowledge in science. In fact, Nordin (2012) revealed that the situation further deteriorated in 2012 as students' enrollment in the science stream decreased to as low as 29%. These statistics make quite a compelling case that the Malaysian government needs to do more to reach out to those Malaysians who appear to be indifferent to or uninterested in S&T (MOSTI, 2008). With the disappointing performance of Malaysian science students' in Trends in International Mathematics and Science Study (TIMSS) in 2011 (Martin et al., 2012) and Program for International Student Assessment (PISA) in 2009 (OECD, 2010), the key question now will be what should the future of science education look like to inspire young Malaysians and ensure they understand the concepts, processes, and role of science in the world (Hartwell, 2010)?

Apart from science and mathematics education, engineering education also seems to face challenges. The lack of qualified engineers and technicians is currently reported to be one of the principal obstacles to economic growth encountered by innovative firms in many industrialized and industrializing countries (UNESCO, 2010). In Malaysia, the Ministry of Education has estimated that the current number of engineers in the country is at about 140,000. Based on an annual output of 15,000 new university graduates in Malaysia, the numbers of engineers are projected to reach over 200,000 by 2017 (Kieong, 2012). These engineers should be academically qualified and have the necessary training and experience in the engineering profession. Though the sustenance of competitive advantage of nations depends more and more on science and engineering, our primary and secondary schools seem to have a limitation in producing enough students with the interest, motivation, and skills they need (Ali, 2012). Science must be taught in a more enriching and interesting manner, and interdisciplinary in nature to keep curiosity alive (Yarker & Park, 2012). Retaining students' interest in science is important for many reasons, not least of which is the need for an adequate number of students to select science in their secondary years (Cleaves, 2005; Lindahl, 2003) in order to pursue science-related careers. In fact, both science and mathematics are sequential in making performance in middle school, and this combination of fields is critical for later access to advanced courses and success in the full array of mathematics and science courses in high school and beyond (Singh, Granville, & Dika, 2002). As a result, the workforce of the 21st century must have science and mathematics skills, creativity, fluency in information and communication technologies, and the ability to solve complex problems (Business-Higher Education Forum, 2005).

Malaysian science education is aiming at making science more appealing to students and indirectly inviting more students to pursue their studies in science-related areas to realize Malaysia's goal of becoming an industrialized country (Saat, 2012). According to Rhoads (2004), the increasing flow in the STEM education pipeline has become a better way to motivate young minds to further their interest in science and mathematics. However, in the face of an increasing emphasis on STEM education, it is crucial that the engineering and technology components are not dominated by the stronger science and mathematics subcultures (Jones, Buntting, & Vries, 2013). Hence, despite the fact that research on the integrative approaches in STEM education has grown, there are still a number of practical challenges that need to be addressed (Zubrowski, 2002).

In line with the above, this paper focuses on the research areas in each of the STEM disciplines that have been researched in Malaysia over a period of 14 years. The purpose of this paper is to give an overview of the STEM education that has been carried out in Malaysia as well as to assess it and discuss its possibilities for future development. In addition, this paper also aims to explore the type and the regularity of research areas that have been researched in Malaysian STEM education. In addition to analyzing the research areas and issues in each STEM field, the type of participants and the research methodology employed are also analyzed. However, it is perceived that some limitations do exist where more research could be carried out involving STEM education across the nation. In principle, meta-analysis offers several advantages over traditional narrative review, which this paper has employed. Though meta-analysis offers a more objective, disciplined, and transparent approach to assimilate extant findings, in practice, meta-analysis still produces erroneous conclusions (Ellis, 2011). Hence, this review describes and reflects on how far Malaysian STEM education has come and where it might go to, including what questions need to be considered in its ongoing development.

METHODOLOGY

This paper identifies published research using the Educational Resources Information Centre (ERIC) as the main scanning bibliographic database. Access to ERIC's database has become considerably easier with the emergence of web-based service providers such as EBSCO, Educational Journals @ ProQuest, Emerald, Science Direct, Scopus ™, Springer Link, Taylor Francis Online, and Web of Science. These multiple databases were scanned to retrieve the published articles involving STEM education in Malaysia. Since there has been a lack of research solely on STEM education, this paper reviews published articles in all four STEM disciplines, which are science, technology, engineering, and mathematics.

These articles were screened using key search terms such as "science and mathematics," "technology," "engineering," "education," and "field." The screened articles were selected based on the research in science, technology, engineering, and mathematics or the entire STEM education in a study. However, these subjects were also scrutinized and analyzed for each of the sub-subjects studied. The science search was divided into biology, physics, and chemistry. In line with that, to avoid bias, the other fields, such as engineering, mathematics, and technology, were divided as well - for example, mechanical engineering, chemical engineering, additional mathematics, design technology, and the list goes on for the sub-subjects that fall under STEM education. These key search terms were identified as representing the fitting characteristics regarding how the articles were screened and designated using web-based service providers. Hence, this research has stood by its objectives and the definition that the STEM poses. This is to avoid prejudicial or one-sided keywords for subjects in STEM education, prior to this research.

The search was limited to 1999–2013, and a total of 57 published articles were identified. Although Malaysia is still behind in publishing articles in high-impact journals, we managed to retrieve several articles from established journals such as Science Education, International Journal of Science and Mathematics Education (formally known as European Journal of Science Education), Research in Science Education, European Journal of Mathematics, Science and Technology Education, Journal of Engineering and Applied Science, and Journal of Engineering Education. By analyzing the articles' titles, abstracts, research areas, samples, methods, and findings, this paper provides empirical results involving temporal distribution of STEM education in Malaysia, research at various education levels, and methodological approaches.

A narrative review supported by descriptive empirical statistics is employed to interpret the research findings in this paper. According to Humphrey (2011), the editorial boards of journal articles have stipulated that the findings must be interpreted in a meaningful way, not just provide the effect sizes without providing perspective. This narrative review is not undertaken to report solely on the collective achievement of a large number of people regarding Malaysian research but rather is to be used as a means for setting a comprehensive foundation for the future research and development of Malaysian STEM education. In short, this narrative review signifies a synthesis in its own right.

RESULTS

The findings provide a descriptive analysis of the STEM education research field. These findings show that there is a research base for STEM education in Malaysia. Parallel to this, these findings summarize the scope of research being conducted by STEM education scholars who are being studied and the institutions in which STEM research is being conducted and published. The findings are organized in four sections:

a) Temporal distribution,
b) Research areas involved in each discipline,
c) Types of participants, and
d) Methodological design employed.

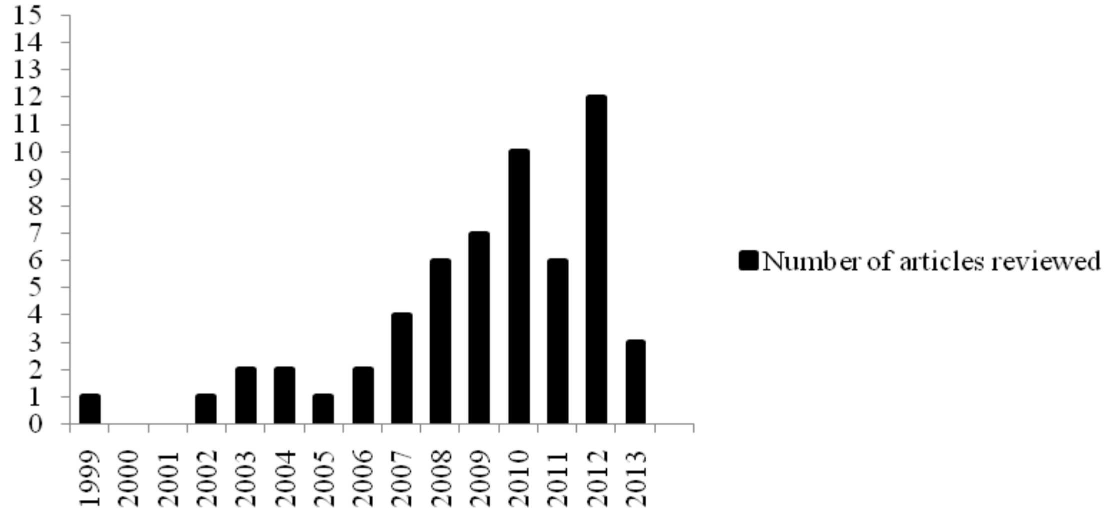

Figure 1. Distribution of reviewed articles from 1999 to 2013

Temporal distribution of research studies in STEM education

Figure 1 presents the distribution of articles during the studied period. The total number of articles analyzed is 57 throughout a period of 14 years. The dispersal STEM articles published in Malaysia fluctuated from 1999–2004, whereby the maximum number of reviewed articles was only two. However, the distribution of articles showed a more positive trend when the reviewed articles increased gradually from 2005–2010. The total increase was 90%. The following year, the reviewed articles decreased by 40% before increasing by a total of 50% in 2012. The highest number of articles reviewed was in 2012, with a total increase of 21% contributed to the overall distribution of the reviewed articles. Though 2012 has the most published articles since 1999, only three articles pertaining to STEM education were retrieved for 2013.

Research areas involved in each discipline

There are 10 research areas that have been summarized from the 57 articles. Some articles have more than one research area or issue, but most of them have one main issue in their write up. A total of 95 issues have been analyzed. Among the four fields in STEM education, the highest number of articles published is in the technology discipline, which totals 55 issues. This is followed by the science and mathematics disciplines (28 issues) and finally engineering education (12 issues). Table 1 below describes the frequency of the research areas discussed in each field of STEM education in the published articles.

The highest number of research areas that were studied over the 14-year period was in using Information & Communication Technology (ICT) as a teaching tool and teaching and learning, which contributed a total of 21% and 20%, respectively. Other issues that have been investigated in this paper include the role of the Internet, distance learning, and theory and practice. The trend of using ICT as a teaching tool in Malaysia has changed over the years. The trend that moved from emphasizing the use of ICT to support teaching subjects and learning to introducing ICT itself as a subject in schools and educational institutions shows just how much importance has been given to technology education. In fact, previously known as Information Technology (IT), it has been studied as a separate field whereby both technology and education are discussed separately. Over the years, the research field of technology has advanced from the realm of computers to digital devices and wireless equipment. Parallel with this, software design programs have also technologically advanced from Microsoft Windows to Vista or XP.

Teaching and learning has also been given priority with respect to STEM education in Malaysia. However, a total of 53% of this research area has been concentrated in the science and mathematics fields whereby perspectives of cognitive knowledge and thinking skills are studied. The evidence also indicates that teaching and learning in science and mathematics comprises the highest number of issues researched compared to all other issues. At the same time, learning strategies and gender issues each contribute 11% to the total number of issues researched over the 14-year period. The studies that indicate the difference in terms of achievement between boys and girls are quite compelling, especially in technology field. In contrast, research areas such as innovation and problem solving, which reflect creativity and higher-order thinking, are given much less emphasis in all STEM fields.

Table 1. Research areas in Malaysian STEM education

No.	Research area	Science & Mathematics	Technology	Engineering	Total
1.	Teaching tool (ICT)	2	16	2	20
2.	Teaching & leaning	10	6	3	19
3.	Learning strategies	2	7	1	10
4.	Gender	2	6	2	10
5.	Innovation	2	4	-	6
6.	Interest & motivation	4	4	-	8
7.	Assessment	2	4	-	6
8.	Problem solving	1	1	3	5
9.	TIMSS 2003 & 2007	3	-	-	3
10.	Other issues	-	7	1	8
Total number of issues		28	55	12	95

Table 2. Type of participants in Malaysian STEM education

No.	Participants		Science & Mathematics	Technology	Engineering	Total
1.	Students	Pre-elementary	-	1	-	1
	(School)	Primary	2	2	-	4
		Secondary	9	3	-	12
2.	Graduates	Under	6	13	8	27
	(University)	Post	-	1	-	1
3.	Practitioners	Teacher	1	3	-	4
		Lecturer	1	-	-	1
4.	Adults		1	6	1	8
Total number of samples			20	29	9	58

Types of participants

There are four major groups of participants that were emphasized in the published research articles. These groups of participants vary from the elementary level up to the university level. Research studies in STEM education have employed them as samples in order to gather feedback on the researched fields. The following Table 2 describes the types of participants involved and the number of samples gathered for each STEM discipline.

STEM education in Malaysia has highlighted the age group between 12–24 years old since a total of 67% of the articles focused on secondary school students and undergraduates in universities. Adults in this paper consist of participants within the age group of 19-60 years old, and they comprise employers, committee members, administrative officers, and journalists. Though Malaysian research in the technology and engineering fields is well established and is in fact still succeeding, research trends indicate that the emphasis in both these fields has been focused on university graduates. This indicates that research on technology and engineering has been focused on the most advanced level of education, leaving students and teachers in primary and secondary schools with much less attention. The research trend also shows the lack of importance given to pre-elementary children since this group of participants is the least employed in Malaysian studies over the years. It can be seen that all STEM discipline research has been concentrated on undergraduates at the university level since 47% of the total number of samples was channeled into higher-learning participants. Apart from university level, more articles were published about secondary school students compared to primary school children. With respect for both university and school-level participants, it is clear that researchers prefer to employ mature participants as their research samples. Surprisingly, only a handful of research has focused on teachers, lecturers, and adults in STEM education studies although these participants are also mature. Conceivably, researchers throughout the years have been directed by policy makers rather than investigating through critical and independent thought.

Methodological design employed

The methodological design trend over the 14-year period shows that there are four types of research designs or methods employed in Malaysian STEM education. Qualitative, quantitative, mixed method, and design and development research (DDR) are the main methodological designs that have been employed in STEM education research by the local researchers. Though the importance of statistical analysis is

Table 3. Research design in Malaysian STEM education

No.	Research design	Science & Mathematics	Technology	Engineering	Total
1.	Qualitative	9	11	5	25
2.	Quantitative	1	6	3	10
3.	Mixed method	9	6	-	15
4.	DDR method	-	4	1	5
5.	Others	-	1	-	1
Total research design		28	55	12	56

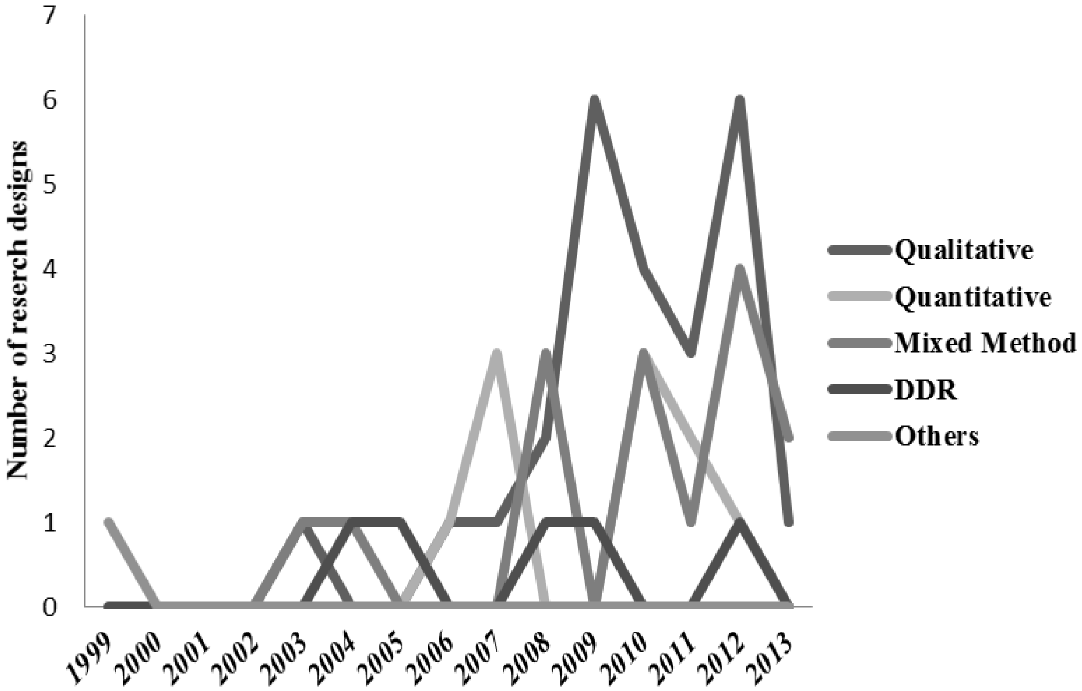

Figure 2. Distribution of research design from year 1999-2013

inevitable, most of the findings in the screened articles were analyzed qualitatively. However, a study in 1999 did not indicate the type of research design employed. Thus, the total number of research designs analyzed in this review is 56. Table 3 below illustrates the distribution of research designs across the disciplines within local STEM education.

A majority of the articles employ a qualitative research design since a sum of 45% add on to the total number of articles. Qualitative research design has been popular over the years among all the STEM disciplines. In fact, despite the sophisticated and advanced software for analyzing research findings, both the technology and engineering fields have emphasized qualitative research over other research designs. More Malaysian STEM studies are focused not only on researching the perceptions of experts but also concentrate on how a process takes place in educational research.

We also observed that mixed method design, which employs both qualitative and quantitative paradigms, has been widely used—especially in the technology, science, and mathematics fields. This is because mixed method design has been employed in a total of 27% of the overall research studies in STEM education. In fact, despite the fact that researchers in the engineering field have not employed the mixed method design over the past 14 years, the overall use of mixed method design is still higher than that of quantitative research design. Quantitative research design is well utilized in the technology field.

The DDR approach is given the least emphasis compared to other research designs since only five articles employed this design in their respective research studies. Unfortunately, the Malaysian-based scholarly articles have concluded that none of the researchers in science and mathematics have focused on the DDR design since 1999. On the other hand, the technology field has employed the DDR design in 80% of its studies. Articles that involved the DDR design in the technology field have concentrated on all the four types of participants—from the pre-elementary, primary, secondary, and university levels. These research studies have focused on designing interactive multimedia courseware and developing learning modules for studies. There is one particular study that has come up with an innovative idea that has contributed to designing educational games to pique students' interest during the teaching and learning process.

Figure 2 illustrates the trend of research designs in Malaysian STEM education over the past 14 years. Apart from the mentioned research designs, this review also analyzed other research designs that have been employed in STEM education. Project-based research designs that were employed early in 2000 did not highlight the type of research paradigm being employed. However, project-based research designs after 2000 have clearly mentioned the research paradigms employed in the STEM education research. The distribution of research approaches also indicates that no particular research design is given main priority since the dispersal of all research designs has fluctuated over the years. Although it can clearly be seen that the qualitative approach has dominated in terms of the methodology of studies, the trend of mixed method design has also seemed to be employed consistently and, in fact, it showed an increase in use in 2012. The trend of STEM education studies in Malaysia indicates that researchers are known for their flexibility and maturity in employing research approaches to produce their scholarly articles.

With respect to the methodological quality of the research, this review has found that validity in most qualitative studies has been measured using a) persistent observation; b) triangulation; c) peers' critical judgment to reduce researcher bias; d) reference materials, including documents and audio tapes that allow analysis; and e) verification of researchers' interpretations against the studied subjects. In contrast, validity in quantitative studies has not been clearly measured despite the fact that the research data have been analyzed using Analysis of variance (ANOVA), Multivariate analysis of variance (MANOVA), and the *t*-test to produce inferential statistics. In fact, some research has overlooked the importance of effect sizes and overall average effect size when citing evidence from quantitative studies. It is inevitable that reliability and validity are bound together in complex ways. Although there is research that has used test/re-test to measure reliability, most of the articles that employed either quantitative or mixed method research designs used coefficient alpha (α-Cronbach) to measure reliability in their respective STEM education articles.

DISCUSSION

Quality STEM education should raise learners' reasoning synthesis regarding the mutually reliant science and mathematics in order to make improvements in engineering and technology (Hernandez et al., 2013). Moreover, an incorporated approach to STEM education naturally entails authentic practices to study how things work together and how technologies are fashioned. Technology and engineering in STEM education are openly involved in problem solving, innovation, and design. Looking at their commercial importance in the world, students should attend to engineering and technology within a STEM perspective and exercise the skills and talents related to the design process (Hernandez et al., 2013).

With respect to the research areas in Malaysian STEM education, compelling evidence has shown that there is a clear dominance of studies on technology compared to other STEM disciplines in Malaysia. The importance of research on technology is inevitable, though studies should branch out from focusing on simply the university level to other educational levels. Using ICT as a teaching tool in teaching and learning has been the main focus of articles pertaining to STEM education. However technology has developed into a world culture, and its spread is not likely to be stemmed (Petroski, 2010). More research on transferring technology from one culture to another could be carried out in terms of STEM education in Malaysia. In fact, the tallest building on the planet was in Malaysia, designed and constructed with the essential help of American structural engineers (Petroski, 2010). Apart from the merging of two cultures together, the intersection of two different fields was also crucial. The interception between science and technology reporting in newspapers and magazines is nothing new, but what about the intersection between science and engineering or scientist and engineers? The contribution of the science and engineering fields merged together has been employed in many inventions, such as building and launching rockets and designing and developing delivery systems for life-saving drugs and countless medical devices that are now in common use. However, there is a lack of a combination of these fields as the emergence of these research studies have yet to be read in our newspapers and discussed in everyday conversation. In fact, for most, STEM education means only science and mathematics, even though the products of technology and engineering have so greatly influenced everyday life. Parallel to this, Petroski (2010) admitted that there is a need for clarification of the relationship between science and engineering since there has been confusion reported regarding overlap between these two fields. As compared to other fields in Malaysian STEM education, the engineering field has the lowest number of published articles. This is because engineering is a field not understood by many people (Poll, 2004). Since engineering involves a broad spectrum of activities and goals, the public is still unable to understand engineering's many aspects and how these aspects interact. In fact, the different representations of engineering may continue to cause public misunderstanding (Mena &Diefes-Dux, 2012).

Similarly, with respect to education level, the highest frequency of STEM studies at the university and secondary school levels reflects a research characteristic in the reviewed sample. The small number of studies focused on the primary level coincided with the general situation of science education studies concerning young children in Malaysia. DeJarnette (2012) stressed that fewer opportunities exist for elementary students and their teachers. Research has shown that early exposure to STEM initiatives and activities positively impacts elementary students' perceptions and dispositions (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee& Fuchs, 2006). DeJarnette (2012) added that by capturing students' interest in STEM content at an earlier age, a proactive approach can ensure that students are on track through middle and high school to complete the needed coursework for adequate preparation to enter STEM degree programs at institutions of higher learning. These interest could also lead students to pursue their careers based on STEM education (Narayan et al., 2013). Hence, more articles involving STEM education should be published focusing on Malaysian children. In line with this, this review has also discovered that not much concentration has been given to practitioners such as teachers and lecturers across the years of research studies in STEM education. Bartholomew, Anderson and Moeed (2012) revealed that content knowledge alone does not make a teacher. According to Kabilan (2003), Malaysian teachers need to learn continuously because continuous learning by teachers holds the key to the transformation of Malaysian schools, training, and preparing its learners to face challenges apart from improving the learners' performances. Hence, with regards to having a positive impact in the present and future of STEM education, more studies should be carried out among the Malaysian practitioners regardless of the level of institution in the Malaysian education system.

Design and development research or instructional research design may sound complex and difficult, but it helps a researcher—whether a practitioner or a graduate student—to make contributions to the growing knowledge base (Reigeluth & Carr-Chellman, 2009). Surprisingly, only five published articles have employed the design and development research paradigm observed in this paper and none of them are in science and mathematics education. According to Petroski (2010), there is certainly nothing wrong with pursuing basic research in search of basic knowledge, but it is not necessarily the way to spend money allocated for attacking a particular problem because to solve real and pressing problems, more emphasis should be focused on design and development research paradigms.

CONCLUSION

Despite many efforts to disseminate and implement STEM education in Malaysia, little research has been documented to determine the effects of the integrative approaches among the STEM subjects on the students' achievement and the infusion between STEM disciplines. Apart from that, in realizing the risk and reassurance for STEM education, more meticulous efforts should be carried out by Malaysian researchers since the future of science education should be able to inspire young Malaysians and ensure they understand the concepts, processes, and role of science, not only within the nation's context but also across the globe. In light of the greater emphasis on STEM education internationally, it is also critical that the science and mathematics education literature and practices do not overwhelm the contributions from engineering education researchers and practitioners.

Unpublished articles are also sought to help minimize the risk of publication bias (The Joanna Briggs Institute for Evidence Based Nursing & Midwifery, 2001). Unfortunately, this paper has limited its study to reviewed published articles only. This is because the findings of unpublished studies are difficult since, by their very nature, there is generally no public record of unpublished articles (The Joanna Briggs Institute for Evidence Based Nursing & Midwifery, 2001). Hence, this paper summarizes all of the past research on STEM education through published articles.

REFERENCES

Ali, A. T. (September, 2012). *Teaching & learning of science & mathematics in schools: towards a more"creative & innovative Malaysia"*. Paper presented at the Colloquium Science & Mathematic Education, University of Malaya, Kuala Lumpur.

Bagiati, A., Yoon, S.Y., Evangelou, D., Ngambeki, I. (2010). Engineering curricula in early education: describing the landscape of open resources. *Early Childhood Research & Practice, 12*(2), 2-13.

Bartholomew, R., Anderson, D., Moeed, A. (2012). Resilience of Science Teaching Philosophies and Practice in Early Career Primary Teaching Graduates. *Eurasia Journal of Mathematics, Science & Technology Education*, *8(2)*, 103-112.

Brown, J., Brown R., & Merrill, C. (2012). Science and technology educators' enacted curriculum: areas of possible collaboration for an integrative STEM approach in public schools. *Technology Teacher, 71*(4), 30-34.

Bybee, R. W & Fuchs, B. (2006). Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching, 43*(4), 349-352.

Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education, 27*(4), 471-486.

DeJarnette, N. K. (2012). America's children: Providing early exposure to STEM (Science,Technology, Engineering and Maths) initiatives. *Journal of Education, 133*(1), 77-84.

Ellis, P. D. (2011). *The essential guide to effect sizes: Statistical power, meta-analysis and the interpretation of research results*. United Kingdom: Cambridge University Press.

Goldberg M. A. (2002). Human Capacity Building for APEC Science, Technology & Innovation: Preconditions & Key Issues to Succeed. (Proceeding APEC-ISTWG Forum Paper Summary. APRU-APEC Committee, Berkeley California.

Hernandez, P. R., Bodin, R., Elliott, J. W., Ibrahim, B., Rambo-Hernandez, K. E., & de Miranda, M.A. (in-press). Connecting the STEM dots: Measuring the effect of an integrated engineering design intervention. *International Journal of Technology and Design Education* http://doi: 10.1007/s10798-013-9241-0

Humphrey, S. E. (2011). What does a great meta-analysis look like? *Organizational Psychology Review, 1*(2), 99-103.

Jones, A., Buntting, C. &Vries, M. J. (2013). The developing field of technology education: A review to look forward. *International Journal of Technology Design Education 23*, 191-212.

Kabilan, M. K. (2003). Online professional development of teachers: An examination of structures and trends in Malaysia. *International Journal of Instructional Media, 30*(4), 367-382.

Kieong, C. K. (2012). *Vision 100K*. Paper presented at the TheInstituitionof Engineers, 53rd Presidental Address, Malaysia.

Lindahl, B. (2003). *Pupils' responses to school science and technology? : A longitudinal study of pathways to upper secondary school*.Unpublished summary of PhD thesis, University of Gothenburg, Kristianstad.

Martin, M.O., Mullis, I.V.S., Foy, P., &Stanco, G.M. (2012).*TIMSS 2011 International results in science*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Meyrick, M. K. (2011). How STEM Education Impress Student Learning. *Meridian K-12 School Computer Technologies Journal, 14*(1), 1-6.

Mena, I. B., Diefes-Dux, H.A. (2012). First-year engineering students' portrayal of engineering in a proposed museum exhibit for middle school students. *Journal of Science Education and Technology 21*(2), 304-316.

Ministry of Science, Technology and Innovation (MOSTI). (2008).*2008 Report: Malaysian science and technology indicators*. Putrajaya: Malaysian Science and Technology Information Centre, MOSTI.

Narayan, R., Park, S., Peker, D., Suh, J. (2013). Students' Images of Scientists and Doing Science: An International Comparison Study. *Eurasia Journal of Mathematics, Science & Technology Education, 9(2),* 115-129.

Nordin, K. (2012). JumlahPelajarSains Di IPT Makin Kurang, BeritaHarian [*The Total Science Students at Local Varsities Are Decreasing*]. Retrieved from *Berita Harian*. Retrieved from http://www.bharian.com.my/articles/JumlahpelajarsainsdiIPTmakinkurang/Article/

OECD (2010), *PISA 2009 at a Glance*, OECD Publishing. (Available at:http://www.oecd.org/pisa/46660259.pdf)

Petroski, H. (2010). *The essential engineer: Why science alone will not solve our global problems*. New York: Vintage Books: A division of random house.

Poll, H. (2004). American Perspectives on Engineers and Engineering: Reveals Public Perceptions of Engineering: 1998. from American Association of Engineering Societies. Retrieved from: http://www.aaes.org/ harris2004_files/frame.htm.

The Joanna Briggs Institute for Evidence Based Nursing & Midwifery (2001). An introduction to systematicreviews. *Changing Practice, 1*, 1-6.

Reigeluth, C. M & Carr-Chellman, A. A. (2009). *Instructional-design theories and models (Volume III)*. London: Routledge.

Rhoads, T. R., Walden, S. E., Winter, B. A (2004). Sooner Element Engineering and Science (SEES) a model for after school science clubs based on university and K-5 partnership.*Journal of STEM Education, 5*(3), 47-52.

Saat, R. M. (2012). Practices in Mathematics & Science Education: A Reflection. In S. N. Akmar (Ed.), *What We Learned From Science Education Reform: The Malaysian Experience*. Selangor Darul Ehsan: Pearson Malaysia.

Singh, K., Granville. M., & Dika, S. (2002). Mathematics and Science Achievement: Effects of Motivation, Interest, and Academic Engagement. *The Journal of Educational Research, 95*(6), 323-332.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2010). Education for all.Global monitoring report.Retrived from: http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/efareport/reports/

U.S. Department of Education. (2007*). Report of the Academic Competitiveness Council*. Washington, D.C. Retrieved from :http://coalition4evidence.org/wp-content/ uploads/ACC-report-final.pdf

Yarker, M, B., Park, S. (2012). Analysis of Teaching Resources for Implementing an Interdisciplinary Approach in the K-12 Classroom. *Eurasia Journal of Mathematics, Science & Technology Education, 8(4),* 223-232.

◈◇◈